# Kerala Agricultural University

## RESEARCH REPORT 2017

**Edited by**
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**Vellanikkara, Thrissur, Kerala**

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# FOREWORD

Vision and mission of the Kerala Agricultural University are Excellence in Agricultural Education, Research and Extension for Sustainable Agricultural Development and Livelihood security of farming community. Kerala Agricultural University is well poised to meet the challenges ahead that transforms agriculture sector into the engine of growth of Kerala's economy by providing skills and technology for the sustainable development of state's agriculture. Applied and adaptive research for enhancing Agriculture production and addressing the current and future challenges of farming community are the prime mandate of KAU.

The University focuses on strengthening problem/location specific research relevant to the state and prevailing agro climatic and socio economic situations and help innovative extension systems for sustainable management of natural resources, enhance agricultural production and overall improvement of rural livelihoods.

KAU fulfills its mandatory responsibility through research programmes implemented in 7 Colleges, 6 Regional Agricultural Research Stations and 17 Research Stations spread across the length and breadth of the State. The All India Coordinated Research projects and Network projects being implemented in KAU also have great role in the development of farmer friendly technologies. The post graduate and doctoral students at various disciplines in the University are also integral part of the research system.

Technologies developed by KAU aim at enhancing productivity and sustainability in agriculture sector. The University can be proud of the fact that many of the research outputs are being widely used by farmers of the state and outside and have improved their living standards.

Continuing the sincere efforts, KAU is proud to present the research report of the year 2016-17 which is a systematic compilation of the major findings of various research projects implemented in different centers to the farming community, policy makers and researchers. The efforts taken by the KAU fraternity to bring out the research accomplishments are appreciated and acknowledged. I take this opportunity to congratulate all those who have contributed to this endeavor.

Dr.R.Chandra Babu
Vice Chancellor

# PREFACE

KAU is one of the prominent R&D institutes in the field of agriculture in the country and has made significant contributions in Agricultural research. The University has an approved research policy for addressing the problems of farmers and to improve the living standards of the farming community of Kerala. KAU provides human resources, skills and technologies required for sustainable development of agriculture in the State. Research activities are being undertaken to increase the productivity of crops and income of farmers through genetic improvement, improved management practices, crop protection, value addition of agricultural produce and fabrication and refinement of farm machines suitable for Kerala and various other technologies.

KAU is having a network of research centers distributed in all the agro-ecological zones of Kerala. Our technologies are mostly evolved through this network centers in addition to the on-farm research with essential refinement and fine tuning. The University fulfills its mandatory functions of applied, strategies and basic research through various station projects and post graduate/doctoral research programmes. The All India Co-ordinated Research Projects and Network projects have a key role in agricultural research system in the state.

The research projects in Kerala Agricultural University is mainly funded by the public sector which include Indian Council of Agricultural Research, Indian Council for Forestry Research and Education, Department of Biotechnology, Department of Science and Technology, State/National Horticulture Mission, Rashtriya Krishi Vikas Yojana, State Planning Board, Kerala State Council for Science Technology and Environment etc.

The research management in the University is done by the Directorate of Research, where the Director of Research is supported by Associate Directors of Research in five zones and in the Head Quarters. There are three faculties viz., Agriculture, Forestry and Agricultural Engineering, where the research implementation is vested with the Research Coordinator. There are 17 Project Coordination groups in Agriculture, 2 in Forestry and 3 in Agricultural Engineering.

The research publications as technical reports and research papers are regularly released by the scientists. It is worth mentioning that the achievements of the University are on account of the joint efforts of the highly qualified and committed faculty with the support of the para-technical, ministerial and other categories of staff and labourers. We also thank all the funding agencies and other organizations, who supported us for effectively discharging the responsibilities. We place this publication of compilation of research projects implemented by the University during 2016-17, before the people of Kerala State.

Dr.P.Indira Devi
Director of Research

# Faculty – Agriculture

# Project Coordination Group - Rice (01)

**Project Coordinator - Dr. Reena Mathew**

**Concluded Projects: 8**
**Ongoing Projects: 97**

## Concluded Projects

1. **Molecular characterization and virulence analysis of *Pyricularia grisea* and*Xanthomonasoryzae* pv *oryzae,* the blast and bacterial blight pathogens of rice in Kerala**

   The objectiveof the project was to study the genotypic variability of blast and bacterial blight pathogens of rice in Kerala and also to study the pathotypic variability of these pathogens. Survey has been carried out in major rice growing areas of the state to collect the blast and bacterial blight pathogens covering 101 panchayts from seven districts, Palakkd, Thrissur, Malappuram, Alappuzha, Kottayam, Ernakulam and Wayanad. Pathogens were isolated from disease samples collected. Molecular characterization of the blast and bacterial blight pathogens of rice viz., *Pyricularia grisea* and *Xanthomonas oryzae* pv. *oryzae* revealed existence of high variability of pathogens in the state of Kerala. Cluster analysis of the data clustered 302 isolates into 85 lineages at 50 per cent similarity showing high variability of Bacterial blight pathogen populaion. Pathotyping of represesntative isolates from each lineage revealed that NILs carrying single genes were susceptible to 30-85 % of the isolates tested.Pathotyping also shows 15 different reaction patterns on a set of 22 NILS carrying single genes or gene combinations in the background IRBB. All pathotypes showed susceptible or moderately susceptible reaction on Xa1, Xa3, Xa10, Xa11and Xa14. Additionally few pathotypes showed susceptible reaction on xa5, Xa7 and xa8. Pathotypes virulent on xa13, Xa21and Xa38 are also present in the current population of Xoo in Kerala. Certain pathotypes shows susceptibility to two gene combinations Xa4+xa5, Xa4+xa13, Xa4+Xa21, xa5+xa13, xa5+Xa21, xa13+xa21. Combinations such as Xa 4 + xa 13 + Xa 21, xa 5 + xa 13 + Xa 21, Xa 4 + xa 5 + xa 13 + Xa 21 are giving broad spectrum resistance.

   Fingerprining of 86 isolates *of Pyricularia grisea* was carried out. These were clustered into five different groups Some of the tested differentials containing resistance genes offered resistance to majority of the isolates of blast pathogen. Tadukan, Tetep, C101 LAC and Ramind STR-3 showed resistance reaction. This suggests the possibility of utilizing the genes, *Pi-1* and *Pikh for* the management of blast pathogen in the state.

   The collection of isolates of blast and bacterial blight pathogen from different parts can be further utilised for future works aimed at resistance breeding or other approaches of management bacterial blight and blast.

2. **Pest and Disease Surveillance and Management in Kole lands**

   Fixed plot as well as rapid roving surveys was carried out. Fixed plot observation was done on pest and disease build up with respect to varying practices of nutrition, water management, weather relation and land ecosystem. A monitoring, surveillance and rapid action service unit for pest and diseases outbreaks in the kole lands was set up. Forewarning system for pest and disease outbreak in kole lands based on data on crop parameters and weather data was developed.

The CSIW Officers were regularly visiting the paddy fields and reporting the conditions as well as providing technical messages to farmers to tackle any particular problem. The unscrupulous use of pesticides and fungicides and nonjudicial use of chemical fertilizers could be reduced due to their intervention in kole lands. This also enabled us for the grassroot level understanding of the constraints in kole land cultivation and to come out with management and technical outputs to overcome these situations. Effectiveness of these corrective measures with respect to climate change was also evaluated.

Based on the data collected and photographs as well as field visits conducted by the experts of KAU in alarming situations, immediate control measures of the field problems were possible during the current year and a successful cropping was done in kole lands. The serious infestation of bacterial leaf blight in Mankody Kole Padavu, Thrips attack in Chithravally Kole Padavu and Iron Toxicity in Manalurthazham Kole Pavdavu were successfully managed by the timely intervention of the CSIW Officers. Nutrient deficiencies of Mg and B could also be detected in time and amendments were suggested. We could facilitate the farmer to go for successful cropping in kole lands. Analysisof soil at regular interval was made to monitor changes in nutrient status including micronutrients and conductivity during on and off season of cultivation. Changes in flora and fauna of the area with respect to seasonal changes and cropping activities and system of cultivation followed were also studied. Similarly pest and disease and physiological disorders were recorded and correction measures were adopted.

### 3. Integrated management of sheath blight of rice

An IDM strategy against sheath blight was evaluated during the year 2016-17. IDM practices involving seed treatment and nutrient management in nursery (FYM @ 1t/1000$m^2$ ; Basal dose - NPK @ 20:50:50 kg/ha; Top dressing - 25kg N/ha) and main field (Compost @ 10t/ha; NPK @ 90:45:45kg/ha; N- 3 splits, P – basal and K – 2 splits and a spray of carbendazim @1g/l after the appearance of disease symptoms) were tested in a susceptible variety, Jyothi; and two moderately resistant high yielding variety varieties, Aiswarya and Aathira.

The disease severity was lowest in variety Aiswarya(26.81%) which was statistically on par with Aathira(27.81%). The disease severity in IDM plots(26.91%) were significantly lower than that in non IDM plots (42.17%). There was significant reduction in disease severity in varieties Aiswarya and Aathira than in Jyothi, when IDM was followed.

### 4. Screening for resistance to leaf blast (RIC-03-02-01/89 PTB(5)ICAR Co-ord)

During the year 2016-17, in National Screening Nursery 1 (NSN1), 373 entries were screened for leaf blast resistance. Among these 7 entries showed resistance reaction to leaf blast with score 1. The National Screening Nursery 2 (NSN-2) consisted of 663 entries of which 2 entries showed resistance reaction with score 1. Out of the 145 entries tested in National Hybrid Screening Nursery (NHSN), 3 entries showed resistance reaction. Out of the 109 entries tested in the Donor screening nursery (DSN) no entries showed resistance reaction.

## 5. Productivity enhancement in rice through promoting zinc nutrition using mycorrhizal symbiosis

The project was conducted for evaluating the role of mycorrhizal symbiosis in Zn nutrition in the presence of AMF and therby developing an economical and enviorment friendly nutrient package for wetland rice under kuttanad condition.

### 1. Direct seeded Rice (Virippu season)

**a) Effect of treatments on yield parameters**

Grain yield as well as straw yield did not vary significantly with the treatments. However the highest test weight, grain yield and straw yield was recorded for the treatment T4 which indicates the importance of zinc nutrition in Kuttanad soils. In addition the lowest yield was recorded with high doses of Zinc (T 6 and T7) which points to the fact that balanced zinc is essential for higher yield in direct sown rice of Kuttanad wetlands.

**b) Effect of treatments on mycorrhizal assays**

Root colonization was not observed at tillering, panicle initiation and at harvest. It can be correlated with the anaerobic conditions created by heavy rainfall during the season. **The AMF culture containing *Glomus fasciculatum,Glomus etunicatum,Glomus mosseae, Sclerocystis microcarpus sp* and *Acaulospora sp*. cannot come up under anaerobic conditions in the paddy wetlands of Kuttanad.** Hence the AMF culture in the following years of experimentation has been changed to ***Glomus intraradices* which** has been proved to come up under anaerobic conditions in nursery conditions.

### 2. Transplanted Rice

The number of grains per panicle, 1000 grain weight, grain and straw yield did not differ significantly with treatments in transplanted rice. But all the superior treatments included AMF which may prove its influence in maximizing yield.

**Effect of treatments on growth parameters**

In direct as well as transplanted rice, number of productive tillers at harvest varied significantly with treatments. The maximum number was noticed in treatments with AMF and AMF – Zinc application which indicates that both of these inputs can have a crucial role in increasing yield.

**Effect of treatments on root parameter**

Root weight did not differ significantly either in direct or transplanted rice with any of the treatments. However root length and width varied in both systems of paddy cultivation. The improvement in root growth with AMF application was very much pronounced in mat nursery raised for transplanting (Plate.)

**Effect of treatments on soil nutrient parameters**

In general under both systems of rice, soil nutrient status varied differently at different stages of sampling which stressed the dynamic soil character of Kuttanad wetlands which makes it difficult to manipulate and manage the soils to enhance plant nutrient absorption and thereby bring increased productivity. Thus it can be concluded that AMF application alone cannot

manage zinc availability to plants as it is regulated by increase in uptake of Fe, Ca, Mg, Cu, Mn and P after flooding. Zinc uptake by rice depends not only in its concentration in the soil solution but particularly on concentration of iron and manganese in soil.In addition wide exchangeable Mg: Ca ratio i.e. ., > 1 may indicate zinc deficiency (Dobermann,A and Fairhurst,T,2000). It is noticed that the soil application of zinc fertilizer at recommended rates suggested to overcome zinc deficiency could not bring required increase in zinc absorption by plants and thereby increase in yield. This can be attributed to the soil nutrient complexities observed in Kuttanad conditions.

**Effect of treatments on plant nutrient parameters**

In transplanted rice, zinc content was high in treatments with either soil or foliar applied zinc with and without AMF. The grain content of zinc was high in treatment with foliar application of zinc with AMF in both direct sown and transplanted rice. Similar result was reported by Solaiman , MZ and Hirata, H(1996).There may be a critical soil zinc concentration below which Zn uptake is enhanced by AMF and above which Zn translocation to plants is reduced. These responses are further complicated by uptake of other nutrients especially P via mycorrhizal pathway which may lead to a decrease in plant zinc concentration due to dilution effects. However response of AMF on Zn acquisition is comparatively low when Zinc is applied at higher rate to soil.

**Effect of treatments on mycorrhizal assays**

Perusal of the results of the first year experiment has shown that the commercial AMF consortia **containing *Glomus fasciculatum, Glomus etunicatum, Glomus mosseae, Sclerocystis microcarpus* and *Acaulospora sp*.** cannot come up under anaerobic conditions in the paddy wetlands of Kuttanad**.** Higher soil moisture had a deleterious effect on AMF colonization in rice especially under flooded condition. ***Glomus intraradices*** is identified as appropriate AMF species that can come up in wetland conditions of Kuttanad rice fields under both direct sown and transplanted condition indicated by colonization and response in certain seasons. The presence of AMF is confirmed up to harvest stage in the roots by staining technique. The study suggests that the technique of nursery level inoculation and transplanting with AMF *Glomus intraradices* is of more benefit to rice under wetland conditions than direct sown rice as water has to be managed in the field at the time of broadcasting. However *Glomus intraradices* can be recommended only after undertaking a large scale trial in station as well as farmers plot.

## 6. Organic pest management in upland rice of Onattukara :

In upland rice, there are zero to moderate incidence of pests like thrips, stem borer, leaf roller and rice bugs and zero to moderate incidence of diseases like brown spot, blast and earhead blackening. 1% Azadirachtin 0.004% at tillering and milky stage and Dasagavya 3% at tillering and at milky stage were found to be effective against stem borer in upland rice. Jeevamruthum 5% at tillering stage + fish jaggery extract at milky stage and Dasagavya 3% at tillering stage + fish jaggery extract at milky stage gave cent percent control of leaf roller attack at 5days after first treatment. 1% azadirachtin (0.004%) at tillering stage+ fish jaggery extract at milky stage recorded the lowest incidence of thrips damage. Dasagavya 3% at tillering and milky stage and Dasagavya 3% at tillering stage + fish jaggery extract at milky stage recorded significant

reduction in rice bug population. The highest grain yield was recorded in treatments Dasagavya 3% at tillering and at milky stage and 1% azadirachtin 0.004% at tillering stage+ fish jaggery extract at milky stage

## 7. Physico-Chemical and Molecular Characterization of Grain Quality of Traditional Rice Varieties

Chemical characterization showed that, amylose content of the varieties ranged from 12.32% (Jeerakasala) to 29.82% (Cheruvirippu). The variety Njavara Veluthath recorded maximum protein content (13.57%) and the varieties like Cheradi, Marathondi and Thondi showed the minimum (8.90%). The Iron and Zinc content of the varieties ranged from 45.45 to 311.54 mg/kg and 27.88 to 102.41 mg/kg respectively. The variety Karimbalan recorded maximum Iron and Zinc content. The carotene content of the varieties ranged from 0.14 to 0.56 mg/100g. The minimum value was recorded for Mullan Kayama and maximum for Njavara Veluthath. Correlation analysis showed positive significant relationship between Iron and Zinc content. The amylose content also showed positive but nonsignificant relationship with volume expansion and optimum cooking time.

In molecular characterization, SSR marker RM535 linked to QTL (Quantitative Trait Loci) for Iron and Zinc content was detected in thirteen varieties. The marker RM190 linked with Wx gene locus associated with amylose content was detected in seventeen varieties and the marker RM520 linked to QTL for protein content was detected in all the varieties. The varieties identified as rich source of genes linked to quality traits can be used for the transfer of these genes to the cultivated varieties for quality improvement through marker assisted selection.

The present investigation has proven that traditional rice varieties are rich in micronutrients and protein. The varieties like Njavara Veluthath and Orumundakan rich in protein can be utilized as donors for this character in further breeding program. The varieties which are superior in Iron and Zinc content like Karimbalan and Veliyan can be utilized as lines for biofortification programs which can nourish the growing population and tackle the "hidden hunger".

## 8. Identifying Donors for Gall midge Resistance from Traditional Rice Varieties Functional Markers

This study conclusively proves that *Gm1* is the gene conferring resistance to gall midge biotype 5 prevailing in Kuttandu rice tract of Kerala. Different combinations of genes *Gm1* and *Gm2* can confer durable resistance. The varieties which have *Gm1* and *Gm2* genes can be used as donors for pyramiding these genes in the popular rice varieties by marker aided selection, to develop Essentially Derived Varieties (EDVs) to tackle the incidence of gall midge.

## Ongoing Projects

1. **Genetic conservation of rice germplasm, collection, maintenance, cataloguing and evaluation**

   Field screening of germplasm collection including traditional rice varieties were done for characterisation of germplasm based on the 62 morphological and biochemical characters identified as per the National DUS Testing Guidelines of Rice. The plants are assessed at different growth stages like germination, booting, panicle emergence, anthesis, milky grain, hard dough and ripening time. The candidate varieties are divided into groups to facilitate the assessment of Distinctiveness. New germplasm were included in collection which comprised of farmer varieties, varieties released from other institutes and recent breeding lines. Characterization of 292 accessions including short and medium duration varieties and traditional rice varieties under the Pattambi germplasm collection were completed during 2016-17. Pure seed multiplication and storage of 452 accessions were also done. The pure seeds multiplied are stored under Medium Term Storage facility developed at RARS, Pattambi under this project.Molecular characterization and field screening of germplasm for biotic and abiotic stress tolerance has been taken up on a large scale from 2016 onwards. A red variant plant selected from land race Veluthitaryan and tested for yield performance along with check varieties during 2016-17.

2. **Breeding high yielding, tall, photo sensitive varieties with good straw yield specifically suited for the mundakan season of Kerala**

   Based on the station and farm trial results, two promising cultures Cul 6 (0614-7-8-24) and Cul 14(0615-01-25-17) were recommended for variety release in ZREAC meeting. State seed sub committee recommended the cultures 6 and 14 as PTB 61(KAU Supriya) and PTB 62 (KAU Akshaya) respectively for second crop season in central zone of Kerala. They are non lodging, high grain and straw yielding with moderate resistance to stem borer, Leaf folder and neck blast. The varieties showed tolerance to moisture stress and high temperature. The varieties possess good cooking quality. Multi Location testing of the entries at Pilicode, Karamana, Puduppadi and Vytilla trials are progressing. Culture 7 (0614-10-14-17) and Culture 17 (0615-20-24-2) were tested under AICRIP as IET 25343 and 25340 respectively. Based on performance, Culture 17 was promoted to and was tested under Advance variety trial and Culture 7 (0614-10-14-17 IET 25343) was tested as Yield Potential Entry in AICRIP during Kharif 2016. Culture 7 was found to be moderately resistant to Blast, Brown spot and Sheath Rot. Culture 17 was found resistant to Sheath rot and moderately resistant to BLB under national pest and disease screening nursery. Cul 5(0614-1-6-21) and Cul 10 (0615-19-19-6-1) were tested under Initial varietal trial as IET 26080 and 26101 respectively among which Cul 5 was promoted in Eastern zone with average yield of 5.7 t/ha in national testing.

   Hybridisation programme involving photoperiod sensitive second crop varieties and popular photoperiod insensitive varieties viz., Pranava, Karuna, Neeraja, Swetha, Vellari, Chettadi, Anashwara, Jyothy, Ponmani, Kuruka, Uma, Makaram have been initiated. Single plant selections from segregating generations of crosses were made. Selected 30 entries were

evaluated in Preliminary yield trials. Out of these, 19 promising entries are being tested in Comparative yield trial.

## 3. Collection, maintenance and evaluation of rice germplasm

During the period 60 entries were added and 710 varieties/ cultures were maintained in the germplasm

## 4. Evolution of semi tall or dwarf types of tall Indica rice varieties

Thirteen mutant lines of PTB 18 and 21 were subjected to selection in M6 generation. Preliminary Yield trials were conducted with three uniform mutant lines (170 Gy Gamma ray mutant of PTB 18) selected from previous generation along with PTB 18 and PTB 21. All three lines were found to be promising and exhibited 100 to 114% improvement in yield over the parents. These entries will be forwarded to advanced trials.

## 5. Initial Variety Trials

Comparative performance of superior rice cultures of different duration developed at different rice research centres throughout the country are evaluated for their yield and suitability for our situation. Initial Variety Trial is the first stage of evaluation of the cultures. The seed material for the trial is received from DRR, Hyderabad. The results of experiments conducted during 2016-17 from the trials are furnished below.

### 5.1 Initial Variety Trial - Early (IVT-E-TP) Transplanted rice--ICAR

The trial was laid out in RBD in Kharif with 64 entries and 2 replications. Observations were recorded on various characters like plant height, days to 50% flowering, grain yield, disease/pest attack etc. The highest grain yield was recorded by Entry No.1112 (11141 kg/ha) followed by Entry No.1136 (10431 kg/ha) which was superior to the grain yield of the local check Prathyasa (7591 kg/ha).

### 5.2 Initial Variety Trial-Biofortification (IVT-Biofort)

In this trial, 36 entries were tested in 2 replications. The highest grain yield was recorded by Entry No.3727 (12021 Kg/ha) followed by Entry No. 3721 (11318 kg). The local check Uma recorded a grain yield of 5350 Kg/ha.

## 6. Advanced Variety Trials

The entries in Initial Variety Trials which give more than 5% yield increase than the check varieties will be tested in Advanced Variety Trials 1 and 2. At Rice Research Station, Moncompu, different duration groups viz., Early and Mid Early are tested for their regional suitability.

### 6.1 Advanced Variety Trials

The trial was laid out in RBD with 22 entries and 3 replications. Observation were recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack *etc*.The highest grain yield was recorded by Entry No. 4304 (6821kg/ha) followed by Entry No.4303 (6725kg/ha) while the local check Jyothi recorded a yield of4193Kg/ha.

### 6.2 Advanced Variety Trial-1-Early (AVT 1 E- T P) Transplanted

The trial was laid out in RBD with 36 entries and 3 replications. Observations were recorded on various characters like plant height, days to 50% flowering, grain yield, disease/pest attack etc. The highest grain yield was recorded by Entry No. 1009 (9334 kg/ha) followed by Entry No.1010 (9163 kg/ha) while the local check Prathyasa recorded an yield of 6851 Kg/ha.

### 6.3 Advanced Variety Trial 2-Early (AVT-2 E TP) Transplanted

The trial was laid out in RBD with 13 entries and 3 replications. Observations were recorded on various characters like plant height, days to 50% flowering, grain yield, disease/pest attack etc. The highest grain yield was recorded by Entry No.907 (8522 kg/ha) followed by Entry No. 906 (8515 kg/ha). The local check recorded a grain yield of 7145 Kg/ha.

### 6.4 Advanced Variety Trial- 2- Irrigated Mid Early (AVT -2 IME)

The objective was to study the comparative performance of mid- early duration elite cultures and hybrids in irrigated areas.Observations were recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack *etc*.The highest grain yield was recorded by US 312 (HC) with an yield of 6780 Kg/ha followed by IET No. 24104 (XRA-27935) (Hybrid) with a per hectare yield of 5246 Kg. The local check Uma recorded an yield of 4209 Kg/ha.

### 6.5 Advanced Variety Trial-1 Biofortification(AVT -1 Biofort)

During 2016, 17 entries were tested in 3 replications. Observations were recorded on various characters like plant height, days to 50% flowering, grain yield, disease/pest attack etc. The highest grain yield was recorded by Entry No. 3602 with an yield of 10553 kg/ha followed by Entry No. 3605 with a per hectare yield of 9434 kg. The local check Uma recorded a grain yield of 7257 kg/ha.The entry with highest yield will be evaluated again to confirm the performance.

### 6.6 Advanced Variety Trial-2 Biofortification(AVT -2 Biofort)

During 2016, 16 entries were tested in 3 replications. Observations were recorded on various characters like plant height, days to 50% flowering grain yield, disease/pest attack etc The highest grain yield was recorded by Entry No. 3501 with an yield of 11890 kg/ha followed by Entry No. 3505 with a per hectare yield of 11517 kg. The local check Uma recorded a grain yield of 9848 kg/ha.

## 7. Initial Variety Trials

Regional Agricultural Research Station, Pattambi is also a Co-operating centre under the All India Co-Ordinated Rice Improvement Project ( AICRIP) and conducts the national trials with different duration group entries for assessing their suitability for the central zone of Kerala

including the districts of Palakkad, Malappuram, Thrissur and Ernakulam. The results from the Initial Variety Trials conducted by the station are furnished below.

### 7.1 Initial Variety Trial (IVT - E - TP)

Out of the 64 entries tested during 2016-17, IET 26316 with 9047 kg/ha was found superior to all other entries with respect to yield.

### 7.2. Initial Variety Trial – Biofort (IVT- Biofort) PTB

Out of the 36 entries tested during 2016-17, IET 26387 with 13977 kg/ha was found superior to all other entries with respect to yield.

## 8. Advanced Variety Trials --PTB - ICAR

At RARS, Pattambi the trial under direct seeded situation is also taken up since large areas in Palakkad and Malappuram Disrtricts are under rainfed situation and direct seeding is routinely practiced here.

### 8.1. Advanced Variety Trial 1 ((AVT-1 E TP)

Out of the 23 entries tested during 2016-17, Gontra Bidan-3(NC) with 5320 kg/ha was found superior to all other entries with respect to yield.

### 8.2. Advanced Variety Trial 2-Early (AVT-2 E TP) PTB

Out of the 13 entries tested during 2016-17, Kanchana (LC) with 5589 kg/ha was found superior to all other entries with respect to yield.

### 8.3. Advanced Variety Trial-1 Biofortification (AVT -1 Biofort) PTB

Out of the 17 entries tested during 2016-17, IET 25470 with 6152 kg/ha was found superior to all other entries with respect to yield. During 2017-18, 15 entries were tested, of which the entry IET 26378 with 4404.27 kg/ha was found to be superior with respect to yield.

### 8.4. Advanced Variety Trial-2 Biofortification (AVT -2 Biofort) PTB

Out of the 16 entries tested during 2016-17, Kalanamak (MC) with 2808 kg/ha was found superior to all other entries with respect to yield. During 2017-18, 15 entries were tested, of which the entry IET 25461 with 3195.25 kg/ha was found to be superior with respect to yield.

## 9. Evolving multiple disease and pest resistant rice var. for second crop of Kuttanad

During 2016-17 Puncha, CYT was repeated with best performing 3 cultures viz. KAUM 236-1-2-1-1-1, KAUM -238-1-1-1-1-1, KAUM 240-1-3-2-2-1 along with 4 checks.

## 10. Evolving high yielding multiple resistant rice varieties through gene pyramiding

Scoring for major pest and diseases are regularly undertaken in promising genotypes identified from different study and in germplasm lines. During 2016-17, promising entries from the crosses Swetha x Kuruka, Pranava x Chettadi, Pranava x Vellari were screened for stem borer, leaf folder and whorl maggot. Among the tested cultures Cul 1(0627-2-11), Cul 2(0627-2-14), Cul 4(0614-1-6-21), Cul 7(0614-10-14-17) and Cul 19(0615-15-16-8) exhibited moderate resistance to major pests screened. Evaluation of these cultures was taken up in yield trials during 2016-17.

Among these Cul 7 (6.8 t/ha) and 19 (6.2 t/ha) performed superior compared to check varieties Jyothi (4.9 t/ha) and Uma (5.3 t/ha).

**11. Breeding for drought tolerant rice varieties suitable for upland ecosystem**

During 2016-17, the cultures C3-2-H-11 and C3-2-H-32 were tested in upland during Kharif 2015 along with checks and AICRP national testing entries. The results were not promising. Pure seed multiplication of these cultures was undertaken.

Promising entries Cul 4(0627-2-24), 5(0614-1-6-21), 6(0614-7-8-24), 7(0614-10-14-17-1), 10(0615-19-19-6-1), 14(0615-01-25-17), 19(0615-01-28-34-1), JS-4(JS 2-1-7-6), JS-5(JS 2-1-30-2), JS-6(JS 3-5-2-1), JS-7(JS4-1-17-4), M1(M2011-45-1-3-1), M6(M2011-46-1-1-2) and NPT cul1(RP5568-PTB-1-1) were tested for performance under rainfed upland condition. The selection of superior progenies was also carried out. Selected entries were screened for High temperature stress tolerance along with Physiology department.

**12. Physiological and biochemical basis of heat tolerance in rice.**

During 2016-2017**,** twenty-one selected AICRIP germplasm accessions were screenedfor high temperature tolerance (8-10°C) more than the ambient condition. Among the entries, HT7,HT 10, HT12 and RFU-26 recorded the highest grain yield(g) and spikelet fertility. 371 Isogenic lines of rice were received from IRRI, Hyderabad during 2016 under NICRA for field evaluation for high temperature stress tolerance . The lines with five local checks were field evaluated in summer season of 2016 with ambient day temperature ranging from 33 to 38 $^{o}$C. Among the 371 ILN lines, sixty two lines were found promising in the first trail. The experiment material will be further evaluated.

**13. Evaluation of fungicides against brown spot**

Among the fungicides tested during the year, lowest disease severity (4.7%) was recorded in hexaconazole 5EC (2.0 ml/l) applied plots. This was followed by tebuconazole 16% (Folicur) and Tricyclazole+tebuconazole 36%SC. The two doses of combination fungicide (Tricyclazole+tebuconazole 36%SC) 2 ml/l and 2.5 ml/l were statistically on par in reducing the brown spot severit

**14. Genetic analysis of gall midge resistance in rice and evolving resistant varieties for gall midge biotype 5**

The release proposal of the culture KAUM 109-1-2-1(IET 23739) was submitted and approved by the Variety Evaluation Committee. It is a semi tall, medium duration, medium tillering variety with medium bold red kernelled grains. The pooled mean yield recorded for the culture in farm trials was 7400 kg/ha which was on par with the ruling variety Uma. The culture is moderately resistant to sheath blight, sheath rot, gall midge and BPH. Collected varieties / cultures from various sources especially DRR, Hyderabad and screening trials were conducted. Donors were identified for gall midge biotype 5 from the screening trials. Hybridisation work was initiated between high yielding locally adapted varieties and donors (gall midge biotype 5 resistant varieties).

Selections were made and the cultures after attaining uniformity were advanced to Initial Evaluation Trials. Initial Evaluation Trial with superior progenies selected from F6 generation was conducted during 2009 additional crop. Ten promising cultures with respect to yield and tolerance to pests especially gall midge biotype 5 were advanced to Preliminary Yield Trial during Puncha 2009-10. PYT was repeated during the additional crop 2010. From PYT 6 promising cultures were carried forward to Comparative Yield Trial during 2010-11 Punja. Based on the results of PYT, CYT *etc*. three superior cultures (2 crosses) viz., M109-1-2-1, M109-1-2-3 and M110-16-1-2 were identified as promising ones with respect to yield as well as resistance to gall midge biotype 5. During Additional crop 2012 these cultures were multiplied. In the 33rd workshop of ZREAC for Problem Areas held on 21.12.2013 at RARS, Kumarakom, it was decided to conduct quality analysis of the culture. In the farm trials, Culture KAUM 109-1-2-1, a derivative of MO 8 (NHTA 8/MO 8) ranked first in yield with a pooled mean yield of 7688 kg/ha and 7150kg/ha during Kharif 2013 and Punja 2012-13, respectively. MLT was conducted along with the check varieties at different Research Stations viz., RARS. Pattambi, CSRC. Karamana and ORARS. Kayamkulam, with a pooled mean yield of 3046 kg/ha

KAUM 109-1-2-1 (IET 23739) was included in Initial Variety Trial –IME of Kharif 2012 in AICRIP in which it was tested with 27 other entries in 37 locations of the country. KAUM 112-10-6-5 was was found to be superior over national check and regional check when the pooled mean was considered. Also it ranked 5th in Gujarat, 7th in Moncompu, 9th in Mugad and Coimbatore respectively. This culture was included in the IVT- IME of Kharif 2013 also in which it out yielded (4742kg/ha) the national check (4557kg/ha) in pooled mean of 34 locations. It ranked first in Punjab, 7th in Tirur and Moncompu and 8th in Mandya.

KAUM 109-1-2-1 (IET 23739) was included in Initial Variety Trial –IME of Kharif 2013 in AICRIP in which it was tested with 63 other entries in 34 locations. On the basis of its performance in the eastern region it is promoted to AVT-1-IME. It is resistant to BPH also.

In all the trials conducted KAUM 109-1-2-1 were found promising with respect to yield and tolerance to gall midge biotype.

**15. Breeding for high yielding rice varieties with resistance / tolerance to adverse soil conditions**

During 2016-17 KAUM 164-1, KAUM 174-6 and KAUM 168-1 were found to be promising with respect to grain yield. These cultures were on par with the check variety Uma in grain yield.

**16. Network project on Seeds And Planting materials production- GoK Plan**

Breeder and foundation seeds of the MO varieties were produced during 2016-17. A total quantity of 3026.48kg Breeder seeds, 933.5kg Foundation seeds and 4204.3kg truthfully labelled seeds were produced and distributed to various agencies, deptl. Farms, farmers *etc*.

**17. Breeding for high yielding rice with resistance to major pests of rice in Kuttanad**

During Puncha 2016-17, CYT was repeated with four cultures viz., KAUM 230-2-1-1, KAUM 230-1-2-1, KAUM 231-5-2-1 and KAUM 230-1-1-1 along with 3 checks. The cultures were on par with Uma and superior to Jyothi and Prathyasa in grain yield and pest and disease resistance especially gall midge, stem borer, sheath blight etc. Among the three cultures KAUM 231-5-2-1

were included in the initial variety trial AICRIP. The varieties Resmi, DV 85, IET 20034, IET 19665,Krishnanjana,Uma and Remya wereselected as donors in the hybridization programme.

The following crosses were made between the identified donors and locally adapted varieties.

| | |
|---|---|
| MO 15/IET20370 | MO 19/IR 36 |
| Jyothy/ IET 19692 | MO 19/IET 20981 |
| Uma/ Jyothy | MO 10/BJ 1 |

## 18. Breeding for high yielding rice varieties with submergence tolerance

CYT was conducted with 2 selected cultures. The submergence tolerant cultures identified from earlier trials viz., KAUM 179-1, KAUM 180-2 were found to be significantly superior to other cultures and on par with each other and with the check variety Uma in grain yield during Puncha 2016- 17. Culture KAUM 179-1 was included in the initial variety trial AICRIP. During 2016-17 Punja high incidence of stem borer attack occurred and KAU M 179-1 and KAU M 180-2 showed low score value compared to the check varieties. Further studies are needed to check the tolerance to important pest and diseases.

## 19. Genetic improvement of the medicinal rice (*Oryza sativa*. L) varieties of Kerala

Five Njavara cultures selected through pureline selection from Yellow Njavara and twelve mutant cultures were yield tested during puncha 2016- 17. The selected cultures were advanced to CYT and were found to be superior to check variety yellow njavara.The segregating population derived from the hybridisation programme involving different ecotypes of Njavara is in comparative yield trial stage.

## 20. Genetic Improvement of rice to meet the location specific varietal needs of Kuttanad

Cultures KAUM 250-1-1-1-1-1-1 and KAUM 242-4-2-1-1-1 were the best performers with respect to grain yield. These cultures out yielded the check variety Uma in grain yield (9210kg/ha.). During Puncha 2016-17 also cul. KAUM 242-4-2-1-1-1 ranked first in yield and is nominated for AICRIP trial IVT boro.

## 21. Breeding for Hybrids in Rice

Collected and evaluated the CMS lines IR 58025 A, IR 68897 A and IR 79156 A for stable male sterility. Collected and evaluated maintainer lines of the CMS A lines. Thirty two hybrids released from public and private institutions were evaluated for its suitability for Kerala during 2014-15 along with check varieties Jyothi and Uma. The evaluation with selected Public bred rice hybrids from Maharashtra (Sahyadri 1 to 5), Tamilnadu (CORH 3 and 4), Karnataka (KRH 4) and Madhya Pradesh (JRH 5) was conducted in Rabi 2016-17 along with varietal checks Jyothi, Matta triveni, Aiswarya, and Uma. KRH4 yielded the highest followed by Sahyadri 4 and Sahyadri 5. KRH4 showed 22% superiority over the best check Uma.

Hybrids with high yield and acceptable cooking quality identified from the study will be recommended for the state. Hybrid seed production package for Kerala is to be finalized utilizing the parental lines of superior hybrids identified from the study.

**22. Screening of rice genotypes for tolerance to soil acidity and related nutritional constraints**

The trial was continued with a new set of 23 varieties in Tharayil kari padasekharam at Thakazhy. Soil analysis data revealed that the soil was clay textured with strongly acidic pH and high organic carbon content. The soil was medium in available N and K and high in available P and deficient in available Ca, Mg and B. Available Zn, Cu and Mn were sufficient with very high level of available Fe.

Based on the results it can be summarized that genotypes responded differentially to lime and NPK application with grain yield increase of 6.4 to 12.1 %. The genotypes responsive to liming were Uma (6.75 t/ha), DRRH - 92(3.78 t/ha) and 27- P-22 (3.50 t/ha) andgenotypes tolerant to native soil acidity were Uma (4.06 t/ha), DRR Dhan -39 (3.49 t /ha) and 27 P – 37 (3.48 t /ha) as they recorded superior yields in comparison to other genotypes in the treatment without liming. Indira maheswari (2.53t /ha), Bamleshwari (3.13 t/ha), DRR Dhan -43 (2.73 t/ha), US - 314 (2.47 t/ha) and RP 5974-4-3-2-8-38-12 (2.59 t/ha$^{-1}$) responded positively to double dose of P&K.

**23. Monitoring soil quality and crop productivity under emerging rice production systems (Kharif and Rabi)**

In Kharif 2016, there was no significant difference in yield. But in Puncha, 2016 transplanted rice recorded significantly superior yield. Straw yield also recorded the same trend. The results indicated superior performance of the transplanted rice over direct sown rice. In case of nutrient management practices, maximum yields were obtained with 75% RDF +25% organics and 100 % RDF+ 50 % through organics in the first and second season respectively. The lowest yielding treatment was 100 % organics. Conjunctive use of organics and inorganics was found to increase yield without deteriorating soil quality. The results of the study indicated that the use of organic matter addition was necessary to sustain soil quality in soil test based nutrient management also.

**24. Gall Midge Special Screening Trial**

Four entries (IC 577588, PTB 26, TH BR 69 and WGL1119) out of 91 entries showed no silver shoot damage of gall midge.

**25. Gall Midge Biotype monitoring trial**

The infestation was very low and none of the 17 differentials had damage.

**26. Gall midge screening trial (GMS)**

Eleven entries out of 70 entries showed no silver shoot damage of gall midge.

**27. Insecticide evaluation trial**

Dinotefuran 20% SG@ 150 -200 g/ha treated plots showed the lowest incidence of BPH at 50 DAT and Thiomethoxam 25%WG@100g/ha was found the most effective treatment against Ricebug at 70 DAT and 90 DAT.

**28. NationalScreening Nursery**

1363 cultures (373 (NSN-1),663 (NSN-2), 145 (NHSN),109 (DSN) were screened against Sheath blight, and Bacterial leaf blight incidence. 126 cultures showed multiple resistance during Kharif ,2016 and 63 cultures during Rabi, 2016-17

## 29. National Screening Nursery 1(NSN-1)

Fifteen out of 383 entries were found with nil gall midge damage.

## 30. National Screening Nursery-2(NSN-II)

416 out of 673 entries were found without gall midge damage due to low infestation.

## 31. Pest Survey Reports

Main objectives of the trial conducted in RRS, Moncompu were to monitor and report incidence, buildup and outbreaks of insect's pests of rice, quantification of affected area and intensity of pest damage and impact on yield. Severe incidence of BPH was observed from August to October, 2016.

## 32. Light Trap Collection of Insects

Insect catches other than sucking pests were low. GLH and BPH showed high activity during the crop growth periods and highest numbers were found in 49th SW (Nv-163 and Nn-178). GLH was not found in light trap catches during 15th to 31st SW, while BPH was found more active during 5th to 14th SW and again during 31st to 44th SW with highest count of 19880 in 38th SW.YSB was found round the year though the catches were low with a maximum of 54 (27+27) in 7th SW. GM, LF, WBPH, and BB were not in considerable numbers.

## 33. Monitoring of Pests and their Natural Enemies

Regarding species composition, three species of stem borers were observed during 2016 Kharif – YSB, WSB and PSB. YSB dominated in all phases of crop growth ranging from 60.0-90.0%, followed by WSB (13.33%) and PSB (8.10%). For natural enemies, three egg parasatoids of stem borer were observed with *Trichogramma japonicum* being the dominant one.. The mean stem borer egg mass parasitisation was 19.67% over four dates of observation with a mean egg parasitisation of 8.01%. *T. japonicum* accounted for 70.13% of the population, followed by *Telenomus* (29.08%) and *Tetrastichus* (0.79%). For gall midge, a total of 123 galls were observed from hundred hills of which 84.55 % were parasitized. The only parasitoid observed was *Platygaster oryzae.*

## 34. National Hybrid Screening Nursery

One enrty out of 155 entries were found highly resistant without gall mildge damageScreening for Sheath blight and Sheath rot resistance to diseases

## 35. Screening for sheath blight resistance

In National Screening Nursery 1 (NSN1), 373 entries were screened for sheath blight resistance during the year 2016-17.Three entries were moderately resistant to sheath blight with score 3. The National Screening Nursery 2 (NSN-II) consisted of 663 entries of which 3 entries showed moderate resistance reaction.No entries in NHSN and DSN were resistant to sheath blight.

## 36. Screening for leaf blast resistance

During the year 2016-17, in National Screening Nursery 1 (NSN1), 373 entries were screened for leaf blast resistance. Among these 7 entries showed resistance reaction to leaf blast with score 1. The National Screening Nursery 2 (NSN-2) consisted of 663 entries of which 2 entries showed

resistance reaction with score 1. Out of the 145 entries tested in National Hybrid Screening Nursery (NHSN), 3 entries showed resistance reaction. Out of the 109 entries tested in the Donor screening nursery (DSN) no entries showed resistance reaction.

## 37. Disease Observation Nursery

The fortnight trial was conducted with the cultivars Shreyas (MO-22, Prathyasa (MO-21) and Uma (MO -16) at three different dates at twenty days interval to identify the time and intensity of the disease occurrence. During Kharif 2016, moderately high disease incidence of sheath blight was observed in the early and late sown crop (May 4$^{th}$ week and June 4$^{th}$ week) of Shreyas (29.16% and 32.96%. It was moderately low in normal sown crop (2$^{nd}$ week of June) of variety Uma (17.84%) followed by Shreyas (19.57%). During Rabi 2016-17, high incidence of sheath blight was observed in the late sown (January 1$^{st}$ week) of Prathyasa (63.70 %) followed by Uma (38.70%) and Shreyas(30.56%).

The disease intensity was moderately high in normal sown crop during previous seasons. Generally, sheath blight incidence was low to moderate in early sown crops. The disease intensity was moderate in normal sown crop during Kharif 2006 (26.5%) and Rabi 2006-07. The highest intensity of sheath blight was recorded in normal sown crops of TN 1 (56.72 %) and late sown crop of Tapaswini (54.69 %). The neck blast incidence was very low in early sown crop followed by late sown crop. Sheath blight incidence was high in early sown Uma (40.55) and normal crop of Swarna (48.0). Sheath blight disease was moderately high in the early sown crop of Uma variety (32.42%) followed by TN 1 (24.76%) and IR 50 (18.73 %). Sheath blight incidence was generally high in all varieties of early sown crop (30-50%). It was very high in Swarna (50.65%) and low in IR-50 (30.56%). Sheath blight incidence was low to moderate in all varieties of normal sown crop (9-12%)during Rabi2012-13.During Kharif2013, Sheath blight disease was moderately high in late sown crop of Swarna (20.7%) followed by Uma (15.80%), IR 50 (10.4%) and Tapaswini (7.82%).In the case of early sown crop, the incidence was high in Tapaswini (12.38%) followed by IR 50 (11.0%) and Uma (10.9%).The incidence was very low in normal sown crop of all varieties.

During Kharif 2016, moderately high incidence of sheath blight was observed in the early and late sown crop (3$^{rd}$ week of May& June 4$^{th}$ week) of Shreyas (29.16 % & 32.96 %). During Rabi 2016-17, high incidence of sheath blight was observed in the late sown (January 1$^{st}$ week) of Prathyasa (63.70 %) followed by Uma (38.70%) and Shreyas (30.56%). In general, early sown crop escaped from Sheath blight disease incidence. But BLB disease was moderately high in normal and late in late sown crop from last year onwards.

## 38. Evaluation of fungicides to location specific diseases

The systemic fungicide Hexaconazole @ 2 gm/l were found superior in restricting the sheath blight disease occurrence during Kharif 2016. The systemic fungicide, Tebuconazole @ 1.5 ml/l and Hexaconazole @ 2 gm/l were found superior against grain discolouration disease. During Rabi 2016-17. Hexaconazole 5%EC @ 2ml/l was found superior against grain discolouration disease in rice and it was on par with Carbendazim 50%WP @1g/l. Out of seven commercially

available fungicides tested, Hexaconazole 5%EC @ 2ml/l was found superior against grain discolouration disease in rice and it was on par with Carbentazim 50%WP @1g/l.

## 39. Production Oriented Survey

Production oriented survey was conducted at Alappuzha (3500 acre), Kottayam (1750 acre) and Pathanamthitta (130 acre) districts duringKharif 2016 from booting stage to maturity stage of the rice crop. The survey covered four taulks in Alappuzha District, viz., Ambalapuzha, Kuttanad, Alappuzha and Harippad, while in Kottayam district two taluks namely Kottayam and Vaikom and Pathanamthitta district Thiruvallataluk could be surveyed

Moderate incidence of the biotic constraints like sheath blight, bacterial leaf blight, leaf folder, case worm, rice bug and rats were observed. Severe incidence of BPH was found in Alappuzha district. Lack of sufficient labourers and high labour cost were the main problems faced by the farmers.

Production oriented survey was conducted in Alappuzha (4756 accre) and Kottayam (1750 acre) districts duringRabi 2016-17. Moderate incidence of the biotic constraints like sheath blight, sheath rot, bacterial leaf blight, brown plant hopper, leaf folder, case worm, rice bug and rats were observed. Rat was the common problem during panicle initiation stage and it was controlled by rat trap using food bait of raw tapioca or lemon peel. Biocontrol agent *Psuedomonas fluorescens* produced at R.R.S, Moncompu was distributed to the farmers for the ecofriendly management of plant diseases.

**District-wise observations:**

**Alappuzha:** 3500 acres of rice area was surveyed at Alappuzha district during Kharif 2016. The predominant cropping sequences were rice-fallow, rice-rice and fallow-rice. The predominant varieties in the district were Uma and Jyothi. The ruling variety of Kuttanad area is Uma (MO 16). Vyttila 6, Chettivirippu, Pokkali, Mundakan were cultivated in some northern region of the district. Prathyasa and newly released variety shreyaswere cultivated in some area of the district. The average rainfall of Kharif season was 2500 mm, but the rainfall received during Kharif 2016 was 1588.72 mm which was 63.54% deficient than the normal rainfall. 75 ha rice area was severely affected by wild rice infestation and crop was neglected during kharif 2016.

Severe incidence of BPH was found Punthuram north padam, Elayidamthuruthupadam, Kariyarmudiyila karipadam and Nalupadam of Ambalappuzha block. 280.22 ha were found to severely affect due to BPH. Severe incidence of wild rice infestation was found in 75 ha of rice field. Moderate incidence of bacterial leaf blight, sheathblight, green leaf folder and stem borer were observed in Changakarychirayakam, Manaprathekkupadam of Champakkulam block, Kuruvapadam of Alappuzha block, Nanekkadupadam and Kapplavelilpadam of Ambalappuzha block.

Severe incidence of BLB was found in Kanakasserry 300 padam of Ambalappuzha block. In Karumady, many of the padashekarams are dried due to the scarcity of water. Severe incidence of brown spot was found in Kariyarmudiyilakaripadam of Ambalappuzha block. Around 500 ha of kariland (acidic soil) was severely affected by brown spot disease.

Some farmers were found to use the biofertilizer namely PGPR mix 1. Azataf (250g/acre) + Contaf (250 ml/) acre combination spray was normally followed by Kuttanad farmers at the time

of booting stage. Trichogramma egg cards were used by few farmers for the management of stem borer and leaf folder pest.

**Pathanamthitta:** In the upland cultivation area of Pathanamthitta district, two villages namely Eraviperoor and Puramattomwere surveyed. They followed organic rice cultivation method. The severity of diseases and pests are low in upland rice cultivation. The blast incidence was noticed in the Jyothi and Kanchana variety. Rice ear head bug was organically controlled by spraying of fish amino acid at the time of flowering stage. The farmers faced difficulties for irrigating the crop due to lack of rainfall. Shortage of suitable varieties, labourers and machineries for upland cultivation are the major problems.

**40. Screening for bacterial leaf blight resistance.**

Out of the 373 entries screened for bacterial blight resistance in NSN 1(Pattambi), during the year 2016-17, seven entries showed moderate resistance with score 3. Ten entries in NSN 2, seven entries in NHSN and two entries in DSN also showed moderate resistance to bacterial blight.

**41. Field monitoring of virulences in Xa*nthamonas oryzae* pv. *Oryzae***

During the year 2016-17, virulence analysis of bacterial blight pathogen of rice *Xanthomonas oryzae pv. oryzae* has been carried out with 31 near isogenic lines (IRBB background) with different bacterial blight resistance genes and their combinations. None of the gene combinations tested offered satisfactory resistance reaction to the native isolate of bacterial blight pathogen. However three NILs, IRBB-59, IRBB-60 and IRBB 66 showed moderate resistance to bacterial blight with Score3.

**42. Field monitoring of virulence in *Pyricularia grisea***

During the year 2016-17(Pattambi), virulence analysis of blast pathogen of rice *Pyricularia grisea*, on 25 differentials/NILs revealed that Tetep and Raminad STR-3 were resistant to local isolate of blast pathogen with score2.

**43. Field Monitoring virulence in *Xanthomonas oryzae.pv.oryzae***

During Kharif 2016, virulence analysis of bacterial blight pathogen of rice *Xanthomonaso ryzae pv. oryzae* was carried out in Moncompu in Kharif. 31 isogenic lines (IRBB background) possessing different bacterial blight resistance genes in the background of rice cultivar IR 24. Seventeen entries (IRBB-1, 3, 4, 5, 13, 14, 50, 51, 52, 55, 56, 58, 59, 60, 61, DV-85, Improved Samba Mahsuri) showed resistant reaction to BLB during Kharif 2016. During Rabi 2017**,** 31 AICRIP entries were tested against BLB pathogen during Rabi 2016-17. Among them 25 entries showed r multiple resistance against native BLB pathogen.

In Rabi 2016-17, 31 AICRIP entries were tested against BLB pathogen and among them 25 entries showed their multiple resistance against native BLB pathogen.All resistant gene combination isogenic lines showed their resistant nature to the native bacterial blight pathogen.

**44. Integrated disease management (Sheath blight)**

An IDM strategy against sheath blight was evaluated in Pattambi during the year 2016-17. IDM practices involving seed treatment and nutrient management in nursery (FYM @ 1t/1000$m^2$ ;

Basal dose - NPK @ 20:50:50 kg/ha; Top dressing - 25kg N/ha) and main field (Compost @ 10t/ha; NPK @ 90:45:45kg/ha; N- 3 splits, P – basal and K – 2 splits and a spray of carbendazim @1g/l after the appearance of disease symptoms) were tested in a susceptible variety, Jyothi; and two moderately resistant high yielding variety varieties, Aiswarya and Aathira.

The disease severity was lowest in variety Aiswarya (26.81%) which was statistically on par with Aathira (27.81%). The disease severity in IDM plots (26.91%) were significantly lower than that in non IDM plots (42.17%). There was significant reduction in disease severity in varieties Aiswarya and Aathira than in Jyothi, when IDM was followed.

**45. Integrated disease management in rice**

During Kharif 2016 (Moncompu), Sheath blight disease was moderate in Uma variety (33.51%) with FYM + PGPR1 + *Pseudomonas* (seed+ soil+ foliar+ Neemcake+ Neem based chemical (V3M1). BLB incidence was very low in Shreyas (11.11%) with FYM + PGPR1 + *Pseudomonas* (seed+ soil+ foliar+ Neemcake+ Neem based chemical (V2M1) and Uma (13.15%) with FYM + PGPR1 + *Pseudomonas* (seed+ soil+ foliar+ Neemcake+ Neem based chemical (V3M1). During Rabi 2016-17, Sheath blight and BLB diseases were low in Uma variety (20.90% and 16.53%) in the FYM + PGPR1+ *Pseudomonas* (seed+soil+foliar) +Neemcake +Neem based chemical(V3M1) treated plot when compared to Jyothi and Prathyasa.

**46. Development of formulation of endophytic Bacteria for the management of soil borne diseases of rice with special emphasis on Sheath blight and Bacterial blight**

Test for volatile compound production of Bacillus cultures namely B 15, B 17 and B 33 were carried out under invitro condition. B 15 produce high quantity of volatile compounds against sheath blight pathogen followed by B 17 and B 33. Pot culture techniques were laid out for testing the biometric characteristic of the effective strains of B 15, B17, B 33 and the shelf life studies of the above strains are under progress. Seed and soil application of the formulations were carried out in the station field. Pot culture experiments were laid out in net house with the promising five isolates viz., Pf 7, Pf 82, Pf 87, B10, and B 42 along with standard culture (P1) for evaluating PGPR studies. Observations on plant characters are being recorded.

**47. Influence of silicon solubilizers on induced stress tolerance in rice genotypes**

During 2016-17, Soil application of imidazole-1.5% and sodium potassium silicate (1.0%) improved the grain yield. Application of silicon showed a positive influence on grain yield. However, the effect was dependent on genotype and location. At Pattambi maximum improvement in grain yield with both imidazole and silixol was observed. Five rice hybrids (PA-6129, PA-6201, PA-6444, PHB-71, US-312, and BPT-5204) and one popular variety (Jyothi) were taken up to study the effect of silicon solubilizer (imidazole-1%) and silixol (2.5%). Result revealed that soil application of imidazole and foliar spray of silixol improved the grain yield in US- 312, PA 6129, PA 6444 and reduction of number of spikelets /panicle. There was no tolerance to pest and diseases.

## 48. Evaluation of rice genotypes for terminal heat tolerance

During 2016-17**,** thirty two entries were evaluated for high temperature stress from seedling stage to maturity. IET 24705, IET 24053, IET24798, NH-219, DRRDhan-43, NDR-97, IET23996 and Luit produced relatively higher yield under heat stress condition. Spikelet fertility under ambient condition ranged from 76.32 to 94% but under high temperature it ranged from 17 to 92%. The variability in tolerance to high temperature of few genotypes may be due to acclimatization process by production of heat shock proteins.

## 49. Screening of elite rice genotypes for Drought Tolerance (Rainfed Upland)

During 2016-17, Seventeen entries were evaluated under rain-fed upland condition, among the entries, IET 25121, 24692, 25103 and IET 25123 performed better and these entries were found suitable for rainfed condition. IET 24692 and IET 25123 recorded the highest yield of 9650kg/ha and 1106 kg/ha respectively compared to the local check, Jyothi (656 Kg/ha) which was constituent with the reports of previous years.

## 50. Physiological characterization of rice genotypes for multiple abiotic stress resistance

During 2016-17(Pattambi), twenty entries were subjected to multiple abiotic stresses (drought-1 and 2% mannitol; salinity-100ppm NaCl; anaerobic germination), among them for water stress 1% mannitol Somali and 2% mannitol IET24674 and for salinity (100ppm) IET 23223 recorded the highest seedling vigour index.

## 51. Identification of molecular markers linked to iron toxicity tolerance through bulk segregant analysis (BSA) in rice (*Oryza sativa* L.)

The $F_1$s obtained by hybridizing genotypeTulasi (PGC 14) that was found to be most tolerant to iron stress (800ppm of Fe) with the most susceptible genotype Cul-8709 (PGC 31) were raised and selfed to produce $F_2$ generation for conduct of Bulk generation analysis (BSA).

**52. Evolution of high yielding rice varieties suitable for Pokkali tract of Northern Kerala through farmer's participatory breeding approach--Plan**

All the released five varieties and pre-release cultures from North Kerala are maintained through breeder seed production programmein Pilicode. Farm trial of culture JO 583 was conducted and the result is given below

**Performance of culture JO 583 in Kaipad tract during 2016 Kharif**
**Area cultivated = 20 cents**

| Name & Address of Farmer | Name of cultures | Yield (kg/ha) | Remarks |
|---|---|---|---|
| Jalaja, Kannapuram Kannur (distict) | JO 583<br>Ezhome -2<br>Ezhome-3<br>JK 59 | 4500<br>5375<br>4750<br>3375 | (non lodging)<br>(non lodging)<br>(non lodging)<br>( lodging )More straw than others |
| C.Govindan Nambiar, Kuruvad, Ezhome, P.O. Kannur (District) (Low saline Kaipad) | JO 583 | 5599 | Non lodging |
| | JK 59 | 2683 | Lodging |
| | Ezhome-2 | 5326 | Non lodging |
| | Ezhome-3 | 3369 | Non lodging |
| | Kuthiru | 1250 | Lodging |

**53. Breeding high yielding rice varieties suitable for pokkali area by hybridization between Pokkali varieties and other high yielding varieties.**

Cross combinations were made under the project to pyramid the salinity tolerance of pokkali and cheruvirippu into the rice variety Uma. The selecte line sare in the F4 Generation.The F1 hybrid of the new cross between VTL 4 with Pusa 44 for incorporation of stiff culm to VTL 4 will be raised in the pot and F2 seeds were collected.

**54. Induced mutagenesis of pokkali rice land races**

The mutant cultures differed significantlyin CYT and the culture M 27.1 recorded the maximum yield of 6250 kg/ha followed by cultures M 51.5 (6067 kg/ha), M 48.4 (5233 kg/ha) and M 27.2 (5142 kg/ha). Culture 27.1 and cul 51.5 showed significantly high yield than the check and they were evaluated in farm trial in five locations.culture 51.5 was proposed for release.the cultures 51.5 and 25.3 performed beter than national yield check in the national level evaluation (CSTVT 2014).

**55. Collection, maintenance and utilization of saline resistant rice varieties**

Fifty nine accessions were raised in the field during Kharif 2017. Data on morphological characters, yield and yield attributes were recorded. True to type panicles were collected.

**56. Breeding for high yielding rice varieties having short duration, seed dormancy and resistance to biotic and abiotic stresses suitable for Kuttanad-RKVY**

During 2016-17 CYT was conducted with 7 cultures along with 4 check varieties. Among them, Culture KAUM 200-2-2-3-2-1 recorded the highest grain yield of 7011.5 Kg/ha, while the check variety Uma recorded 6815 Kg/ha.

**57. Network project on Seeds and Planting materials production- Plan**

Breeder and foundation seeds of the MO varieties were produced during the period. A total quantity of 5460 kg Breeder seeds, 1021 kg Foundation seeds and 9980 kg truthfully labelled seeds were produced during 2016-17 period and distributed to various agencies viz., NSC, KSSDA, Dept. farms, farmers etc.

**58. Permanent Manurial Trial**

The treatments comprised of combination of major nutrients either alone or with lime, zero fertiliser application with and without straw incorporation, and nutrient recommendation based on soil test data in the test variety MO -6 (Pavizham).

The results of the experiment for the last 30 years revealed that continuous omission of nitrogen and phosphorous resulted in severe nutrient deficiency symptoms and significant yield reduction both during *Kharif* and R*abi* seasons. The yield during the period under report in different treatments was in conformity with the results obtained in the previous years. The yield in the treatment without the application of potassium for the last 29 years was on par with that of the treatment based on soil test data.

**59. Response of pre-release Moncompu cultures to varying nutrient ratios**

The fertilizer recommendation of the variety Shreyas (MO-22) can be fixed as 80:45:45 NPK kg/ha. The yield of the variety was statistically on par with that at 90:45:45 NPK kg/ha applied at seedling, active tillering and panicle initiation stage of the crop.

**60. Evaluation of new herbicide product in puddle direct sown rice**

The results of evaluation of the new test molecule Rinskor 2.5% EC@ 31.25 g ai/ha was found to be effective for broad spectrum control of weeds in direct sown rice both in Kharif and Rabi seasons. The chemical is to be applied at 4-7 leaf stage of the weeds.

**61. Yield maximisation of rice through SSNM**

This AICRP trial is being conducted with the objective of assessing the indigenous nutrient supplying capacity of soils in various rice growing ecologies and to compare the yield and economic performance of field specific fertilizer recommendations with the existing blanket recommendations. SSNM based fertilizer application (NPK @ 93:5:41 kg/ha) recorded the highest grain yield which was on par with RDF (NPK @ 90:22:45 kg/ha) during both Kharif and Rabi seasons.

**62. Monitoring soil quality and crop productivity under emerging rice production systems**

The trial was started in 2015 and targeted to continue for five years. In Kharif 2016, there was no significant difference in yield. But in Puncha, 2016 transplanted rice recorded significantly superior yield. Straw yield also recorded the same trend. In case of nutrient management practices, maximum yields were obtained with 75% RDF +25% organics and 100 % RDF+ 50 % through organics in the first and second season respectively. The lowest yielding treatment was 100 % organics. Conjunctive use of organics and inorganics was found to increase yield without deteriorating soil quality. The results of the study indicated that the use of organic matter addition was necessary to sustain soil quality in soil test based nutrient management also.

**63. Ecological Engineering of Plant hopper management (EEPM)**

The bund planting of marigold was taken up in EE plots. The pooled analysis revealed that number of hoppers did not differ significantly in EE and FP plots. However, green mirids (3.19/hill) and spiders (0.75/hill) were significantly higher in ecological engineering plots. Drynid parsitisation of hoppers did not differ significantly between the two treatments.

**64. Identification of Local Strains from Kuttanad Suited for Mushroom Production and Agro waste Composting**

Twenty one cultures were isolated and stored from the thirty three species of mushrooms collected. *Pleurotus djamor*, *Volvariella volvacea, Tricholoma sp, Calocybe sp, Auricularia sp, Ganoderma sp Termitomyces* sp. etc were included. A gaint mushroom of *Calocybe* sp (pileus diameter- 47cm, stalk length- 15cm, weight- 2.600kg) was collected from Nadubhagham, Champakulam panchayat .Isolation of culture, preparation of spawn on rice grain and production of mushroom on paddy straw were successfully completed.

Amino acid analysis of two mushroom samples (*Pleurotus florida* and *Pleurotus eous*) revealed that the essential amino acids like L-Histidine (9.6 mg/g), Threonine (0.082 mg/g), Methionine (0.01 mg/g) and Isoleucine (0.12 mg/g), were high in *P.eous*. But *P.florida* was found to have the highest value for Arginnine (0.1 mg/g), Phenylalanine (65.0 mg/g) and Lysine (0.9 mg/g). Relative concentration of nutrient factors and minerals in fruit bodies of *Pleurotus eous* at different stages of maturity were analysed. *P.eous* harvested at first day after pinhead formation showed increased quantity of carbohydrates (6.39g%), fat (0.4g%) and minerals like sodium (82 ppm), potassium (3320 ppm), calcium (84 ppm) and iron (30 ppm). A drastic reduction in the calcium content was found on the third day after pinhead formation. - The three species of mushrooms i.e. *Pleurotus eous, P.florida* and *Calocybe indica* (Bhīma) were tested for their suitability to make three popular dishes namely baji, thoran and soup based on different sensory parameters. *Calocybe indica* (Bhima) was identified as the best mushroom for the preparation of these dishes. In an experiment to find out the best time of sterilization in substrate sterilizer, different treatments were tried i.e. 30, 45, 60 and 90 minutes (open vessel). It has been found that 30 minutes sterilization gave the highest mean yield of mushroom ie. 801.4g/ bed while the standard method of sterilization in open vessel for 90 minutes gave only 461.8g/bed.Pest and disease incidence was also the least in 30 mts .Springtails (*Collembola*) , Rove Beetle (*Stephylinidae* :*coleoptera* ) and a larval pest of moth (*Ctenuchina* sp) were found as pests infesting mushroom. Trichoderma and an un-identified fungus were found growing on

mushroom bed as contaminants. Presence of Carbendazim was detected in a mushroom sample collected from Pathanamthitta District in the residue analysis for Pesticides in mushroom.

**65. Development of weather based forewarning system for Blast disease and Leaf folder pest of rice and Formulation of Crop-Weather advisories to the rice farmers of Kuttanad region**

During Kharif 2016, leaf folder (19.03 %) in normal nitrogen (90Kg/ha) and normal seed rate (100kg/ha) at the pot of alternatively irrigated condition at the temperature of 23.7-30.9$^0$C and RH ranges from 67.1-92.1%. Leaf blast infection was high (24.67%) in high seed rate and high nitrogen level at the plot of alternatively irrigated condition at the temperature of 23.7-30.9$^0$C and RH ranges from 67.1-92.1. During Rabi 2016-17, (32.1%) in high nitrogen (120Kg/ha) and high seed rate (150kg/ha) at the plot of alternatively irrigated condition at the temperature of 25.06-34.420C and RH ranges from 61-90.6.Blast disease infection was moderately high in (32.8%) in high nitrogen (120Kg/ha) and high seed rate (150kg/ha) at the plot of alternatively irrigated condition At the temperature of 23.3-31.6$^0$C and Rh ranges from 64.3-89.5.

**66. Conservation and Utilisation of Rice Biodiversity in Kuttanad**

179 traditional varieties were planted in the field for evaluation of morphological characters. Morphological characterization based on Rice Descriptor of 125 accessions has been completed. The accessions were evaluated for submergence tolerance by providing artificial stress to identify their resistance/ tolerance reaction. 25 traditional varieties were sent to Vyttila station for molecular analysis.

**67. Crop establishment practices for ecofriendly weed management in Kuttanad**

The results during 2016-17 showed that drum seeding along with cono weeding at 18 and 30 DAS and integrated nutrient management (RD + PGPR 7.5 kg/ha) gave on par yield with drum seeded, cono weeded, organically managed field (PGPR). Weed management using cono weeder at 18 and 30 DAS followed by hand weeding the within the rows was found to be equally effective as herbicide application, revealing the efficiency of cono weeding for effective weed management and crop growth in organic rice production. In machine transplanting, the fully organic and integrated nutrient managed plots with herbicide application gave on par yield revealing the efficiency of the PGPR Mix 1 in its nutrient supplying capacity. Application of PGPR thrice (at 20, 35 and 50 DAS) @ 7.5 kg/ha during the crop season had lesser chaffing and higher yield compared to application twice @ 5 kg/ha (at 20 and 45 DAS).

**68. Variability, over wintering and eco-friendly management of bacterial leaf blight pathogen of rice in Kuttanad**

Hypersensitive studies using tobacco variety *Nicotiana rustica* and differential reaction of BLB isolates towards 20 IRRI lines with BLB resistant genes showed that variability existed among different isolates. Biochemical analysis of rice leaf samples at 48 hrs after artificial inoculation showed that resistance to BLB is directly proportional to the antioxidant content. Resistant variety Ptb -5 showed highest antioxidant activity as compared to the tolerant variety MO – 16, while the susceptible variety MO -4 exhibited the least. For carbohydrate content, rice leaves

there was no difference between control and treated samples of susceptible MO- 4 and tolerant MO – 16 varieties. 10 fold increase was observed in treated sample of resistant variety (Ptb -5) over control. Highest content of protein was exhibited in resistant variety Ptb- 5 (10g/100g). Varietal reaction towards bacterial leaf blight pathogen was studied with SEM based on anatomical basis of resistance. Results showed that there was no clogging of water pores in rice leaves (one hour after artificial inoculation) of resistant variety Ptb- 5 as similar to untreated samples. But clogging of water pores was observed in tolerant (Mo- 16) and susceptible (MO- 4) varieties.Results of pot culture experiments for ecofriendly management of BLB, lowest disease severity was observed in Srepto G(50 ppm) treated plants, while highest yield was obtained in the treatment Thuja 30P. Panchagavya, $KMnO_4$ 4 per cent, Pseudomonas + cow dung supernatant 2 per cent, cow dung supernatant 2 per cent and Kocide0.2 per cent were alsofound to be promising both for reducing disease severity ofBLB and for getting higher yield. A new bacterial disease other than Xanthomonas blight was found occurring in rice fields of Kuttanad for the past three years exhibiting symptoms like yellowing and drying of leaves, blackening of sheath and panicles. Kochs postulates was proved and etiological studies confirming the identity of the causal organism based on DNA sequencing is in progress.

**69. Isolation and field efficacy evaluation of entomo-pathogenic fungi for biological control of rice leaf folder and brown plant hopper in Kuttanad.**

Studies using poisoned food technique was conducted using four commonly used insecticides viz. Acephate 75% SP, Flubendiamide 20% WDG, Quinalphos 25% EC and neem oil to determine the effect of insecticides on the mycelial growth of *Beauveria bassiana*. Among the insecticides tested, Quinalphos 25% EC showed maximum growth reduction of *Beauveria* on 14 DAI when compared with control.

**70. Development of alternative chemicals for weed management - Development of alternatives for paraquat-RKVY**

The herbicide Glufosinate ammonium and the combination herbicide Oxyfluorfen + Glyphosate (0.15+1.0 kg/ha) could be suggested as alternatives for Paraquat in stale seed bed for broad spectrum non selective management of weeds. Glufosinate ammonium was found effective for all the weeds except *Fimbristylis* for which only 73 per cent weed control was observed. The field has to be submerged in water after two days of spraying the herbicide and inundated for 15 days for effective control of weeds during stale seed bed preparation before sowing. Farm trial was conducted in different locations of Kuttanad with promising results.

**71. Insecticides for label expansion (Lower & Higher doses of Recommended Insecticides)**

Chloratraniliprole 0.4 G @ 12 Kg/ha treated plots showed the lowest incidence of stem borer at 30 ,50 and 90 DAT and it was found the most effective treatment against gall midge at 50 DAT. Flubendiamide 20 % WDG @ 150 g/ha treated plots showed the lowest incidence of Leaf folder at 50 DAT and 90 DAT. Chloratraniliprole 18.5 % SC@ 200 ml/ha treated plots showed the lowest incidence of BPH at 70 DAT it was highly effective controlling Rice bug at 90 DAT.

**72. Development of Location specific technology packages for different agro-ecological zones of Kuttanad through PTD**

Soil samples from representative sites at different locations from each agro ecological zone were collected and analysed for estimating the inherent fertility status of the area.

Experiments were conducted in the different agro-ecological zones of Kuttanadu viz., Upper Kuttanadu (Mannar and Pavukkara), Lower Kuttanadu (Veliyanad), North Kuttanadu (Kumarakam), Kari lands (Purakkadukari and Vaikomkari) and Kayal areas (E-Block kayal). Standardization of technologies like drum seeding, application of lime/dolomite, soil test based fertilizer application, and use of biocontrol agents like Trichocard and *Pseudomonas* for pest and disease management, providing kachal and vachal in the field were carried out in the farmers field and compared with the general practices followed by farmers. P and K were applied in accordance with the soil test values but Nitrogen was applied as per POP recommendation. Magnesium and Boron were deficient in all locations and was supplied as per soil test results. Dolomite was found to be the suitable liming material in kari area. However, during the Puncha season, drum seeding recorded higher yield compared to broadcasting in upper Kuttanad, lower Kuttanad and north Kuttanad. The broadcasted crop was lodged leading to lower yield in lower Kuttanad. The incidence of pests and diseases was lower in drum seeding compared to broadcasting in all the locations. 50% of the chemical pesticides could be reduced due to the application of biopesticides like *Pseudomonas* and trichocard placement. 40 per cent of cost of cultivation can be reduced due to our technologies including reduction in cost of fertilizers, quantity of seed and cost of pesticides.

**73. Crop management approaches for sustainable rice farming in Kari soils**

A total of 25 samples were collected from different locations of Kari soils in Kuttanad and analysed for 13 soil fertility parameters Extensive soil acidification, excess levels of phosphorus and wide spread deficiencies of calcium, magnesium and boron were the major limitations to crop production in these soils. Amelioration of soil acidity and external inputs of secondary and micronutrients along with the major nutrients are essential for enhancing crop productivity in these soils.

**74. Management of aquatic weeds with special emphasis to rice fields of Kuttanad**

Survey on the infestation of aquatic weeds in the Kuttanadu region revealed the presence of certain new invasions of *Polygonumbarbetum* sp, *Ipomoea aquatica*, *Alternathera philoxiroides* along the borders of paddy fields and channels. Management of aquatic weeds in paddy fields using weedicides and its combinations were tried in famers' field during the land preparation stage. Trail has to be continued.

**75. AVT Trials on selected AVT-2 rice cultures under high and low input management**

Seven AVT-2 IME (Transpl) rice cultures (IET 24117, IET 24323, IET 24326, IET 24331, IET 24334, IET 24338 and IET 24825) were evaluated with five standard checks (IR 64, PR 113, Lalat, Sasyasree and MTU 1010) and local checks at ten locations. Maximum grain yields were recorded at 150% of RDN and performance of IET 24117 and IET 24338 were promising in all other locations.

**76. Yield maximization of rice through site specific nutrient management (special collaborative trial – Agronomy, Soil Science & IPNI)**

International Plant Nutrition Institute (IPNI) is providing the remote sensed SSNM in the form of Nutrient Expert, an easy to use interactive computer based decision tool that can rapidly provide nutrient recommendations for farmers in the presence or absence of soil testing data. SSNM data was implemented and responded the yield of 5.01 t/ha on par with our POP yield of 4.92 t/ha. The SSNM data was reduced the P to the tune of 50% of our RDF. No much changes in N and K.

**77. Selective mechanization for enhancing productivity and profitability of rice cultivation**

The results revealed that selective mechanization treatments had marked influence on the performance of rice crop at all the locations. Normal transplanting + vigore application proved significantly superior in productivity over other treatments. The cost of cultivation was highest in farmer's practices. The same trend was observed in Rabi seasons also.

**78. Estimation of yield losses in direct seeded rice under puddled irrigated conditions**

The grain yields ranged from 2.93 t/ha at when the plot was not weeded up to 60 DAS. The mean weed dry weight showed very high 67.25 $g/m^2$ indicating the severity and intensity of weed problem. Also showed that the sedges were dominant population followed by grasses and BLW. Yield loss of 50 to 60% when the field was not weeded during the initial stages.

**79. Climate Resilient Management Practices in Rice land rice based cropping systems**

Conservation agriculture and resources such as paddy straw and brown manuring in rice - rice system was implemented in Pattambi. The yield was sustained at paddy straw incorporation with microbial fertilizers such as Azospyrillum, P mobilizing bacteria at 50 % RDF (3.65 t / ha) when compared with 100 % RDF (3.4 t/ha).

**80. Frontline Demonstrations (FLD) on Chemical weed management in rice**

Total of 25 acres of rice plots were selected at Thiruthala, Pirayiri, Mankara, Palayannur, Muntur and Parlai panchayat's for conducting this program funded by IIRR ( Indian Institute of Rice Research, Hyderabad). Sequential application of pre and post emergence herbicides such as Pretilachlor, Clincher, 2,4-D, and Almix were tried. Complete avoidance of manual labour for weeding and yield enhancement of 20 to 30 per cent more yield in most of the plots.

**81. Initial Variety Trial New plant Type**

Out of the 36 entries tested during 2016-17, PA 6444(HC) with 9110 kg/ha was found superior to all other entries with respect to yield.

## 82. Advanced Varietal Trial-2 Irrigated Mid Early

Out of the 12 entries tested during 2016-17, IET 25341 with 6185.52 kg/ha was found superior to all other entries with respect to yield.

## 83. Advanced Varietal Trial-2 Near Isogenic Lines – Blast

Out of the 12 entries tested during 2016-17, Samba Mahsuri (RP) with 4570 kg/ha was found superior to all other entries with respect to yield.

## 84. Evolution of high yielding rice hybrids suitable or Kerala

Collected and evaluated the CMS lines IR 58025 A, IR 68897 A and IR 79156 A for stable male sterility. Collected and evaluated maintainer lines of the CMS A lines. Thirty two hybrids released from public and private institutions were evaluated for its suitability for Kerala during 2014-15 along with check varieties Jyothi and Uma. The evaluation with selected Public bred rice hybrids from Maharashtra (Sahyadri 1 to 5), Tamilnadu (CORH 3 and 4), Karnataka (KRH 4) and Madhya Pradesh (JRH 5) was conducted in 2015-16 and was continued in Rabi 2016-17 along with varietal checks Jyothi, Matta triveni, Aiswarya, and Uma. KRH4 yielded the highest followed by Sahyadri 4 and Sahyadri 5. KRH4 showed 22% superiority over the best check Uma.

## 85. State Seed Testing Laboratory

Quality of 373 seed samples were analysed in the State Seed Testing Laboratory Pattambi during 2016-17, in various crops like Rice (255), Vegetables (97) and pulses (21). This includes 50 samples submitted by the Dept. of Agriculture and 323 samples from Seed production centres of the University. Technical Auditing of State Seed testing Laboratory was conducted during 2016-17

## 86. Development and evaluation of non conventional nutrient management technologies in rice (COE)

Field experiments for validation of suitable enrichment methods of nutrient content of rice seedlings before transplanting to an attainable limit is taken. Paddy seed priming in 2% solution of Sampoorna KAU multi-mix (Paddy) for 4 hours and foliar application of 1 % Sampoorna KAU multi mix at 10 and 20 days after sowing improved seedling vigor and increased average pooled grain yield by 13.1 and 14 % over control.

## 87. Planting geometry modification in rice to exploit border effect in rice

Four different types of planting geometry viz-paired row planting with 35-15X10 cm, paired row planting with 30-15X10 cm, Circular planting geometry and 20X15 cm spacing were compared to assess the border effect under different spacing and its contribution towards yield. 20X15 cm spacing have 60 per cent border effect compared to 20 per cent border effect in paired row planting with 35-15X10 cm. This difference in border effect distributed trough out the field in paired row planting resulted in significantly higher yield compared to other treatments.

**88. Evaluation of Radiation and Nitrogen use efficient promising rice genotype**

During 2016-17, trial was conducted with two nitrogen treatments (100kg/ha and 50 kg/ha) and recommended P & K fertilizer as basal dose. The performance of twelve entries was evaluated based on grain yield recorded under low nitrogen treatment. Rasi, MTU 1010, Sampada, BPT5204 and Jaya were promising genotypes for high radiation and nitrogen use efficiency.

**89. Physiological and biochemical basis of heat tolerance in rice.**

During 2016-2017, twenty-one selected AICRIP germplasm accessions were Screenedfor high temperature tolerance (8-10°C) more than the ambient condition. Among the entries, HT7, HT 10, HT12 and RFU-26 recorded the highest grain yield (g) and spikelet fertility. 371 Isogenic lines of rice were received from IRRI, Hyderabad during 2016 under NICRA for field evaluation for high temperature stress tolerance. The lines with five local checks were field evaluated in summer season of 2016 with ambient day temperature ranging from 33 to 38 $^{o}$C. Among the 371 ILN lines, sixty two lines were found promising in the first trail. The experiment material will be further evaluated.

**90. Development of rice varieties for Kerala with pyramided genes for Resistance to BLB by marker assisted selection**

The presence of the gene for resistance to BLB, *Xa 21, xa13 Xa33* and *Xa38* in the respective donors was confirmed using the respective markers. Hybridization between three donors (ISM, SM and PR-114) and two recurrent parents (Aiswarya and Prathyasa) were done. 100-250 seeds were obtained in the six crosses. Hybrids with heterozygous loci for the respective genes were used for back crossing with the recurrent parent. $BC_1F_1$ plants obtained were screened with foreground markers and identified the plants with genes of interest. The DNA isolated from the $BC_1F_1$ plants given for background screening. $BC_1F_1$ plants were intermated to pyramid the genes. Intermated seeds from the $BC_1F_1$ plants selected in the background selection were used for the next backcrossing.

**91. Invasion impact of greater club rush (*Scirpusgrossus* L. f) on wetland rice ecosystem**

Study of invasive characteristics, Anatomy, physiology, reproduction, dispersal and nutrient removal, Weed Mapping and Habitat Analysis, Invasion impact on biodiversity and ecosystem functioning of wetlands, Impact on biodiversity, Diversity and abundance of flora, fauna and microbes, Weed seed bank availability, Impact on nutrient cycling and microbial activity, etc. of greater club rush were done .Management of greater club rush was done in field experiment and stat analysis going on

**92. Development of Near Isogenic Lines of rice variety 'Uma' for blast resistance genes through molecular marker assisted backcross breeding**

Present study entitled "Development of Near Isogenic Lines of rice variety 'Uma' for blast resistance genes through molecular marker assisted backcross breeding" was undertaken at the College of Agriculture, Vellayani Thiruvananthapuram, todevelop Near Isogenic lines (NILs) of rice variety Uma for blast resistance genes (*Pi1*, *Pi-2* and *Pi-kh*) using identified donors through marker assisted back cross breeding.

DNA markers closely linked to the blast resistance genes*viz*., RM527 (*Pi2*gene), RM 224 (*Pi 1*gene) andRM 206 (*Pikh*gene) were used for validating marker polymorphism in the identified traditional donors of blast resistance genes*viz*.PTB 21 (Thekkan) with *Pi2*,PTB 7(Parambuvattan) with *Pi1* and *Pikh* andsusceptible recipientparent Uma (MO16).This validation confirmed the absence of genes in recurrent parent, Uma chosen for the study. Thesepolymorphic gene specific markers were also usedfor foreground selection in $F_1$ plants and backcross generations.

Hybridisation was carried out between recipient parent Uma and the two donor parents*viz.,* PTB 21 and PTB 7to transfer genes for resistance.$F_1$ plantswith heterozygous loci for blast resistance genes specific markers were identified through foreground selection and backcrossed with recurrent parent Umato obtain the $BC_1F_1$ generation.

This research could identify NILs of Uma for three blast resistance genes *viz., Pi1*, *Pi2* and *Pikh* with more than 94% recurrent parent genome recovery with two backcrossing through marker assisted selection. This confirms the utility of marker assisted backcross breeding in recurrent parent genome recovery. The NILs can be used in intermating programmes to develop pyramided lines of Uma with all the three blast resistance genes (*Pi1, Pi2* and *Pikh*) to ensure durable and broadspectrum resistance to the blast pathogen.

## 93. Genotyping of Rf (Restoring fertility) loci of rice varieties of Kerala using molecular markers

In the present study twenty one rice varieties were screened with 13 SSR markers linked to different R*f* genes i.e R*f3*, R*f4*, R*f5*, R*f6* and R*f7*. Three varieties had only one R*f* gene, seven varieties had two R*f* gene, four varieties had three R*f* gene. Rice varieties Remya, Manupriya and Swarnaprabha had four R*f* genes and PTB-9 had all the R*f* genes.For identification of maintainers and restorers from among the 21 rice varieties under study, these lines were crossed with 4 CMS lines (IR58025A, UPRI95-17A, CRMS31A and CRMS32A). Pollen and spikelet fertility of the hybrids recorded thatRemya, Swarnaprabha, Manupriya, Varsha and Aiswarya were restorers for CMS line IR58025A, Remya, Jayathi, Annapoorna, Neeraja, Aiswarya and Pavizham were restorers for UPRI95-17A. Remya, Jayathi, Swarnaprabha, Kanakom and Neearaja were restorers for CRMS31A and Remya, Jayathi, Swarnaprabha, Annapoorna, Kanakom, Mattatriveni and Pavizham were restorers for CRMS32A. Rice variety Remya alone was found to be the restorer for all four CMS lines. Rice varieties Jyothi, Kanchana and Aruna were identified as maintainers for IR58025A. Only one variety Kanchana identified as maintainer for UPRI95-17A. Bharathy, Jyothi, Kanchana and Aruna were identified as maintainers for CMS line CRMS31A, while Kanchana and Bharathy were identified as maintainers for CRMS32A. Kanchana alone was found to be the maintainer for all four CMS lines. In field validation Remya which had 4 R*f* genes (R*f3, Rf4*, R*f5* and R*f6*) was found to be a restorer for all the lines with WA Cytoplasm studied. All the restorers identified through field validation had either R*f3* or R*f4* gene which were reported as the major genes for fertility restoration.

Study of inheritance pattern of restorer gene was analysed in $F_2$ generation of the crosses between CMS lines and the restorers. It was found thatin UPRI95-17A x Remya, UPRI95-17A x Jayathi, UPRI95-17A x Annapoorna, UPRI95-17A x Aiswarya and UPRI95-17A x Pavizham the restoration of fertility is governed by 2 dominant gene. Co-segregation of the molecular marker linked to R*f*loci and the trait of restoration of fertility in the segregating population was analysed through Bulk Segregant Analysis (BSA) and found co-segregation of marker RM1 with R*f3* gene and marker RM171 with R*f4* gene. This shows that the marker loci and fertility restoration genesR*f3* and R*f4* are tightly linked.

To assess the genetic parameters of the selected twenty one rice varieties they were grown in completely randomized block design with 2 replications in pots and observations were taken on 12 metric traits. The study revealed high heritability coupled with high genetic advance as per cent of mean for Pollen fertility, number of spikelets/panicle, number of filled grains/panicle, LB ratio, number of grains/panicle and grain yield/plant. Hence these traits are predominantly under the control of additive gene action and hence these characters can be improved by selection. Grain yield per plant recorded a significant positive correlation with total no of tillers, number of productive tillers per plant, panicle length, number spikelets/panicle, number of filled grains/panicle, number of filled grains per panicle. Divergence analysis grouped the rice varieties into eight clusters. Cluster II consisting of Mattatriveni and cluster VI consisting of Jayathi, Swarnaprabha, Kanakom and Aiswarya was the farthest.

The hybrid developed from 23 crosses between identified restorers and 4 CMS lines were evaluated for heterosis and identified promising hybrids were UPRI95-17A x Aiswarya, UPRI95-17A x Neeraja, UPRI95-17A x Remya and CRMS31A x Kanakom based on high mean grain yield per plant and high standard heterosis over standard check Uma.

In order to assess heterosis in different combination of the identified maintainers and restorers an L x T analysis was done with maintainers as the lines and restorers as the testers.Perusal of findings indicated that line Jyothi is a good general combiner as it recorded a high over all GCA status. The hybrid Aruna x Varsha was the best specific combiner followed by, Jyothi x Pavizham and Kanchana x Mattatriveni. Three crosses viz; Aruna x Varsha, Jyothi x Pavizham and Bharathy x Annapoorna registered high significant heterosis for grain yield per plant over mid parent, better parent and standard check Uma.

The present study could identify restorers and maintainers for 4 CMS lines from the Kerala rice varieties and also heterotic combination of restorers and maintainers. By reconstituting the identified maintainer with sterile cytoplasm of the CMS lines heterotic hybrids with grain qualities specific to Kerala can be developed. The superior hybrids obtained from identified restorers and CMS lines can be directly used for commercial release after yield trial.

## 94. Pyramiding bacterial leaf blight resistance genes into popular rice varieties of Kerala through Marker Assisted selection

The study was undertaken at the College of Agriculture Vellayani Thiruvananthapuram, to pyramid the genes for resistance to bacterial blight (*xa*13, *Xa*21, *Xa*33, *Xa*38) into the popular rice varieties, Prathyasa and Aiswarya through foreground selection for the genes using molecular markers, to obtain lines with the two/three resistance genes combination in the background of above cultivars.

DNA markers closely linked to the BB resistance genes, such as pTA248 (*Xa*21gene), xa13 pro (*xa*13gene), RMWR7.1 (*Xa*33gene) and Oso4g53050-1(*Xa*38 gene) were used for validation of the marker polymorphism in the donors of the genes for resistance to BB *viz.* Improved Samba Mahsuri with *xa13* and *Xa21,* Improved Samba Mahsuri with *Xa*33, and PR-114 with *Xa*38 and susceptible recipient parents Aiswarya and Prathyasa .This validation confirmed the absence of the genes in the recurrent parents chosen for the study. These polymorphic markers were also used for foreground selection in $F_1$ plants and backcross generations. Work is in progress.

**95. Breeding of short duration rice varieties for virippu season and photosensitive, semi tall high yielding varieties for mundakan season in Onattukara**

The objective of the experiment isto develop a short duration rice variety suited to virippu season in Onattukara tract incorporating adaptive genes of Kochuvithu as a substitute of Jyothy and to develop a superior high yielding variety suited to mundakan season incorporating the adaptive genes of Ptb-20 to substitute Lakshmi.

Farm trial was conducted with culture-23, culture -28 and culture -35 at four different locations of six farmers and the result was presented in ZREAC, is given below:

| Location | Culture 23 ( Kg/ha) | Culture 28 ( Kg/ha) | Culture 35 ( Kg/ha) | Local check ( Kg/ha) |
|---|---|---|---|---|
| Abubecker, Elippakkulam | 3375 | 3700 | 3750 | 2550 |
| Sureshkumar, Vallikunnam | 3325 | 3875 | 3700 | 2850 |
| Kuttan Pillai, Chettikulangara | 3250 | 3825 | 3950 | 2650 |
| ChandranPillai,Chettikulangara | 3400 | 3675 | 3700 | 2550 |
| Gopalakrishnan,Oachira | 3575 | 3950 | 3900 | 2450 |
| Remabai, Oachira | 3650 | 3900 | 3775 | 2800 |
| Mean | 3445.8 | 3820.0 | 3795.8 | 2642 |

**96. Elucidation of the salt tolerance mechanism and development of saline tolerant rice variety through marker assisted back crossing**

The saline tolerant varieties like pokkali, chellanam chettivirippu, kuruka, ponkuruka, karuthakuruka and the susceptibile check Variety Jyothi were screened on Yoshida *et al.* nutrient solution of EC 0, 8 and 12 dS/m for 21 days and the seedlings were scored for salinity tolerance. Varieties pokkali, chellanam chettivirippu and ponkuruka showed tolerance with a score of three. These varieties were crossed with Jyothi and F1 seeds were collected.

**97. Evolution of High Yielding Abiotic Stress tolerant rice varieties for acid saline submerged areas through MAS (CoE BSL)**

The pyramiding of salinity tolerance and submergence tolerance into Jyothi, Uma and Jaya was completed and the lines are under field evaluation.the saltol QTL introgressed Jyothi line BIL 4 is proposed for release.

# Project Coordination Group - Spices and Plantation Crops (02)

**Project Coordinator: Dr. V.S. Sujatha**

**Concluded Projects: 5**
**Ongoing Projects: 32**

## Concluded Projects

### 1. Organic farming in cardamom

Evaluation of the effect of different organic amendments on the growth and yield of cardamom (variety PV2) showed that application of *Jeevamrutha* + *Azospirillum* (10g/clump) + PSB (10g /clump)+ *Trichoderma* (10g/clump) was the best treatment with highest fresh (2424.43g plant$^{-1}$) and dry capsule yield (479.66 g plant$^{-1}$). The incidence of thrips was low in this treatment. There was no significant difference among treatments with respect to shoot borer and *azhukal* disease incidence.

### 2. Liming in cardamom

The results showed that application of dolomite @ 2 kg/plant recorded the highest wet and dry capsule yield. The lowest wet and dry yield was registered in control plants which was significantly inferior to all others. The incidence of thrips and *azhukal* were less in T4 (dolomite @ 2 kg/plant) compared to all other treatments. There was no significant difference among accessions with respect to *azhukal* incidence levels

### 3. Characterisation of boron deficient coconut palms (Cocos nucifera L.) (PG Project)

Hundred coconut palms from different farmers' fields in Kalliyoor panchayat showing boron deficiency were identified based on the visual symptoms of leaf, inflorescence, nut and crown. Among the hundred coconut palms surveyed, 14 palms came under mild group with the score coming between one to three.

Eighty six per cent of severe intensity palms showed fused leaves. The aborted inflorescence, bunches showing hen and chicken symptoms and necrotic inflorescence were 72, 71.11 and 71.52 per cent respectively in palms showing severe intensity. Crowded crown was noticed in 57.14 per cent of the palm with severe intensity while it was 25 per cent in the palm with moderate intensity. The percentage of fish bone appearance, discoloration of mesocarp nuts with uneven kernel development and nuts without any kernel was 71.42, 22, 28.78 and 28.47 per cent respectively in palms with severe intensity of boron deficiency. Boron deficiency was noticed in the fields where intercropping was practiced which contributed 63 per cent of the fields surveyed even though the field was applied with organic manure and fertilizer. The hundred percent of the palms showing boron deficiency showed pest incidence. Mite and coreid bug were the major pests found over there.

Out of the hundred palms showing boron deficiency 52 percent of the boron deficient coconut fields showed boron deficiency between zero to 25 percent, 26 percent of the boron deficient fields showed boron deficiency between 26 to 50 percent, 22per cent of boron deficient fields showed boron deficiency ranging from 51-75 percentage.

The yearly mean revealed that the number of bunches in the mild (6.53) and moderate (6.04) intensity were on par and differed significantly from the severe (5.20) intensity and healthy (7.47) palms. The nuts set per bunch of healthy palms ranged from 13.20 to 13.80 and that of mild, moderate and severe palms ranged from 7.60 to 9.2, 5.60 to 6.40 and 3.00 to 3.80 respectively. The nuts produced in severe intensity palms were only 15.6 showing a drastic reduction the yield compared to healthy palms. The mean nut weight of husked nut from the four

groups of palms were 726.67, 583.02, 476.91 and 370.36 g for the healthy, mild , moderate and severe palms respectively. The mean nut weight of unhusked nut from the four groups of palms were 1449.71, 1172.36, 845.31 and 619.58 g for the healthy, mild , moderate and severe intensity palms respectively. The mean weight of opened nut 601.46 gram in healthy compared to 264.16 g in severe showed a yield reduction of 56 per cent over the healthy. The mean weight of kernel was 416.49 gram in healthy compared to 177.16 g in severely affected palms showing a yield reduction of 57 per cent over the healthy. The mean weight of copra was 208.14 gram in healthy compared to 88.43 g in severe showed a yield reduction of 57 per cent over the healthy. The mean oil content 65.49 gram in healthy compared to 52.48 g in severe showed a yield reduction of 19 per cent over the healthy.

4. **Development of production units for hybrid coconut seedlings and other planting materials in three major districts of north Kerala**

Production of hybrid coconut seed nuts and other elite coconut seedlings and planting materials of intercrops and fruit crops are being produced in all the 6 centers. Nearly one lakh hybrid coconut seedlings were produced and distributed to farmers from the date of inception of the project. Field Training on mother palm selection, hybridization and seed production were given to male workers for pollinating selected WCT mother palms in farmers field. SHG's were engaged in planting material production of other fruit crops, vegetable seeds and ornamental plants such as banana, mango, sapota, spices, tuber crops, vegetables, ornamentals etc. Farmers encouraged to produce the hybrid seedlings with the participation of KAU. The revenue of the farmers from coconut farms was increased four to five fold by seed production alone.

5. **Product diversification in ginger- Plan**

Among the 14 ginger somaclones, highest yield was obtained from SE 8681, SE 8640 and SEHP 9. Highest recovery of volatile oil (2.40%) was observed in SE 8640 followed by CHP 118 (2.02%). Highest content of oleoresin was noticed in SE 8681(5.90%) followed by CHP 118 (5.3%) and lowest in SE 8683 (3.40 %). Crude fibre content ranged between 2 to 4 %. Himachal showed highest fibre (4.56 %) & low fibre content (less than 3%) was observed in SE 8683, SE 8626, C 8632 and SE 86131. Highest driage was recorded by C 8632 (25.06%) and lowest was in CHP 282 (16.25 %). Standardized the protocol for development of products from ginger like squash, candy, soft drinks /ready to serve beverage (RTS), paste, jelly, fudge, medi ginger etc.

## Ongoing projects

1. **Germplasm collection, characterization, evaluation and conservation (Black pepper)**

At present 299 cultivated types, 54 wild types and 3 exotic types of black pepper are being maintained in the station. The survey work was carried out and 9 new genotypes were collected during the year. During the year 2016, the genotypes PRS 64, PRS 154 and PRS 137 were the top yielders. PRS 64 ranked first with 4.68 kg green berry yield and 1110 spikes/vine. Spike length was maximum for PRS 155 (15.3 cm). The number of developed berries/spike was more for PRS 64 (60.0). The 100 berry weight was high for PRS 154 (12.1 g). The dry recovery % was more for PRS 154 and PRS 137 (36 %).

2. **Inter varietal hybridization to evolve high yielding varieties.**

The hybrids PRS 160, PRS 161 and PRS 165 were found to be promising with mean green berry yield of 5.3 kg/vine, 5.12 kg/vine and 4.91 kg/vine respectively. Number of spikes/vine was higher for PRS 160 (510). Spike length was maximum for PRS 161 (20.0 cm). 100 berry weight was higher for PRS 165 (16.0).

3. **Hybridization to evolve varieties tolerant to biotic and abiotic stresses.**

The seedlings of PRS 4 x PRS 8 and P 1 x PRS 78 were planted. Seedlings of P 1 x PRS 48 were lost due to *Phytophthora* infection. The crosses P1 x PRS 64, P1 x PRS 4 and P1 x PRS 48 were carried out during the year.

4. **Coordinated Varietal Trial (CVT) 2006 Series VI**

The trial was started during 2007. During 2016, HB 20052 recorded the highest green berry yield of 3.27 kg/vine followed by Acc.no.53 (3.26 kg/ vine). The highest plant height was recorded for Panniyur 1 (4.87 m).

5. **CVT 2015 on Farmer varieties of Black pepper Series VII**

The trial was started during 2015. The plants are in the vegetative stage and there was no significant difference between the treatments for morphological characters.

6. **CVT 2015 on Black pepper Series VIII**

The trial was started during 2015. The plants are in the vegetative stage. The highest plant height was recorded by Karimunda (1.91 cm). Number of leaves /plant and number of flushes were the highest for PRS 161 (22.5 and 1.41 respectively). Number of nodes /plant was the highest for Panniyur 5 (31.0).

7. **Standardisation of drip fertigation in black pepper**

The trial was started in 2012-13. During 2016-17, **$T_5$** (50 RDF + 8 l drip daily) recorded comparatively higher spike yield (3.72 kg/vine) , 925 spikes /vine , green berry yield ( 2.75 kg / vine) and with low disease intensity – yellowing was significantly low (9.25 %) . The treatments $T_5$ (Drip irrigation @ 8 litres of water daily + 50 RDF fertigation) , $T_4$ (Drip irrigation @ 8 litres of water daily75 RDF fertigation) and $T_1$ (Conventional irrigation @100 litres of water once in 10 days100 RDF basal) were statistically on par for yield and associated characters . Maximum disease intensity (23 %) was noticed in $T_3$ (Drip irrigation @ 8 litres of water daily100 RDF fertigation).

Drip irrigation in black pepper @ 8 litres of water daily and 50 RDF (Half the Recommended Dose of Fertilizer as liquid fertilizer) in 3 equal splits as fertigation was found to be superior to the conventional method of irrigation and basal fertilizer application with the highest benefit cost ratio. The disease incidence was low in drip irrigated plots with half the recommended dose of fertilizer.

## 8. Black pepper based mixed cropping system for sustainable productivity and food security

The trial was started during 2013-14. The pepper vines were at the initial stages of growth. During 2016-17, good yield was obtained from the intercrops in black pepper garden except tapioca. Among the intercrops, $T_3$- elephant foot yam recorded maximum yield of 8.42 kg followed by $T_5$ -greater yam (6.75 kg ) from an inter space of 4 m x 2 m spacing between black pepper. Colocasia ($T_1$) yielded 3.59 kg and arrowroot ($T_2$) 2.13 kg respectively. It was difficult to maintain the intercrops tapioca and arrow root due to wild boar attack.

## 9. Biological Management of slow wilt in black pepper

During 2016-17, all the treatments were significantly superior in reducing yellowing due to slow decline disease in black pepper. Application of *Trichoderma viride* + Neem cake @ 2 kg/vine ($T_1$) recorded maximum yield of 4.296 kg/vine. Among the various biocontrol agents tested, intensity of disease was minimum recorded (3.13 %) in $T_1$ (*Trichoderma viride* + Neem cake @ 2 kg/vine).

## 10. Strengthening research on Black pepper at Dept. of Plantation Crops & Spices, College of Horticulture, Vellanikkara

The existing germplasm in the pepper research unit were collected and planted in the nursery for raising a new germplasm block. Additional collections were included in the germplasm by collecting 40 new accessions and 9 new species from NBPGR and planted in the nursery. They were properly labelled and maintained. In addition to this, a gravel filter was also purchased for use in the pepper garden. A demonstration plot of 17 released pepper varieties were raised in the nursery with provision for inclusion of newer varieties in the nursery.

## 11. Evaluation of promising small cardamom (*Elettaria cardamomum* Maton) cultivars/varieties for organic cultivation in the high ranges of Idukki district

Data of yield as well as pest and disease incidence of promising small cardamom cultivars (2015-17) is given below. PV 1 is found to be the high yielder.

| Accessions | Fresh weight (g/plant) | Dry weight (g/plant) | Thrips incidence (%) | Borer incidence (%) | Azhukal incidence (%) |
|---|---|---|---|---|---|
| | 2016-17 | 2016-17 | 2016-17 | 2016-17 | 2016-17 |
| PS 27 | 1409.66$^{f}$ | 281.93$^{e}$ | 31.33$^{b}$ | 3 (1.72) | 6 (2.43)$^{ab}$ |
| GG | 1048.67$^{g}$ | 199.24$^{f}$ | 43.66$^{a}$ | 2.83 (1.67) | 8.33 (2.87)$^{a}$ |
| Pl. No. 14 | 1605$^{d}$ | 321$^{c}$ | 29$^{b}$ | 3 (1.70) | 4 (1.98)$^{bc}$ |
| PV2 | 1896.66$^{b}$ | 379.33$^{b}$ | 31.66$^{b}$ | 2.66 (1.62) | 2.33 (1.52)$^{c}$ |
| PV1 | 2113.33$^{a}$ | 422.66$^{a}$ | 30$^{b}$ | 2.5 (1.57) | 2.66 (1.60)$^{c}$ |
| S1 | 1508.33$^{e}$ | 301.66$^{d}$ | 39.66$^{b}$ | 2.83 (1.68) | 6.33 (2.49)$^{ab}$ |

| | | | | | |
|---|---|---|---|---|---|
| ICRI 2 | 1766.33[c] | 335.35[c] | 32.33[b] | 3.66 (1.90) | 4.33 (2.07)[bc] |
| CD (0.01) | 124.19 | 3.07 | 3.54 | NS | 14.88 |
| CV | 3.07 | 24.52 | 3.73 | 10.28 | 0.79 |

## 12. Coordinated Varietal Trial 2006 – Series VI

All the yield and yield attributing characters have shown significant difference among the accessions both at 1% and 5% level. This indicated the enormous quantity of variability in accessions for these characters. *Karimunda* recorded highest fresh and dry weight of berries which was statistically on par with P1 and HB 20052. Most of the yield attributing characters were high in P1 except the volume of 100 berries. Even though *Karimunda* was the best performed accession for the last three years, the yield attributing characters were not that much comparable with high yielding accessions except the number of berries per spike (Table 1).

## 13. Coordinated Varietal Trial 2007/2009 - Series VI

The pooled analysis for three years indicated that Pl.No. 14 was the accession with highest fresh yield and which is statistically on par with IC 547185 & SKP 104. The same trend was shown for dry yield also. Among the characters studied, 100 capsule weight and 100 capsule volume were not significantly different. This means, the capsule characters did not contribute significant difference in the dry and fresh yield among the accessions.

Among the biotic stress characters, *azhukal* incidence was highest in IC 547167 and it was significantly different from all other accessions; however the accession had reported lowest value with respect to borer and thrips incidence. SKP 104 recorded comparatively higher yield with low incidence of thrips (2.95%).

Among the characters studied the highest variability was observed for *Azhukal* incidence (99.15 %) followed by borer incidence (36.35%) and the least variability was observed for the 100 capsule volume. SKP 104 and Pl. No. 14 were selected as good accessions with respect to yield & thrips incidence and yield and tolerance to biotic stresses respectively.

## 14. Germplasm collection, characterization, evaluation and conservation

Each year, top 10 high yielding accessions have been statistically analyzed. Among them, 6 accessions repeated three years (2014-17) continuously for the consistent nature of higher yield. These six high yielding accessions were subjected pooled.

Among the characters looked into, the fresh and dry weight of capsules and 100 capsule volumes were significantly different from the one another. Highest fresh yield of capsule was recorded in HY 13 which was statistically on par with HY 12 and the same trend was also extended in dry weight of the capsules. The hybrid produced by the cross of PS1 x GG recorded highest volume for 100 capsules (134.92 ml) followed by HY 13, and they were significantly different. There was no significant difference in biotic stress characters among the accessions. The consistency in the yield of these six accessions for last three years (comparatively drought affected years) was an indication for its drought tolerance mechanisms. Scientific study on this aspect is required in the era of climate change.

As a part of this project, we have collected seven farmers' cultivars of small cardamom from Anakkara village of Idukki district during November 2016 and had been added to the germplasm. The passport details of the cultivars (Seven numbers) for getting IC numbers have been sent to the NAG centre, Appangala. The list of cultivars with their peculiar characters is given below.

| Sl.No. | Name of cultivar | Peculiar character |
|---|---|---|
| 1. | *Thiruthaly* | Long panicle |
| 2. | *Mylady* | Known as *Mysore Njallani* |
| 3. | *Chainchedi* | Low internodal distance |
| 4. | *Palakudi* | Tolerant to biotic stresses |
| 5. | *Pachilamani* | Dark green extra bold capsule |
| 6. | *Kaniparamban* | Dryage efficiency high |
| 7. | *Elarajan* | Very short intermodal length |

## 15. Initial Evaluation Trial

In this experiment, a total of seven accessions, namely Pl.No.14, PV 2, PPK 2, HY 9, BEP 2, HY 6 and *Green gold* (local check), were planted during June 2015. Plants in this experiment are in vegetative stage. One more year is required to take the first observations on yield and its attributing characters.

## 16. Evaluation of new insecticides for thrips control

The pooled data of five sprays revealed that fipronil 5 SC @ 0.005% and spinosad 45 SC @ 0.0135% had significant reduction (79.99 and 68.28 respectively) over untreated check.

## 17. Nematode pest management in cardamom using bio-control agents and organic supplements

The result of the post treatment observations showed that, the application of *Pochonia chlamydosporia* @ 50g/clump and *Paecilomyces lilacinus* @ 10g/l registered least symptoms *i.e.* 1.29% and 1.65% respectively.

## 18. AICRP- Project mode centre on nutmeg

Morphological and biochemical characterization of the mother trees of the twenty accessions identified during project period. Passport data of thirteen unique accessions along with other necessary documents have been submitted to NBPGR, New Delhi for registration and issue of IC number. Budded plants (orthotrops) of 15 unique accessions (Acc.1, 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 17, 20, 23, 24) were made and five each of these accessions have been supplied to IISR Kozhikode, KKVV Dapoli and TNAU Pechipparai for evaluation.

A booklet on unique germplasm of nutmeg authored by Mini Raj *et al* was published and the same was released in the annual workshop of AICRPS held at IISR, Kozhikode.

## 19. Strengthening Research on Nutmeg- Plan

In the first major experiment of the study ie, Survey, collection and characterization of nutmeg germplasm, out of the 30 superior clones of nutmeg identified, five clones have been found superior with respect to the economic characters. Budded plants of these elite clones have been made and germplasm block and bud wood nursery established. Chemoprofiling of the mace and nut volatile oil has been done in 15 accessions. 16 more accessions have been identified during the period under report. Collection of germplasm and expansion of the germplasm block would be continued. All the germplasm have to be registered with NBPGR, after molecular characterization.

In the second major aspect of the study ie developing safer management strategies for aflatoxins, many treatments involving botanicals are found to be effective. Based on the one year storage studies, it was found that the mace, and nut of nutmeg could be stored without any contamination using any one of these methods: Sodium benzoate (1 %); Decoction using **c**itrus leaves (100 g/l) or Curry leaves (100 g/l) or *Annona* seed extract (5%); Fumigation using black pepper leaves or *Leucas* leaves. The experiment was repeated with bulk quantity of nut and mace with the promising treatments except Sodium benzoate as it is not used in food at present. Bimonthly enumeration of microflora is being carried out.

With respect to the third major part of the project *ie*, standardization of primary processing techniques and value addition, fresh nutmeg rind was utilized for product preparation and the process was standardised for nutmeg rind wine, jam, osmodehydrated chunks, candy stick, candy shreds pickle, mouth freshner etc. Spent nutmeg rind after making wine was utilized for making diversified traditional and non traditional products like jelly, jam, halwa, sweet meat chunda, sweet meat chunda-hot& sweet, candy, preserve, pickle and syrup. Turnover from select products has been worked out. This has to be done with all the products on a pilot scale which will help in the transfer of technology.

## 20. Germplasm collection and maintenance of cocoa

GVI G included in germplasm introduced from University of Reading, UK which was reported to be resistance to *Phytophthora* in other part of the world. Thirty accessions of cocoa which are in the steady bearing stage serve as the material for the study of Genetic stock development for *Phytophthora* resistance.

## 21. Heterosis breeding - Breeding for Vascular streak dieback disease resistance

Ten pods obtained from different crosses (double cross hybrids) were used for raising seedlings. Screening of these hybrids is progressing in the nursery.

## 22. Breeding for Phytophthora pod rot resistance

The hybrids bred under the programme breeding for *Phytophthora* resistance were field established and evaluated in the field by screening for the disease during peak season. It resulted in identification of thirty hybrids in the field which showed no symptom. To confirm the resistance by artificial inoculation, pod inoculation method was carried out. Genotype SIV 1.26 X TISSA (2.4), GVI 216 X GVI 304(35.5) showed 100 percent infection in non pricked

condition. Genotype GVI 188 X GVI 304 (35.9) showed 7.13 percentage infection in non pricked condition. Hybrid seedlings from these crosses were evaluated in the nursery for vigour.

**23. Intercropping in Cashew**

Objective of the experiment was to identify suitable medicinal plants that can be grown as inter crops in the initial years of cashew. The economic analysis of inter cropping in cashew garden with different medicinal plants revealed that *Koduveli* (*Plumbago zeylanica*) is the most economical followed by *Adlodakam* (*Adhatoda vasica*).

**24. Organic Management of Cashew**

Seven different organic manure treatments in combination with biofertilizers were compared with recommended doses of fertilizer, to explore the possibility of increasing nut yield and quality and to find out economic feasibility over conventional farming. There was significant effect for different treatments on yield parameters of cashew. Highest duration of flowering was observed in T7 (120days), maximum flowering laterals/panicles in T2 (8nos.) and highest nut weight in T7 (8.13). Lowest nut weight (6.20g) was recorded inT6. Highest annual nut yield was recorded in T5 (3.84kg/ha) followed by T3 (3.52kg/ha) and maximum cumulative nut yield in T3 (11.04kg/tree) followed by T6 (10.80kg/tree).

**25. Chemical Control of pest complex in cashew - Evaluation of insecticides for control of TMB and other insect pests**

The project aimed at identifying the effective insecticide amongst the newer synthetic insecticides in comparison with recommended spray schedule, which were safer as well as economically feasible for managing the insect pests of cashew. Tea mosquito bug intensity was very low during the season. At seventh day after second spray, comparatively less damage was observed in thiamethoxam @0.2g/l *Beauveria bassiana* @1g/l and ƛ-cyhalothrin. At 15$^{th}$ day of second spray, all the treatments recorded comparatively less damage and were superior to control. At 30$^{th}$ day of spray, the damage was less in all the treatments except in buprofezin, which was on par with control. On panicle, at seventh day after second spray, thiamethoxam 0.1g/l & 0.2g/l *Beauveria* 1g/l & 5g/l, ƛ-cyhalothrin and KAU POP recorded comparatively less damage. At 15$^{th}$day, ƛ-cyhalothrin recorded least damage and thiamethoxam 0.1g/l & 0.2g/l *Beauveria* 1g/l & 5g/l and KAU POP were on par with ƛ-cyhalothrin.

Insect pests other than tea mosquito was practically nil during the season. Control trees harbored significantly high red ant population before as well as during second spray observation and *B. bassiana* @ 1g/l was on par with control. In third spray observation, control itself harbored maximum red ant population though statistically not significant from other treatments.

**26. Control of cashew stem and root borer - Curative control trial**

Among the insecticides tested for curative control after Post Extraction Prophylaxis, swabbing of fipronil @ 2ml/l recorded 100 per cent recovery followed with imidchloprid (90%) and chlorpyriphos (80%). Swabbing with neem oil soap 5 per cent recorded 65 per cent recovery of treated trees and the recovery in untreated check with grub extraction only was 36.8 per cent.

**27. Influence of biotic and abiotic factors on the incidence of pest complex of cashew**

The objective of the project was to investigate the population dynamics of pests of regional importance and to correlate it to prevalent weather parameters. The test varieties were Anakkayam -1, Madakkathara-1, Kanaka and Dhana. The correlation analysis with regard to tea mosquito bug and weather factors revealed that morning relative humidity had a significant negative correlation with the damage by tea mosquito bug, whereas significant positive correlation was established with wind velocity. However during last year, minimum temperature, relative humidity and rainy days had a significant negative correlation whereas significant positive correlation was established with bright sunshine hours and wind velocity.

**28. Screening of germplasm to locate tolerant / resistant types to major pests of the region**

Tea mosquito bug infestation was very low during the reporting year and the damage was not observed in ODR and the score was maximum in Peechi (0.276). The accessions ARL-1, ARL-2, K1, K2, Peechi and Pathannur recorded comparatively less damage by tea mosquito bug. During last year, TMB damage score varied from 0.010 in Pathannur to maximum 0.312 in Peechi.

The Leaf miner infestation was absent in all the accessions except K-1, K-3, Mannar and Ummannur and a maximum of 5.15 per cent was observed in K-1 and minimum in K-3 (0.67%). Thrips infestation was absent in K-2, K-3, Kottukkal and ARL-2. Apple and nut borer incidence was very low in all accessions during the reporting year and was within the range of 1.5 to 3.0 per cent with highest damage in Mannar.

**29. Evaluation of biointensive technologies in the management of tea mosquito bug, *Helopeltis antonii* Signoret in cashew**

Objective of the project to evaluate the prospects of indigenous plant extracts and botanical oils for tea mosquito bug management in cashew and to compare yield performance and pest status in bio intensive and conventional methods. Among the aqueous extracts and botanical oil emulsions tested against tea mosquito bug *Helopeltis antonii* on cashew under laboratory conditions, pongamia oil at 5% concentration has shown both insecticidal and antifeedant property. Vayambu rhizome powder has shown antifeedant property at 5 % concentration and exhibited both antifeedant and insecticidal property at 10 % concentration.

**30. Development of short statured high yielding coconut variety with good nut quality**

One dwarf ecotype with nut quality similar to tall (high copra and oil content) from Payyannur called Annur local was located in 2005.After evaluation, seednuts produced by interse in the particular farmers field were sown in nursery . Simultaneously it was crossed with GB and MYD and these nuts were also planted in the field at RARS Pilicode during 2009-10.Started bearing in 2016. Presently the morphological and yield characters are being recorded. Among these at the seedling level and at palm level, Annur local x MYD is found superior. Further studies are being continued.

## 31. Strengthening Research on Evaluation of Coconut Hybrids

Screening of the existing germplasm at RARS, Pilicode showed several superior genotypes such as Ayiramkachi, Philippines Lono, Kudat etc. Ayiramkachi was crossed with MYD, Lacadive Micro, Lacadive Ordinary, Philippines, Andaman ordinaryand WCT both as male as well as female parent. These crosses are under evaluation among these the D x T cross MYD x Ayiramkachi was found superior. Yield and quality data are being recorded for evaluation.

## 32. Utilization of Existing Germplasm and Description of Varieties - Coconut

Among the 16 different genotypes evaluated, a tall cultivar, Philippines Lono was found to be superior than WCT . Analysis of yield and quality data from 2000-2012 proved the superiority of the same over all other genotypes and WCT. Hence this was presented in the XXX and XXXI Zonal Workshops held at RARS-Pilicode and was recommended for submitting proposal for releasing as a variety suited to laterite soil under medium and well managed conditions of Kerala. Accordingly the proposal was submitted for releasing the variety in the name 'Kerasulabha'. However, the Variety Release committee recommended to collect more data. Hence the data for 2013-2017 were collected and being analysed for submitting the proposal in next ZREAC of Northern Zone.

# Project Coordination Group – Vegetables (03)

**Project Coordinator – Dr. S. Nirmala Devi**

**Concluded Projects: 3**
**Ongoing Projects: 2**

## Concluded Projects

1. **Evaluation of hybrids of indeterminate tomato (*Solanum lycopersicum* L.) under protected cultivation-PG**

The main objective was to evaluate the yield and quality of F1 hybrids of indeterminate tomato under protected cultivation. Ten superior F1 hybrids from a previous study, five parents and two standard checks Naveen and Akshaya were evaluated. Based on mean performance and heterosis, LE 20 x LE 1 was superior for fruit length, fruit girth, fruit weight, yield/plant and yield/plot. The hybrid LE 2 x LE 20 was superior for earliness to flowering and to fruit set, fruit set percentage, pollen viability percentage and fruits/truss and for fruits/plant LE 2 x LE 39 was superior. The hybrid LE 2 x LE 38 was superior for TSS and lycopene content LE 2 x LE 39 and for ascorbic acid content LE 2 x LE 1 was superior. Thus the promising hybrids for yield and yield attributes were LE 20 x LE 1 followed by LE 2 x LE 20.

2. **Development of hybrids in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) -PG**

The main objective was to study the heterosis and combining ability of yard long bean and to develop superior $F_1$ hybrids with high yield and quality. Twenty eight F1 hybrids derived from eight diverse parents differing in yield, pod length, pod weight and pod colour were selected for the study along with eight parents and a check NS 634. Based on the mean performance, specific combining ability and standard heterosis, the hybrids VS 34 x VS 50 (Githika x Kakkamoola Local), VS 50 x VS 26 (Kakkamoola Local x Vellayani Jyothika) and VS 34 x VS 13 (Githika x Neyyattinkara Local) were the most promising for yield and quality characters. Among these hybrids VS 34 x VS 50 and VS 50 x VS 26 were tolerant to CABMV whereas VS 34 x VS 13 was resistant. Hence the study revealed that heterosis breeding is useful for development of hybrids in yard long bean through the utilization of non-additive gene action for all the traits except pod weight.

3. **Effect of seed protectants against pulse beetle, on viability, vigour and health of cowpea seeds – PG**

**a) Brief summary of the findings up to the commencement of the period:**

Two separate storage experiments were initiated with cowpea varieties Kanakamony and Lola in a completely randomized design with thirteen treatments. Freshly harvested seeds of each variety was dried to 9 % moisture content and treated with the seed protectants. Untreated seeds will serve as control (T13). Both and untreated seeds were packed in polyethylene bags of 700 gauge thickness and stored under ambient conditions for a period of thirteen months. Seed quality parameters were recorded at start of storage period indicated the seeds were of high quality. The seeds of both the varieties were found to be totally free from pulse beetle infestation (0 %). The per cent germination in variety Kanakamony and Lola on one of storage was 99.71 and 94.32 per cent respectively. Analysis of variance also revealed that, there existed significant differences in the impact of various seed treatments on seed quality parameters, pulse beetle infestation and seed microflora infection over the storage period of two months.

b**) Results obtained during the period under study:**

Irrespective of variety, significant differences in germination and other seed quality parameters like seedling shoot and root length, seedling dry weight, seedling vigour indices, electrical conductivity of seed leachate, seed moisture content, mortality of adult pulse beetle, number of eggs laid by beetle, egg hatchability, seed infestation and seed infection due to seed treatment was observed during storage of cowpea seeds.

In both the cowpea varieties Kanakamony and Lola, the seed protectants significantly enhanced the viability and quality of treated seeds. The quality of treated seeds was higher than that of untreated seeds for most part of the storage period. The germination in untreated seeds was retained above 75 per cent (the minimum seed certification standards (MSCS) required for cowpea) for eight months while it was retained for nine months in all treated seeds.

Seed germination, speed of germination, seedling growth parameters and vigour indices were invariably high on treatment with neem based seed protectants *viz*., neem kernel powder, neem leaf powder and neem oil as well as other oils *viz*., coconut oil and castor oil. Among the neem based botanicals used, seed treatment with neem kernel powder (T8) maintained higher germination and seed quality parameters *viz.*, seedling shoot length, seedling root length, seedling dry weight and seedling vigour index I and II and lower conductivity of seed leachate during storage.

The effectiveness of different seed protectants on mortality of adult pulse beetles, fecundity, egg hatchability and infestation caused by beetle were studied in two varieties of cowpea, namely, Lola and Kanakamony. The results revealed that all the seed protectants used were effective against pulse beetle during the initial period of storage and were significantly superior to control over the period of storage. Among the seed protectants evaluated, highest mortality of adult beetles, lowest fecundity, egg hatchability and seed infestation were recorded in seeds treated with spinosad followed by oils *viz.*, neem oil, coconut oil and castor oil as well as other neem based botanicals.

## Ongoing Projects:

### 1. Advanced centre for tropical vegetable research

a) Identification of varieties/hybrids and standardization of agro techniques for rain shelter/high tech vegetable production

**Cabbage : -** Four F1 hybrids viz., NS 183, NS 43, NS 35 and Disha were evaluated initially inside rainshelter. Among these, NS 43 was found ideal for protected cultivation during off season. In an experiment to standardize, the time planting for off season cabbage production inside rain shelter, six planting dates were tried. Among these May 15$^{th}$ planting was found ideal for off season cultivation of cabbage inside rainshelter recording maximum value for head characters.

**Cherry tomato: -** Performance of ten cherry tomato types inside rainshelter indicated the superiority of SLc-2 and SLc-9 with respect to yield.

## 2. Maintenance of germplasm of tropical vegetables

Among the eleven genotypes of dolichos bean evaluated, Hima, DL- 50 and DL – 204 recorded maximum yield. Pod length was maximum for DL-22 and Hima. All the accessions were photo sensitive.

Among the ten types of winged bean evaluated, maximum yield was recorded by Vellayani type followed by Revathy.

Fifteen genotypes of Amaranth were screened against leaf spot disease during rainy season and all the genotypes were found susceptible to leaf spot disease with minimum incidence for AT 83.

Twenty genotypes of chilli and fifty genotypes of brinjal were evaluated in field. Among chilli genotypes, Ujwala, Vellayani Athulya, Vellayani Samrudhi, Anugraha etc. were found resistant to bacterial wilt disease. Among the brinjal genotypes evaluated, Green Long followed by SM – 398 recorded high yield. Green Long was highly susceptible to bacterial wilt disease.

Twenty accessions of snake gourd were evaluated in field and among these TA 65 and TA 1042 was found high yielders.

# Project Coordination Group – Fruits (04)

**Project Coordinator - Dr. M.L.Jyothi**

**Concluded Projects: 7**
**Ongoing Projects: 27**

## Concluded projects

1. **Diversity mapping and characterization of landraces of mango (*Mangifera indica* L.) -** Ph D

A wide variation among the young leaves was noted with respect to the colour and it varied from light green, light green with brownish tinge, light brick red, reddish brown, and deep coppery tan. Flowering was noted from November to March making into early (November to December), midseason (January to February) and late season (from March) as noted among the different accessions and two intermediate periods between the seasons. Regular bearing was predominantly noticed in majority of the accessions but for few accessions which exhibited secondary/perpetual type of flowering. All most all the accessions produced terminal borne inflorescences but few accessions showed axillary and terminal emergence of inflorescence.

Based on maturing period, the trees are classified as early - if the fruits become mature for harvest by February, as intermediate - if ready for harvest by March to May and as late - if ready by June. For pickling purpose, the stage for harvest varied from marble stage (for Kadu/tender manga pickle), to pre-mature (three-fourth) mature stage for Chethu manga. Wide variation among the land races was noted with respect to fruit shape, fruit colour and pulp colour. Presence of fibre in the fruit pulp was a unique feature of all the accessions. Pulp aroma was mild, intermediate or strong. Polyembryony was also noted in few accessions with emerging seedlings per stone ranging from two to four.

Overall diversity assessment clearly noted the predominance of the type Moovandan throughout the entire Pazhayannur region. Among the different villages maximum number of rare landraces could be spotted in Elanad village (39) followed by Vennur (19), Pazhayannur (19) and Vadakkethara (12). Accessions spotted from the extended locations of the survey (Tiruvilwamala and Panjal) were also added in to the rare group. ITK associated with these mango land races with special reference to the conventional and traditional processing of fruits were also documented. A conceptual model for *in situ* conservation of the spotted land races for the region could also be worked out and a comprehensive village diversity register of mango land races of the region in the specified format was prepared as a material for future reference. Initiatives were also taken up for the *ex situ* conservation of some rare mango land races spotted. Scion material of rare land races was collected and grafted plants prepared for planting in the mango gene sanctuary maintained by the department. Crossing and hybridization were also taken up during the project period involving selected land races of the region as male parents with Moovandan and Neelum types maintained at the orchard of the college as female parents.

2. **Vegetative propagation of promising jack fruit types -PG**

Among the two methods of grafting tried in five types of jack fruit, epicotyl grafting resulted in early sprouting in Gumless type(KJ397) while softwood grafting resulted in maximum sprouting per cent in the same type. Maximum survival of grafts were recorded by epicotyl grafting in Seedless type (KJ180).

### 3. Morphochemical evaluation of Jamun (Syzygium cuminii Skeels) collections-PG

Fifty nine collections of jamun maintained in the department orchard and in and around the KAU campus were used for the study. Variability was observed for tree characters, inflorescence characters, fruit characters, quality attributes and pest and disease incidence. Grouping of collections based on fruit characters resulted in five non-overlapping clusters. Among the collections, KJ 45 had higher yield (54 kg per plant), fruits per cluster, fruit weight, pulp/seed ratio, TSS and anthocyanin content. Hence KJ 45 is considered as superior followed by KJ 48, KJ 47 and KJ 7.

### 4. Morpho – physiological characterization of litichi (Litchi chinensis Sonn.) in Wayanad-PG

A total of 32 collections maintained at farmers' field as well as RARS, Ambalavayal in Wayanad were evaluated. Variability was seen for tree characters, floral characters and fruit characters. Principal Component Analysis (PCA) performed on the basis of tree characters revealed that the first two principal components (PCs) accounted for 77.3 per cent of the total variation with contributing characters such as tree age, height, trunk girth, leaf length, shoot length and intermodal length. Clustering resulted in formation of nine clusters. Majority of the collections had medium skinned fruits and mature fruits were pinkish red to greenish yellow in colour. Based on fruit size, weight, yield, quality and sensory parameters collection No. 2, 10 and 13 were identified as superior types. These collections need to be evaluated to ascertain the stability under different regions which can be exploited in order to secure premium price for the crop.

### 5. Assessment of variability in Annona spp. -PG

In a purposive sample survey, 30 trees of *Annona reticulata*, 16 trees of *A. squamosa* and 25 trees of *A. muricata* were identified from the homesteads of Ernakulum, Thrissur, and Palakkad districts of Kerala. Tree characters, leaf characters, inflorescence characters, fruit characters and quality parameters were recorded as per IPGRI crop descriptor. Clustering of three species done separately using score plot, confirmed that the promising accessions in *Annona reticulata* is AR 2, in *A. squamosa* AS 7 and AS 11 and *A. muricata* is AM 8. The study revealed that three different species of *Annona* had wide variability in terms of their growth, vegetative, flowering and fruiting characters. Among the three species with regard to fruit quality parameters *A. squamosa* was superior in TSS and total sugar whereas fruits of *A. muricata* were superior with respect to anti-oxidant activity.

### 6. Variability studies in rambutan (*Nephelium lappaceum* L.) -PG

A total of hundred types of rambutan were collected from important rambutan growing tracts of Kerala (Pathanamthitta-40, Kottayam-37, Thrissur -18 and Idukki–5). The collected accessions showed wide variability in their tree characters, inflorescence and fruit characters and quality parameters which were recorded as per IPGRI crop descriptor. Flowering and fruiting characters were observed to be a function of the location. The study on phenological growth stages of rambutan according to BBCH scale in different locations opened out a new area on the possibility of staggered fruit production on rambutan in Kerala. Clustering of all the three categories of rambutan collections namely elite, export and industrial use types using score plot confirmed the superiority of six collections (Col. 021, Col. 022, Col. 023, Col. 052, Col.055 and Col. 061) over others which were selected further for developing a selection criteria in rambutan. In the sensory analysis Col. 061, Col. 021 and Col. 042 were most preferred because of their better fruit weight, taste, juiciness and easy detachment of aril from seed. The study revealed that

rambutan selections from Kerala are not only comparable with the best known cultivars in the world, but even excel them.

### 7. Sucker production and activation techniques in banana (Musa spp.) -Ph.D. project

Objective of the experiment was to have a basic understanding of the sucker genesis (origin), variation in sucker production of important cultivated clones, with different ploidy and genomic constitution, photosynthate and nutrient allocatory pattern to different suckers using 14 C and 32 P and for probing the effects of physical and cultural methods of sucker activation techniques. Among the different clones tested for sucker production, Karpooravalli (AAB) recorded the highest number of suckers, followed by Njalipoovan (AB), Nendran (AAB), Kadali (AA), Robusta (AAA) and Bodles Altafort (AAAA) respectively. Suckering habit was positively correlated with decreasing ploidy level and an increase in *Musa balbisiana* blood in the genomic constitution of the particular clone. Differences in sucker production were observed between the different clones with respect to planting seasons, Kadali (AA), Njalipoovan (AB) and Robusta (AAA) recorded the higher number of suckers in Sep - Oct planting where as in case of Nendran (AAB) and Karpooravalli (AAB) Feb - March planting recorded the best sucker production. Morphological characters like plant height, collar girth and total number of leaves recorded very strong and positive correlation with sucker characters but negative correlation was observed with average leaf production interval. Bunch weight recorded strong significant correlation with improved sucker production. Communality values in factor analysis clearly revealed that the collar girth was the high relative contributing trait for deciding sucker yield in banana. Photosynthates partitioning from the mother plant to daughter suckers using 14 C in six sucker retention intact system revealed that the last formed suckers got maximum share of photosynthates. Studies on physical methods revealed that replanting the entire clump in trenches in oblique manner ten days after harvest produced maximum total no. as well as quality suckers. Application of NPK (7:17:l7) @ 5 g and 10 g N equivalent per clump yielded maximum number of total as well as quality suckers.

## Ongoing Projects

### 1. Collection, characterisation, conservation, evaluation and utilization of germplasm

During this period no primary collections were made. Eight secondary collections were made from NBPGR, New Delhi as proliferating cultures and were established in the field. Two balbisiana accessions were collected from NRCB, Trichy.

Particulars of utilization

| Names of accessions utilized for breeding work and trait for which exploited | Number of collection so far utilized along with names so far and specific purpose for which utilized |
|---|---|
| Before reporting period- Pisang Lilin, Calcutta -4<br>During reporting period | *For commercial exploitation for cooking*-Monthan(ABB), Kanchikela(ABB),Batheesa(ABB),Nendrapadathi(AAB) **FHIA-03,Pelipita,Cachaco,Sakai<br>*For commercial exploitation for dessert*<br>Robusta(AAA), Grand Naine(AAA), Dwarf Cavendish(AAA), |

| | |
|---|---|
| - nil | Amritsagar(AAA), Chenkadali(AAA), Palayamkodan(AAB), Njalipoovan(AB),<br>Kunnan(AB),Poomgalli(AB),Poovan(Rasthali)(AAB),Yangambi Km 5(AAA), BRS-1, BRS-2, Karpooravalli<br>**SH 3640(AAAB), TMBx 5295-1(AAAB),Kluai Namwa Khom(ABB)<br>*For commercial exploitation for processing-*<br>Nendran clones(AAB), Zanzibar(AAB), Big Ebanga(AAB), Popoulu(AAB) for chips<br>**All dessert varieties listed above are suitable for jam preparation.<br>*For Breeding/hybridization work* - Pisang Lilin, Calcutta -4<br>*Identified accessions suitable for pseudostem sweetened juice* – Palayankodan (AAB), Nendran (AAB), Popoulu (AAB), Grand Naine (AAA), Kadali (AA), Kunnan (AB). Best accession – Palayankodan in terms of acceptability and shelf life.<br>*Accessions suitable for pseudostem and rhizome pickle* – Palayankodan (AAB), Popoulu (AAB), Kluai Namwa Khom (ABB), Poovan (Rasthali) AAB<br>*Accessions suitable for fibre extraction* – Palayankodan (AAB), Nendran (AAB), Grand Naine (AAA), Kunnan (AB).<br>*Accessions suitable for banana flour* – Popoulu (AAB) is the best in terms of diversity in utility. Next best is Nendran suitable for use in semi-moisterized food like chapathi. |

## 2. Classification of germplasm accessions to Eumusae leaf spot disease based on three years of screening

Resistant (PDS 0-10) types are given below:

AA : BRS 1, BRS 2, Culcutta 4, Cultivar Rose, H 4, Paka, Pisang Jaribuaya, Pisang Lilin, Sannachenkadali, 1Tongat

AAB : Kalibow

ABB : Pey Kunnan, Udayam

Hybrid : FHIA-01 (AAAB), FHIA17 (AAAA), FHIA-18 (AAAB), FHIA-3 (ABBB), Nendran, Hybrid SH 3640 (AAAB), TMB 3 X 15108-6, TMB-5295-1 (AAAB)

Moderately Resistant (PDS 10.1-20.0)

Pedapacha, Robusta

Highly Susceptible (PDS 31.0 -40.0)

AA : Anaikompan, Erachivazha, Leite

AAA : Grand Naine, Gros Michel, Sapumal Anamalu, Wather

AA : Pisang Madu, Sikuzani

AB : Agniswar, Kalyan Bale, Kunnan, Nani Poovan, Nattu Poovan, Njali Poovan, Pacha Bale, Poomkalli, Rasa Kadali, Rasagalli, Valiya Kunnan

AAB : Chakkara Keli, Manjery Nendran, Mysore Ethan, Pisang Keling, Pisang Nangka
Pisang Ceylan, Popoulu, Vannan

ABB : Fougamu, Vella Palayankodan

AAA : Manoranjitham, Pisang Mulik

Hybrid ; FHIA-23 (AAAA), SH-3436-9 (AAAA)

Susceptible (PDS 20.1 -30.0)

AA : Kadali, Matti, Namrai

AAB : Akpatpak, Figue Pomme Geante, Krishna Vazha, Ladies Finger, Navral,
Pisang Radjah, Velipadathi

ABB : Blue Jawa, Pelipita
AAA : Amrit Sagar, Chinese Cavendish, Chenkadali, Dwarf Cavendish, Guineo, High Gate Lacatan, Monsmarie, Pachakappa

### 3. Clonal selection in banana

Three exotic AAB French plantains Obubit Ntanga, Mbe Egome and Akpakpak, three Nendran (AAB) types from Palakkad and Thrissur districts and four new collections of Poovan (Rasthali, AAB) made during the period were evaluated for yield, quality and tolerance to biotic and abiotic stresses.

### 4. Standardization of organic nutrient schedule in banana

In Nendran, the treatments involving application of FYM 10 kg + Neem cake 1.25 kg + vermicompost 5 kg + wood ash 1.75 kg + biofertilizers (AMF 25g/pt + *Azospirillum* 50g/pt + PSB 50g/pt + *T. harzianum* 50g/pt), along with triple green manuring with daincha/cowpea had a comparable yield with inorganic control treatment. No significant difference was observed among treatments for quality characters (TSS and shelf life) and Eumusae leaf spot incidence.

### 5. Assessment of phenology, productivity and incidence of insect pests and diseases in banana grown under varying climatic conditions

Incidence of Eumusae leaf spot, *Fusarium* wilt, rhizome rot and bract mosaic recorded a decrease compared to last year . The mean per cent disease index (PDI) of Eumusae leaf spot observed was 15.93% which was 11.29 % less than the last year. Disease severity observed was in the range of 0 - 54. 1 %. Low rainfall and high temperature are the probable reasons for reduction of disease index. Apart from climatic factors, varietal difference in disease incidence was noticed. Among the varieties, Nendran is a highly susceptible and Njalipoovan is moderately resistant.

### 6. Assessment of post-harvest loss in banana

In the 2$^{nd}$ round survey (cv. Nendran), the loss during harvest ranged between 1.80 to 2.00 % and that at transportation ranged between 1.80 to 2.00%. Loss at whole sale market was 2.35% on an average. Among the ripening practices, keeping in smoking chamber reduced the loss (3.20% PHL) compared to that kept in ripening chamber (6.40%). Loss at retail market is more due to unsold lot which amounted to 7.40%. The quantities of rejects were very low (1.10% on an average of two districts)

### 7. Survey on emerging insect pests of banana

**Fixed plot survey :** Incidence of major pests *viz.,* pseudostem borer, rhizome weevil, leaf eating caterpillars (*Spodoptera litura* and *Pericallia ricini*) were regularly present in the fixed plots. The occurrence of sucking pests *viz.,* mirid bugs, lacewing bugs, whiteflies etc. were seen sporadically in rainy season with higher number of mirid bugs. Gregarious infestation of leaf eating caterpillars (*Pericallia ricini* and *Spodoptera litura*) started from pre-monsoon and the attack persisted till August, 2016. Maximum infestation was recorded during June and July, the months which received maximum rainfall. Infestation by pseudostem borer (PSB) was observed intermittently and their number rose with the age of the plants. Maximum infestation of pseudostem weevil and rhizome weevil were 25.0 and 15.0 percent respectively during the monsoon season with maximum during June-July. White fly (*Dialeurodicus disperses*) infestation was high during the month of July (10%). Incidence of banana skipper butterfly (*Erionota torus*) was observed from February to September, 2016. Peak leaf roll formation was seen in the months of June to August coinciding with monsoon in Kerala and later subsiding during the dry periods.

**Roving surveys :** Pseudostem weevil and rhizome weevil were observed to infest banana in all the surveyed areas of Thiruvananthapuram, Kollam, Pathanamthitta, Palakkad, Ernakulam, Thrissur, Idukki, Wayanad, Kannur, Kasargod, Alappuzha and Kottayam districts. Nendran, Red banana and Robusta were found highly susceptible. Location specific difference in pest attack and intensity in attack was observed. The variety Popoulu recorded very high susceptibility to fruit fly attack when bunches started ripening. In addition to fruit flies, 5 different types of flies (Order: Diptera) were also collected from the Popoulu fruits. These observations were recorded from Thrissur, Palakkad and Kollam districts. Fruit flies were readily attracted to methyl eugenol lure.

Heavy incidences of slug caterpillar (*Miresa decendens*) was observed at Thrissur, Wayanad, Idukki, Alappuzha and Kottayam districts on cv. Nendran and Njalipoovan. Severe attacks were seen in Nendran plots in Kottayam district. Root mealy bug (*Geococcus sp.)* was observed only at Kannur in Nendran variety. Infestation of mealy bug (*Ferrisia virgata)* and white flies *(Dialeurodicus disperses)* were high at hilly terrains of Idukki, Wayanad, Kannur and Kasargod districts. Severe infestations of banana spittle bug (*Phymatostetha deschampis)* was recorded from Pathanamthitta (June - July, 2016) and Idukki (September, 2016) districts. Similarly, heavy incidence of root mealy bug (*Dysmicoccus* sp.) was recorded in Wayanadu, Thrissur and Ernakulam districts. Red spider mite infestation was observed from Thrissur, Palakkad, Malappuram and Idukki districts. Intensity of the attack was high during the reporting period. Incidence of Skipper butterfly was high in the districts of Idukki, Wayanad, Kannur and Kasargod. The attack was more in Nendran varieties.

## 8. Integrated management of banana pseudostem weevil (*Odoiporus longicollis*)

Highest number of holes/plant was observed in control (16.81), where as the least was recorded in the treatment Swabbing chlorpyriphos (0.05%) (5.56). Second least formation of symptoms of PSB infestation was recorded in Pseudostem trapping with EPF, *Beauveria bassiana* (9.28). Number of weevils per plant and number of grubs was least in Swabbing chlorpyriphos 0.05% and pseudostem trapping with EPF, *Beauveria bassiana* which were on par. Swabbing chlorpyriphos 0.05% was found to be the best management for reducing the number of pupal stages in the plants. Significant difference was observed for bunch weight between the treatments. Swabbing chlorpyriphos 0.05% (2.5ml/litre) at $5^{th}$, $6^{th}$ and $7^{th}$ months after planting recorded the highest bunch weight (9.01 kg), compared to control (6.20 kg).

## 9. Survey of plant parasitic nematodes associated with banana

Survey of nematode pests of banana was conducted across the state of Kerala. Major banana nematodes *viz., Radopholus similis, Meloidogyne incognita, Helicotylenchus multicinctus, Pratylenchus penetrans, Heterodera oryzicola* were recorded at Thiruvananthapuram, Pathanamthitta, Kollam, Palakkad, Thrissur, Ernakulam, Wayanad, Idukki, Alappuzha and Kottayam districts.Severe incidences of *Meloidogyne incognita* was observed in banana monoculture or in banana intercropped with tubers (*Dioscorea*) and vegetables at Wayanad, Idukki, Thrissur, Ernakulam, Kottayam and Alapuzha districts. Incidence of *Radopholus similis* was more at Wayanad district closely followed by Kottayam. Banana spiral nematode, *Helicotylenchus multicinctus* was more at Palakkad. Incidence of *Pratylenchus* sp. was more in the hilly tracts of Idukki, Kottayam and Wayanadu and also in coastal district of Alappuzha. Scattered incidences of banana cyst nematode *Heterodera oryzicola* was identified from the soil samples collected from Kollam district.

## 10. Biological control of banana nematodes

Among the biocontrol agents, combined application of *Pseudomonas fluorescens*@ 12.5 g/m2 + *Paecilomyces lilacinus*@ 12.5g/m2 significantly reduced the soil nematode population (58.28% ), which was on par with treated check. Root population was least in treatment with *Paecilomyces lilacinus* @ 25g/$m^2$. The highest infestation was noticed in control. Among the biocontrol agents, combined application of *Pseudomonas fluorescens*@ 12.5 g/m2 + *Paecilomyces lilacinus* @ 12.5g/m2 was found most effective to reduce the soil and root nematode population.

## 11. Biological control of banana stem weevil, *Odoiporus longicollis*

Significantly higher number of holes were recorded in T7 (control) and T4 (Stem trap swabbed with *Beauveria bassiana* @ 20g/trap at $5^{th}$, $6^{th}$ and $7^{th}$ month after planting). The least number of holes was recorded in treated check (T6: Insecticide check –chlorpyriphos application) followed by T5 (Stem trap swabbed with *Heterorhabditis* sp.) and T1 (Fungus, *Beauveria bassiana* @1x$10^7$ spores/ml, spray at $5^{th}$, $6^{th}$ and $7^{th}$ month after planting + stem trapping. Similarly when number of weevils, grubs and pupae were considered, significant reduction of infestation was observed only in the case of number of weevils and grubs. T5 (Stem trap swabbed with *Heterorhabditis* sp. @ 1x$10^9$ IJs/ml at $5^{th}$, $6^{th}$ and $7^{th}$ month after planting) and T6 (Treated check) significantly reduced the number of weevils whereas T1 (Fungus, *Beauveria bassiana* (1x$10^7$ spores/ml)spray at $5^{th}$, $6^{th}$ and $7^{th}$ month after planting + stem trapping) and T6 was most effective against grubs.

Among the yield characters, highest bunch weights of 8.96 kg, 8.54 kg and 8.23kg were recorded in T6 (Insecticide check–chlorpyriphos (0.1% (2.5 ml/l), T5 (Stem trap swabbed with *Heterorhabditis* sp. @ 1x$10^9$ IJs/ml at $5^{th}$, $6^{th}$ and $7^{th}$ month after planting) and T3 ( EPN Entomopathogenic nematode formulation of *Heterorhabditis* sp. spray at $5^{th}$, $6^{th}$ and $7^{th}$ month after planting) respectively. The least bunch weight of 5.57 kg was recorded in control.

## 12. Management of banana skipper butterfly-*Erionota torus*

Data recorded 30 days after first round of treatment application showed that there was no significant effect of the treatments on the formation of leaf rolls. After the $2^{nd}$, $3^{rd}$ and $4^{th}$round of treatments, least number of leaf rolls were recorded in T1-Foliar application of Chlorantraniliprole 18.5 SC. Highest number of leaf rolls were recorded in T6- control (The number of leaf rolls ranged from 0.747 to 2.747 in first to last spray). Among the biocontrol agents, foliar application of Bt solution proved to be best, with the least number of leaf rolls being formed 30 days after every application.

## 13. Diagnosis of banana viruses in germplasm and planting materials used in experiments

141 genotypes in germplasm and the planting materials used in experiments were screened for viruses based on symptom. Ten accessions of germplasm, 41 experimental plants and 900 tissue culture plants were indexed by DAC-ELISA. Of the indexed germplasm accessions, Ladies finger was positive for BBTV, Mottapoovan was positive for BBrMV, Uzhakkan was positive for BBrMV. Of the 41 samples of experimental plants the infection of BBTV, BBrMV and CMV were 0, 2.4 and 12.2 % respectively. Of the 900 TC plants, the infection of BBTV, BBrMV and CMV were 8.9, 9.0 and 7.6 % respectively. Indexing of germplasm accessions conducted by DAC ELISA from 2008 to 2016 period showed that twelve accessions were free of BBTV, BBrMV and CMV *viz*. Basrai (AAA), Gros Michel (AAA), Monsmarie (AAA), Nallabontha(

AB), Pachabale (AB), Padapacha (AAA), Rasgalli (AB), Robusta (AAA), Sapumal Anamalu (AAB), Valiyakunnan (AB), Agniswar (AB).

## 14. Management of Sigatoka or prevalent leaf spot disease with oil based formulations

Statistical analysis of the data on disease parameters and vegetative and yield characters revealed that there is significance difference between the treatments. The lowest disease index (PDI) at 6 MAP and at flowering was recorded for T3 (Chemicals + mineral oil) and it was on par with T4 (Alternation of chemicals alone) and T2 (Propiconazole(0.05%) + Mineral oil(1%) three sprays at 25 days interval). The disease development time (DDT) in T3 was significantly superior to all other treatments. Significant difference was recorded in bunch weight with the maximum bunch weight of 11.93 kg inT4 which was in par with T3 (11.53 kg). The treatment T3 (alternation of chemicals + Mineral oil) was the best treatment for management of Emmusae leaf spot and this was on par with treatment T4 and standard check, T2 (Propiconazole 0.05% +Mineral oil 1 % ). The percent disease index in treatment T3 was 2.19 % less than standard check at 6 MAP and 1.94 % less than standard check at flowering. The effect of T3 also influenced yield characters especially bunch weight. The B:C ratio of the best treatment (T3) was 2.94 but the highest. B:C ratio of 3.07 was recorded treatment T4.

## 15. Survey of fungal, bacterial and viral diseases of banana

No new diseases were recorded during the period under report. However, incidence of pseudostem rot was observed in variety Rasthali. The incidence of Emmusae leaf spot, fusarium wilt, Rhizome rot and Bract mosaic and infectious chlorosis, recorded a decrease compared to last year. This may be due to low rain fall and high temperature observed in last year. Nendran was more susceptible to Emmusae leaf spot and Rhizome rot. The major diseases of banana in Kerala are Emmusae leaf spot, Fusarium wilt, banana bract mosaic, Bunchy top and Rhizome rot.

## 16. Screening of germplasm for diseases

**Emmusae Leaf Spot** : Of the 141 accessions screened against Emmusae leaf spot, 37 accessions were resistant with PDI zero to ten. 50 accessions were moderately resistant with PDI 10.1-20.0, 46 accessions were susceptible with PDI 21.0-30.0 and 8 accessions were highly susceptible with PDI more than 30 in the range of 1-10, 28 accessions showed PDI in the range of 11-20, 28 accessions showed PDI in the range of 21-30 and 10 accessions showed PDI more than 30.

**Fusarium wilt :** Of the 141 germplasm accessions, natural incidence was observed in four accessions *viz:* Gros Michel (AAA), Kadali (AA), Kali (AAB) and Vellapalayamkodan (ABB). Screening of 16 accessions (Chenkadali, Karimkadali, Blue Torres strain Island, Pelipeta, Pisang Nangka, Nendrakali, Dudhsagar, Amrithsagar, Pome type, Thiruvanandhapuram, Njalipoovan, BRS I,BRS II, Big ebanga, Chengalikodan, Yangambi) against Fusarium wilt by artificial inoculation was carried out as pot culture experiment. Of this, 4 accessions *viz*., Nendrakali, Dudhhsagar, Pome Type and Njalipoovan were infected and others were free of disease.

**BBTV :** Of the 141 germ plasm accessions incidence of BBTV was observed in 7 accessions *viz.*, Pachakappa (AAA), Njalipoovan(AB), Nanipoovan(AB), Poomkalli (AB), Pisang Ceylon (AAB),Paloor(ABB) and H-513.

**Rhizome rot :** Of the 141 germplasm accessions, incidence of Rhizome rot was observed only in 4 accessions viz., PV-03-22,Rajavazha (ABB) , Bhimkol (BB) and SH- 3640(AAAB).

## 17. Collection, conservation and evaluation of pickling mangoes

77 accessions are maintained of which 30 produced fruits during this season. Observations were recorded on quantitative and quality characters of tender, mature and ripe fruits. Acidity of

tender fruits varied from 1.1 to 2.7%, moisture content from 40 to 66 percent and shrinkage from 27 to 65 percent. Length of mature fruits varied from 5.0cm to 8.5cm, width from 4.25cm to 8.3cm, weight from 60g to 180g and volume from 70ml to 190ml. Acidity of mature fruits varied from 1.72 percent to 4.72 percent, moisture content from 51.2 to 76.9 percent. Most of the accessions produced near round fruits, skin colour varied from green to yellow and orange, pulp was either soft or juicy. Skin content varied from 12.9 to 26.8 percent, stone content from 14.7 to 33.5 percent and pulp content from 46 to 67 percent. Juice content varied from 30.0 to 66.7 percent and TSS from 14 to 23$^{o}$brix.

## 18. Strengthening research on pineapple - Collection, conservation and evaluation of pineapple germplasm

30 varieties of pineapple (*Ananas comosus*), both introduced and indigenous, were planted in the experimental field. Among the collections, Simhachalam and Espanola Roja, with high Brix and Giant Kew with good fruit weight are potential candidates in future breeding programmes. Performance of MD-2 pineapple was assessed. The mean fruit weight ranged from 1.55 – 2.50 kg. The fruits had cylindrical shape, deep yellow colour with good taste and quality. The mean TSS ranged from 13 to 18 $^{0}$b and mean acidity ranged from 0.31 to 0.49 %. The crop had 13- 14 months duration

## 19. Evaluating the performance of pineapple varieties with different types of planting materials

Evaluation of the performance of pineapple varieties Kew and Mauritius with respect to yield and quality, with different types of planting materials like suckers, slips and crowns was conducted. No significant differences were observed between plants raised from suckers and those raised from crown and slips with respect to vegetative characters like mean plant height and number of leaves in varieties, Kew as well as in Mauritius at 3 months and six months after planting. Duration of plants raised from crown and suckers in Kew variety were on par. Mauritius plants raised through suckers, slips and crowns took 415-419 days for harvest. Mauritius plants had shorter crop duration as compared to Kew irrespective of type of planting materials. Fruit quality characteristics like acidity, TSS and fruit weight without crown was similar in all. The results of the studies revealed that apart from suckers, rooted Kew crowns as well as rooted Mauritius slips and crowns can be used as planting material in pineapple.

## 20. Field evaluation of tissue culture plants of pineapple varieties

Results of the study revealed that tissue culture plants of Mauritius variety of pineapple were as good as plants raised through suckers, slips and crowns with respect to yield and quality characteristics. Rapid multiplication of selected elite types can be effected through this technique.

## 21. Breeding pineapple for evolving varieties with high yield and quality

A breeding programme was initiated with Mauritius as female parent and Kew as male parent in one set of hybridization programme and with Kew as female parent and Mauritius as male parent in a second set of hybridization programme. M x K hybrids. About 100 crosses were made with Mauritius as female parent and Kew as the male parent resulting in 97 M x K hybrids. Based on fruit weight and fruit quality parameters like fruit shape, TSS and sweetness, 30 hybrids registering a fruit weight of more than 1 kg and TSS of $10^{0}$ brix and above were selected and advanced to the next generation. Among the selected MxK hybrids, maximum fruit weight was recorded by H-57 (2.258 kg) and a TSS of $14^{0}$B. The MxK hybrid H-14 registered a fruit weight of 1.940 with a TSS of $11^{0}$brix, also resembled Kew in its fruit shape, but was sweet like

Mauritius. Another promising hybrid, H-13 with a fruit weight of 1.895 kg and TSS of H-13 resembled Kew in its cylindrical fruit shape and its flesh was sweet as Mauritius. All the above three M x K hybrids can be rated as promising.

**M x K hybrids (Plant crop II) -** Hybrid, H-57-11, repeated its superior performance with respect to fruit characteristics, yielding Mauritius type fruits, weighing 2.20 kg, oval in shape, with large eyes, with a mean eye length of 2.5 cm and golden yellow flesh. Fruits recorded a TSS of $14^0$ brix and were sweet with good taste and flavour and low acidity of 0.435. Two promising hybrids, H-10-11and H-13-11 recorded fruit weights of 1.714 and 1.903 kg respectively in Plant crop 11. The fruit shape of H-10-11 was Kew like with Mauritius like crown, which is a desirable character. Fruits recorded low acidity of 0.460 per cent and were sweet, with a total sugar content of 18 5. H-13-11 bore Mauritius type fruits with golden yellow flesh with a TSS of $12^0$ B.

**K x M Hybrids -** About 30 crosses were made with Mauritius as female parent and Kew as the male parent resulting in 24 K x M hybrids. Based on fruit weight and fruit quality parameters like fruit shape, TSS and sweetness, 5 hybrids registering higher fruit weight and high TSS and super quality characteristics were selected and advanced to the next generation (Plant crop 2). Among the selected K x M hybrids, H-115 with a fruit weight of 1.680 kg and a TSS of $14^0$brix registered a high value for total sugars (24 %). Fruits resemble Kew, with respect to fruit shape, crown, juiciness and fruit flesh and were tasty. Two selected K x M hybrids, H-118 and H-121 recorded vey high fruit weights of 1.827 kg and 2.0 kg respectively, with the former having typical cylindrical shape like Kew, large crown and golden yellow flesh and like Mauritius in TSS ($9^0$B). H-121 produced Mauritius like fruit with respect to shape, but juicy like Kew, and a TSS of $9^0$B. Another promising hybrid, H – 119 had Mauritius type fruit with golden yellow flesh and protruded eyes but with cylindrical fruit shape, like Kew. Fruit is extremely sweet with a TSS of $22^0$B, acidity 0.384% and reducing sugar 8.33 %. The other selected hybrid, H-113, with a fruit weight of 1.290 kg was extremely sweet, with a TSS of $20^0$B and a low acidity (0,460%). Fruits were Kew like, with flat eyes, but crown was small with sparse spines, resembling Mauritius. Crosses conducted with Kew as the female parent and Mauritius as the male parent resulted in a greater proportion of abnormal progenies (H-100, H-102, H-104, H-108, H-111, H-120) like those with misshapen fruits and multiple crowns, as compared to the reciprocal crosses.

## 22. Post harvest handling, storage and value addition in banana and pineapple for domestic and export market

Maturity indices were standardized for domestic market in the case of banana and pineapple. Suitability of pineapple varieties namely Kew, Mauritius, Amritha and MD-2 was established for squash preparation. Pineapple squash prepared from Kew, Mauritius, Amritha and MD-2 varieties retained the colour, flavour, taste and texture up to 6 months of storage. These four varieties were suitable for jam preparation and the jam can be stored up to 9 months with out deterioration in quality. Variety Kew was most suitable for pickle making. Maximum score for colour and texture for fresh pulp and juice was obtained for Mauritius followed by Amritha. However maximum pulp and juice percentage was obtained in Kew variety which was closely followed by MD-2 variety. Storage of pineapple fruits under different treatments *viz.*, immersing in cold water, chlorinated water, treating with fungicide and waxing along with a control revealed that waxing was better for increasing storage life in Mauritius variety.

## 23. Organic versus inorganic nutrient management of pineapple varieties for safe and sustainable production

Amritha took 270 days for flowering and 291 days for fruiting and 360 days for fruit maturity from the date of planting. Nutrient application in general advanced the fruit harvest by about a week compared to the control. After ethephon application, Amritha flowered in 25 days, Mauritius in 32 days and MD-2 in 39 days. Mauritius produced maximum fruit yield of 34.07 t/ha followed by MD-2 (30.83 t/ha) and Amritha produced least yield (26.98 t/ha). Nutrient applications by any means were statistically similar but significantly superior to the control treatment.

The maximum yield is obtained for Mauritius receiving organic manure (37.89 t/ha). Mean effect of both the variety and the nutrient management are statistically significant but with no interaction effect. Hence cultivation of Vazhakulam Pineapple (Mauritius) with any source of nutrient application (Organic, inorganic or integrated) is statistically on par and any differentiation is not scientifically justifiable. Considering the marginal benefit: cost ratio, cultivation of Mauritius pineapple with inorganic fertilizers seems to be most economically viable which is most prevalently followed for pineapple cultivation in Kerala.

## 24. Collection, characterisation, conservation, evaluation and utilization of jackfruit germplasm

During exploration**,** the traits targeted were earliness, extended cropping period, fruit, flake and seed yield and quality attributes of raw and ripe jack. Evaluation of twenty accessions identified (13 dessert types, 6 cooking types and 1 all purpose type) is being done. Clonal progenies of these accessions were established in the nursery. Ten new accessions were also identified in exploration in Thrissur and Wayanad districts. All the accessions are found suitable as dessert.

## 25. Varietal trial on jackfruit - MLT I

Muttom Varikka and Pechiparai-1 are vigorous growing than other varieties. Number of fruits were high in Muttom Varikka, followed by Pechiparai-1. Maximum height recorded was for G-11a (214.80cm), which was on par with Konkan Prolific, Swarna, Sindoor and Muttom Varikka. Maximum girth was also for G-11a (12.68 cm) which was on par with Konkan Prolific, Swarna and Sindoor. Highest spread recorded was for Sindoor (143.50 cm and 144.67 cm, EW and NS respectively).

## 26. Survey and incidence of disease in jack fruit

Collectotrichum leaf spot (20-30%) and Rhizopus fruit rot (10-20%) were the most prevalent diseases of jackfruit in Kerala. Leaf blight (*Alterneria* sp and *Pestalotia* sp), fruit rot (*Botridiplodia* sp), algal rust and pink disease (*Corticium salmonicolor*) were also recorded.

## 27. Survey for new and emerging insect pests of jackfruit

Roving survey - Survey was conducted at Thiruvananthapuram, Kollam, Pathanamthitta, Thrissur, Ernakulam, Idukki, Wayanad, Palakkad, Alappuzha, Kottayam, Kasargod and Kannur districts of Kerala. Among the insect pests of economic importance, Lepidopteran and Coleopteran defoliators/stem borers were observed sporadically with severe incidences in jackfruit growing locations. Severe incidence of leaf eating cerambycid beetles (*Olenecamptusbilobus)* was observed during the monsoon period. They feed alone or in groups of 3-4 beetles and severely defoliate the jack plants across the surveyed locations. *Glenea multiguttat*a, acerambycid beetle was observed to cause damage to Jack leaves by severing the veins leading to drying of leaves and young shoots. The beetle was reported from Thiruvananthapuram, Pathanamthitta, Thrissur, Ernakulam, Idukki, Wayanad, Palakkad,

Kottayam and Alappuzha districts. Incidence of *Oberea artocarpi* was recorded from Central zone (Thrissur and Palakkad districts) mainly from trees aged less than 5 years. Jack fruit aphid (*Greenidia artocarpii)* causes crinkling of leaves in young shoots. The spittle bug (*Clovia lineaticollis*), which is a mild but regular pest appear whenever new shoots are formed. Defoliation by grass hopper and leaf caterpillar was of regular occurrence. Infestation by the tingid bug was wide spread but of mild nature. Bud weevil (*Ochyromera artocarpi)* heavily feed on young and tender jack fruits. Rodents like 3 banded common squirrel, Malabar giant squirrel, and birds have a special preference for ripening fruits. The combined attacks of these pests cause appreciable yield loss.

Fixed plot surveys - Gregarious infestation of leaf beetle (*Olenocamptus bilobus*) coincides with the profuse flushing especially during the monsoon period. This was closely followed by infestation of leaf caterpillar (*Margaronia bivitralis*). Isolated incidences of breadfruit mealy bug (*Icerya aegyptica*) was also recorded. Incidence of defoliators like *Oberea artocarpi, Epepeo tesuncinatus* were recorded from April, 2016- March, 2017. Attack of stem borer, *Batocera rufomaculata* was noticed on trees during monsoon and post monsoon period (July-October). Attack of long horned grasshoppers (katydids) were high. Gregarious chrysomelid beetles of orange colour were found severely attacking the leaves during the months of June and July, 2016.

*Epepeotes uncinatus* is emerging as a noticeable pest jack fruit in the fixed plot survey, whereas the long horned beetle complex consisting of *Oleno camptusbilobus, Obere aartocarpi, Epepeo tesuncinatus, Glenea multiguttata* and stem borer, *Batocera rufomaculata* are causing appreciable loss to jackfruit both as defoliators in the adult stage and trunk borers as grubs.

# Project Coordination Group - Pulses, oil seeds, fodder crops and green manure crops (05)

**Project Coordinator - Dr. Elizabeth K. Syriac**

**Ongoing Projects: 42**

## Ongoing Projects

### AINP on Arid Legumes and Mullarp - Experiments Conducted

1. **Summer Cowpea (AVT-2 + AVT-1)**
   Thirteen entries of cowpea were evaluated in summer and the entry GC1008 recorded maximum yield (802 Kg/ha).
2. **Summer Cowpea (IVT)**
   Among the eleven entries evaluated, it was found that the entry PGCP-63 recorded maximum yield of 715 Kg/ha.
3. **Summer Mung bean (AVT-I)**
   Fourteen entries were evaluated and found that three entries *viz*., HUM-16 (773 Kg/ha), Pusa-1501(761 Kg/ha) and COGG-8 (724 Kg/ha) recorded maximum yield.
4. **Summer Urd bean (AVT-I +II)**
   Nine entries were evaluated and found that the entry KPU 524-65 recorded the maximum yield of 1202Kg/ha.
5. **Summer Urd bean (IVT)**
   Among the ten entries evaluated, the entry SUG 137 recorded the maximum yield of 833Kg/ha.
6. **Rice fallow Urd bean (IVT)**
   The three entries *viz*., LBG 752, IPU 10-33 and COBG 1103 recorded the maximum yield of 939 Kg/ha, 906 Kg/ha and 898 Kg/ha respectively.
7. **Rice fallow Urd bean pathology**
   Sixteen entries of Urd bean were evaluated and found that the entry RFUP 15-14 is recording the maximum yield of 1271.67 kg/ha and was statistically on par with RFUP 15-11 (1265.83 kg/ha). These entries were found resistant to yellow mosaic disease. The entry RFUP 15-2 was the next best entry with a yield of 1087.92 kg/ha, but was found susceptible to yellow mosaic disease.
8. **Rice fallow Mung bean Pathology**
   Among the eleven entries evaluated during summer, the entry RFMP 15-2 recorded highest yield of 414.17 kg/ha. RFMP 15-3 was found to be the next best entry with a yield of 387.92 kg/ha and was found to be statistically on par with RFMP 15-9. The entry RFMP 15-2 found resistant to yellow mosaic disease.
9. **Extra early summer Mung bean (IAVT)**
   Fourteen entries of Mung bean were evaluated during summer. The results showed that the entry EESM 16-12 gave highest yield of 765 kg/ha and was statistically on par with EESM 16-4 (753 kg/ha). The next best entry was EESM 16-5 with a yield of 717 kg/ha.
10. **Frontline demonstration of Black gram and Green gram**
    Frontline demonstrations on black gram variety LBG 752 and Co-6 carried out at Kozhinjimpara of Palakkad district recorded yield of 1400 kg/ha and 1250 kg/ha respectively.
    Frontline demonstration on green gram variety LGG 460 carried out at Palakkad district recorded yield of 500 kg/ha.

## 11. Summer Black gram

Among the six Black gram entries tested for yield during summer, Vamban 3 gave highest yield of 907.81 kg/ha. The entry Vamban 6 (890.31 kg/ha) was found on par with Vamban 3.

## AINP on arid legumes (Rabi 2016-17) - Experiments conducted

## 12. Management of Cowpea aphid

Among the nine treatments tested against cowpea aphid, pooled data over three years showed that the application of Dinotefuran @ 0.4g/litre (T7) and Ethiprole + Imidacloprid @ 0.3g/litre (T5) are the best treatments to manage cowpea aphid. The least count of aphids after 48 h of application of insecticide was recorded in T7 (0.89) and is statistically on par with T5 (1.72 ). Dinotefuran @ 0.4g/litre (T7) and Ethiprole + Imidacloprid @ 0.3g/litre (T5) were given 99.40 and 97.60 per cent control of cowpea aphid. Flubendiamide + Buprofezin @ 1.75ml/litre (T6), Neem leaf extract 30% (T1), Azadirachtin 10000 ppm @ 2.5ml /litre (T3), Tag folder @ 4ml/litre (T4), Buprofezin @ 1.75ml/litre (T8) were found on par with each other in terms of cowpea aphid management.

## 13. Evaluation of Cowpea entries for pests

### IVT on cowpea

The cowpea entries *viz*., CPP-21, CPP-23, CPP-24, CPP-25, CPP-26, CPP-27, CPP28, CPP-29, CPP-30, CPP-33, CPP-35 and CPP-36 were recorded no incidence of aphid.

### AVT on cowpea

The cowpea entry CPP-1 was found free of aphid incidence and CPP-10 was the most susceptible entry for cowpea aphid incidence.

## 14. Survey of pests occurring in Cowpea Palakkad district

The survey on DC-15 cowpea fields showed that the variety is was infested with aphids in Ongallur, Thrithala, Edappalam and Vilayur parts of Palakkad district.

## 15. Management of seed mycoflora of Cowpea

Among the six treatments tested, pooled data over three years showed that the treatment T2 (Carbendazim 12% + Mancozeb 63% seed treatment @ 2g/kg of seed) found to be the best in increasing the germination, reducing the dry root rot incidence and in increasing the yield of cowpea. Seed treatment with Carbendazim @ 2g/kg (T1) was found to be on par with (T2) in reducing dry root rot incidence and increasing yield. The lowest germination per cent and highest dry root rot incidence was recorded in control.

## 16. Efficacy of different Rhizobium cultures on Cowpea

Among the five treatments tested to determine the efficacy of *Rhizobium* cultures on cowpea yield, pooled data over three years revealed that the seeds treated with RCW 33b (T1) recorded the highest yield of 1478.40 kg/ha. RCW 33c (T2) was found the next best treatment with a yield of 1422.09 kg/ha and was found on par with CP3 (T3).Control recorded the lowest yield of 939.36 kg/ha.

## 17. Evaluation of Cowpea entries for diseases

**AVT on cowpea**

Among the ten entries tested, no disease incidence was observed in all the entries

**IVT on cowpea -** Out of the twelve entries tested, CPP-27 recorded maximum dry root rot incidence (58.33%) and the rest eleven showed resistant reaction.

## 18. Evaluation of Horse Gram entries for diseases

Out of the fifteen entries tested for disease incidence, three horse gram varieties *viz*.,HG1, HG3 and HG4 showed resistant reaction to dry root rot disease and the rest twelve entries *viz*., HG2, HG5, HG6, HG7, HG8, HG9, HG10, HG12, HG13, HG14, HG15 and HG16 showed susceptible reaction to dry root rot disease.

## 19. Evaluation of Guar entries for diseases

No disease was observed in all the fourteen entries.

## 20. Survey of diseases occurring in Cowpea in Palakkad district

The survey on DC-15 cowpea fields showed that the variety is free from diseases.

## 21. AVT on Cowpea

Among the ten entries tested, the entry CP 1 recorded the highest yield (2236.373 kg/ha) followed by CP2 with the yield of 2014.613 kg/ha. CP7 recorded the lowest yield (937.493 kg/ha).

## 22. IVT on Cowpea

Among the twelve entries evaluated, the entry CP 29 recorded highest yield of 1655.57 Kg/ha. The entry CP 22 and CP 26 which recorded the yield of 1521.23 kg/ha and 1510.08 kg/ha respectively was found to be the next best entries. The lowest yield was recorded in CP 25 (682.88 kg/ha) and was found to be on par with CP 28 (742.72 kg/ha).

## 23. AVT+ IVT Horse gram

Among the eleven entries tested, only HG2 could flower and recorded yield of 485.76 kg/ha.

## 24. FLD on Cowpea variety DC-15

Frontline demonstrations on cowpea variety DC-15 carried out at different places of Palakkad district recorded an average yield of 2018 kg/ha.

## 25. FLD on Horse gram variety CRHG-19

Frontline demonstrations on horse gram variety CRHG-19 carried out at Mudavanoor and Thithala recorded an average yield of 1950 kg/ha.

**26. Crosses attempted at RARS, Pattambi**

A total of three crosses, two in cowpea and one in horse gram were attempted at RARS, Pattambi during 2016-17 and the progeny seeds were stored for further work.

**27. Hybrids developed at RARS, Pattambi**

Among the eleven crosses developed at RARS, Pattambi, the pooled data over four seasons (IET-1, CYT I, CYT II and CYT III) showed that there is no significant difference between the eleven entries and four check varieties (Kanakamony, Polo, DCS-47-1, Anaswara) in terms of yield.

**28. Evolution of high yielding variety of cowpea (*Vigna unguiculata*) with synchronized maturity suited to the summer rice fallows of Onattukara**

Breeder seed production of two released varieties Sreya and Hridya was undertaken.

Germplasm consisting of 11 accessions were maintained. F2 generation of four different crosses viz. Culture-1 x Sharika, Culture-6 x Sharika, Culture-4 x Sharika and Sreya x Sharika were made and promising lines were selected.

**29. Genetic improvement of local sesame variety "Ayali"(*Sesamum indicum*) suited to the drought conditions of Onattukara**

Comparative Yield Trial-III was carried out with the selected lines and ASS-11, ASS-10 and ASS-7 recorded significantly higher yield than the check variety Thilak. In Hybridisation and selection trial, highest yield was recorded by K-04-2-2 (698 kg/ha) followed by K-05-4-15 (596 kg/ha)

## AICRP on Forage crops & utilization

**30. Germplasm collection, maintenance and evaluation of Guinea grass**

39 accessions of guinea grass is maintained in the centre.

**31. Evaluation of Bajra -Napier hybrid cultures for yield and Forage quality**

Fifty one bajra-napier hybrids received from IGFRI, Jhansi were evaluated. Out of the 51 hybrids sown, 20 hybrids have germinated and they were multiplied. Evaluation of 20 hybrids was done and five hybrids with superior fodder attributes were selected for yield trials. The five cultures were compared with the local check (Suguna) and the green fodder yield was significantly different in all harvests. Culture 1 was selected for farm trial in the 2016 ZREAC workshop of Kerala Agricultural University.

**32. Induced mutagenesis for delayed flowering and high tillering in guinea grass**

Objective of the study is to develop high yielding guinea grass types with delayed flowering and high tillering through induced mutagenesis. This is part of the PhD programme and the study is in progress.

**33. Initial varietal trial in forage cowpea (AICRP Trial)**

Based on the results of the study, out of 10 accessions, IVTC-12 recorded higher green fodder yield (300.66 q/ha/year).

**34. Initial varietal trial in rice bean (AICRP Trial)**

Based on the results of the study, out of 6 accessions, IVTRB-1 recorded higher green fodder yield (97.00 q/ha/year).

**35. Advanced varietal trial in forage cowpea (AICRP Trial)**

Based on the results of the study, out of 9 accessions, AVTC-7 recorded higher green fodder yield (238.66 q/ha/year).

**36. Advanced varietal trial in forage rice bean (AICRP Trial)**

Based on the results of the study, out of 6 accessions, AVTRB-3 recorded higher green fodder yield (79.25 q/ha/year).

**37. Initial varietal trial in forage maize (AICRP Trial)**

Based on the results of the study, out of 12 accessions, IVTM-6 recorded higher green fodder yield (168.33 q/ha/year).

**38. Initial varietal trial in forage pearl millet (AICRP Trial)**

Based on the results of the study, out of 12 accessions, IVTPM-6 recorded higher green fodder yield (111.33 q/ha/year).

**39. Evaluation of sesame genotypes for tolerance to water logging - PG**

Preliminary screening of thirty sesame genotypes revealed that ten genotypes recorded comparatively high survival percentage under excess moisture conditions. They were Thilak, Thilarani, *Sesamum malabaricum*, Ayali, Rama, TKG 308, TKG 22, SV2, OSC 207 and GT 10. Analysis of variance of thirteen biometric characters revealed significant differences among genotypes for all the characters studied revealing the presence of high genetic variability. Among the selected genotypes highest survival percentage was recorded by the wild species *Sesamum malabaricum* while Ayali recorded the highest survival percentage in *Sesamum indicum* genotypes. Biochemical studies revealed that genotypes like *Sesamum malabaricum*, Ayali and OSC 207 have comparatively more production of antioxidants and osmoregulants after water logging. Anatomical study emphasized that among ten genotypes *Sesamum malabaricum*, Ayali and OSC 207 have significant formation of aerenchyamatous tissues in roots. Number of capsules plant$^{-1}$ had highest positive direct effects on seed yield plant$^{-1}$. All the sixteen characters have high heritability. Days to maturity have highest heritability (99.9 %). Number of capsules plant$^{-1}$ had highest positive direct effects on seed yield plant$^{-1}$.

**40. Production package of palisade grass (*Brachiaria brizantha* (Hochst. ex A. Rich) Stapf.) - PG**

The main objectives were to standardise the nutrient requirement, spacing and cutting pattern of palisade grass under open and partial shaded condition and to work out the economics of cultivation. The results indicated that the cutting pattern, nutrient levels and spacing had significant effect on the growth, yield, physiological and quality parameters, uptake of nutrients, available nutrient status and economics of cultivation in both the experiments.

Under open condition among the cutting pattern, $C_2$ (cutting at 10 cm from the ground level) recorded the highest plant height and $C_1$ (cutting at ground level) recorded the highest number of tillers plant$^{-1}$ and leaf area index during the first and second year. The highest RGR was recorded by $C_2$ in first year and $C_1$ in second year. CGR and NAR was the highest in ground level cutting in second year. The total green fodder yield was the highest for $C_2$ in the first year whereas in the second year $C_1$ and $C_2$ were found to be on a par. $C_2$ recorded the highest crude protein content and lowest crude fibre content in both the years. The uptake of all nutrients were the highest for $C_2$ in the first year and $C_1$ and $C_2$ were found to be on a par in the second year except in nitrogen uptake. The net returns and B : C ratio was also highest in the treatment $C_2$ in the first year whereas $C_1$ and $C_2$ was on a par in the second year.

Under partial shaded condition among the cutting pattern, $C_2$ recorded the highest plant height and $C_1$ recorded the highest number of tillers plant$^{-1}$ and leaf area index during the first and second year. The regeneration percentage and RGR were the highest when 10 cm cutting height was followed in the first year. Ground level cutting registered highest RGR and cutting at 10 cm cutting height recorded highest CGR in second year. The total green fodder yield was the highest for $C_2$ in the first year whereas in the second year $C_1$ and $C_2$ were found to be on a par. $C_2$ recorded the highest crude protein content in the first year and in the second year $C_1$ and $C_2$ was found to be on a par in all the harvests except final harvest. The crude fibre content was the lowest when cutting at 10 cm from the ground level. The uptake of nutrients was highest for $C_2$ in the first year and $C_1$ and $C_2$ were found to be on a par in the second year except in nitrogen uptake. The net returns and B : C ratio were the highest for $C_2$ in both the years. Among the nutrient levels $N_3$ recorded the highest growth, yield and physiological attributes, crude protein content, uptake of nutrients, net returns and B : C ratio in first and second year both under open and partial shaded condition.

Under open condition among the spacing levels, $S_1$ (60 x 30 cm spacing) recorded the highest plant height and leaf area index both in first and second year. The number of tillers plant$^{-1}$, regeneration percentage and RGR were found to be the highest in $S_3$ (60 x 60 cm) in both the years. The highest CGR of 4.78 g g$^{-1}$ day$^{-1}$ was observed by $S_1$ between first and second harvest and 3.92 g g$^{-1}$ day$^{-1}$ by $S_2$ (60 x 40 cm) between fourth and fifth harvest during first year. The total green fodder yield was the highest for $S_1$ which was on a par with $S_2$ in first year and $S_1$ was found to be significantly superior to $S_2$ and $S_3$ in the second year. The uptake of nutrients was highest for $S_1$ in both the years. The net returns and B : C ratio were not significantly influenced by spacing treatments in first year whereas $S_1$ recorded highest net returns and B : C ratio in second year.

## 41. Cutting intervals and additives for quality silage production - PG

**Effect of cutting intervals on quality fodder production for ensiling.**

The treatments comprised of three cutting intervals - 45 days, 60 days and 75 days. 75 days cutting interval recorded highest green fodder yield from single cut. Lowest green fodder yield was recorded when the crop was harvested at 45 days cutting interval. Whereas the total green fodder yield from one year was not influenced by the cutting intervals. Highest dry fodder yield from single cut was also recorded by 75 days cutting interval. As in the case of green fodder

yield, lowest dry fodder yield from single cut was registered by 45 days cutting interval. Similar to dry fodder yield $cut^{-1}$, highest dry fodder yield from one year was recorded from 75 days cutting interval and the lowest from 45 days cutting interval. Highest crude protein and lowest crude fibre content was estimated from 45 days cutting interval. Lowest crude protein and highest crude fibre were estimated in fodder harvested at 75 days cutting interval.

**Effect of additives and cutting intervals on quality silage production**

Three types of ensiling materials tested were - $E_1$ (fodder harvested at 45 days interval), $E_2$ (fodder harvested at 60 days interval) and $E_3$ (fodder harvested at 75 days interval) and additives tested were - $A_1$ (Urea 2 %), $A_2$ (Jaggery 2 %), $A_3$ (Urea 1 % + Jaggery 1 %), $A_4$ (Molasses 2 %) and $A_5$ (no additives).The colour of the hybrid napier silage were slightly different according to the additives used for ensiling. Cutting intervals couldn't influence the colour of silage. Silages with urea as additive had more greenish colour. Both cutting intervals, additives and their interactions did not exert any significant influence on silage pH. The pH of the silage was in the range 3.7- 4.8.Additives tried in this experiment could not significantly influence the total ash content of silage. Cutting interval alone had significant effect on acid insoluble ash content. Lowest acid insoluble ash content was registered by fodder harvested at 45 days interval and highest by fodder harvested at 75 days interval.

Highest crude protein content was obtained from fodder harvested at 45 days interval. Urea 2 % recorded highest crude protein content among the additives .Cutting intervals alone had significant influence on crude fibre content of silage. Lowest crude fibre content was observed in silage prepared from fodder harvested at 45 days interval. Based on the study, it can be concluded that quality silage from hybrid napier can be prepared by ensiling the fodder harvested at 45 days interval and by adding urea 2 % or urea 1 % + jaggery 1 % as additive.

## 42. Baby corn (*Zea mays* L.) as a dual purpose crop in summer rice fallows- PG

The objective was to study the effect of different maize varieties under different plant densities and its effect on growth parameters, baby corn yield, fodder yield and quality, content and uptake of nutrients as well as the economics of production of baby corn as a dual purpose crop in summer rice fallows. The study results revealed that the plant height increased with increasing plant density. Taller plants were formed at planting geometry of 40x15 cm at 30 and 60 DAS. Maximum plant height and leaf area was recorded for the variety NSC 1009 B at 30 day stage. Maximum leaf area index was noticed for the variety NSC 1009 b at both stages. Similarly maximum LAI was noted for the planting geometry 30x15 cm. Leaf stem ratio remain unaffected among varieties and different spacing levels. Plant spacing of 30x15 cm recorded maximum dry matter production of 0.79 t/ha and 8 t/ha at 30 and 60 day stage, respectively. The variety NSC 1009 B took lesser number of days for tasseling, silking and first harvest. Variety G 5414 produced maximum number of three cobs per plant. Wider plant spacing of 50x15 cm produced cobs and corn which are longer, thicker and weighed maximum. Green cob and baby corn yield among the three varieties were comparable. Closer planting (30x15 cm) of baby corn resulted in higher green cob yield of 12.48 t/ha, baby corn yield of 3.22 t/ha and green fodder yield of 34.09 t/ha. Maximum nutrient content was found in leaf compared to stem and corn as compared to that in stem and husk. Nutrient content in crop increased with decreasing plant density.

Potassium was the element found to be more concentrated in the crop, followed by Nitrogen. Maximum uptake of Potassium followed by Nitrogen was noticed among baby corn plant. Fodder quality parameters like Crude protein, crude fibre and crude fat content was found to be maximum in plants sown at wider spacing. Maximum crude protein content was noticed in the variety CO 6. B:C ratio was also found to be higher for closer planting of 30x15 cm.

# Project Co-ordination Group
# (06) Floriculture

**Project Coordinator - Dr. Sheela.V.L**

**Concluded Projects: 15**

## Concluded project

### 1. Strengthening Research in floriculture – Plan

Annual flowers like marigold, celosia, zinnia, coreopsis, gaillardia and gomphrena were maintained in the floriculture field. They were raised in rainy and summer seasons. Different shades of flowers in marigold, celosia and zinnia were collected and maintained. Foliage plants such as *Philodendron, Aglaonema, Dracaena, Dieffenbachia, Calathea* and different tropical palms and ferns were maintained under partial shade. Collections were added in crops like *Alpinia, Zingiber*, torch ginger, heliconia *etc*. Large scale multiplication of ornamental plants was done by *in vivo* methods. Produced quality seeds of annual flower / planting materials of the selected plants and multiply selected varieties of annuals.

### 2. Additional support for landscaping - Plan

Maintained the lawn in the College of Horticulture and in front of the Headquarters by weeding, mowing, rolling, watering, application of fertilizers and plant protection chemicals. The ornamental trees/ shrubs/ palms adjacent to building, entrance, main junction, road sides were maintained by regular pruning, weeding *etc*. Areas along the central circle near to the Administrative Block and college of Horticulture were maintained. Procured high value ornamental plants for use as indoor plants. Landscaped the Central circle of the main campus with perennial shrubs and maintained it. Interior plantscaping were done in the blocks of College of Horticulture. Hedge and edge plants along the road were pruned regularly. Extended the irrigation facilities. Maintained avenue trees by pruning. The lower branches of avenue trees are to be regularly pruned to permit traffic. The over grown branches are also to be pruned to avoid hazard. Purchased consumables like pots, media, PPchemicals, organic and inorganic fertilizers and other aids for the maintenance of plants in the landscape.

### 3. Maintenance of area landscaped in and around KAU, Headquarters and College of Horticulture,Vellanikkara- Untied projects

Maintained the existing gardens and lawn in and around the KAU headquarters and college of Horticulture by weeding, rolling, watering, application of PP chemicals and fertilizers. Maintained the topiaries by regular pruning. Maintained and extended irrigation facilities. Procured attractive mother plants of new ornamentals and planted in the central circle. Pruned ornamental trees/ shrubs adjacent to building entrance and road sides. The lower and over grown branches of avenue trees were pruned regularly.

### 4. Maintenance of area landscaped in and around KAU, Headquarters and College of Horticulture,Vellanikkara - Plan

Maintained the landscape of the central circle by replanting attractive flowering shrubs and annuals of different colours.Maintained the existing gardens and lawn in and around the KAU headquarters and college of Horticulture by weeding, rolling, watering, application of PP chemicals and fertilizers.Purchased mother plants of different colours of rose and other attractive ornamentals, planted in attractive pots and arranged in front of the central circle of KAU headquarters.Procured attractive mother plants of new ornamentals and planted in the central circle.Pruned ornamental trees/ shrubs adjacent to building entrance, road sides, etc. The lower and over grown branches of avenue trees were pruned regularly.Collected attracted novel ornamentals for interiorscaping also.Maintained the medians by planting new flowering plants.

## 5. Network project on seed and nursery programme-Planting material production – Plan

Purchased mother plants and consumables for implementing large scale multiplication of high value ornamental plants by *in vivo* methods. Purchased mother plants of high value ornamentals and foliage plants. Ornamental plants were purchased for large scale multiplication and also for landscaping the premises. Mother plants of perennial and annual flowers were purchased and started multiplication of the same. New varieties of fruit plants like pulasan (*Nephelium mutabile*), rambutan (*Nephelium lappaceum*), sweetlime (*Citrus limetta*),sweet ambazham(*Spondias mombin*), hybrid chamba (*Syzigium jambos*), durian (*Durioz ibethinus*) and star fruit *(*Averrhoa carambola*)* purchased during 2013-14 were established and started flowering and fruiting. Purchased consumables like pots, media, PP chemicals, organic and inorganic fertilizers and other aids for the maintenance and propagation of plants.Maintained and extended the available irrigation facilities.

## 6. Introduction, evaluation and large Scale Production of exotic cut flowers and foliage – GOK

Developed the protocol for post-harvest handling of Heliconias. Evaluated 25 varieties of fragrant vandas for use as cut flower and pot plant classified them for various landscape and other uses.Forty one species/varieties of ornamental gingers belonging to six different genera, namely, *Alpinia*, *Costus, Etlingera*, *Zingiber*, *Curcuma* and *Tapeinochilos,* were evaluated during the period. Among the evaluated species, *Etlingera sp*, *Costus sp*. and *Zingiber sp*. are tall growing and found suitable as accent plants for background planting, foundation planting, screening for privacy, corner planting and border planting. *Costus curvibracteatus* and *C. osae* having different coloured foliage, can be planted in attractive combinations. *Curcuma sp*. and *Costus sp.* were suitable for border planting. Inflorescences of *Etlingera sp., Zingiber sp., Alpinia purpurata and Curcuma sp.* were ideal for use as cut flowers in bouquets and flower arrangements. None of the ornamental gingers was suitable for use as loose flowers. Performance of foliage plant species, viz, *Cordyline, Aglonema and Philodendron* for use as cut foliage was done. Twenty seven *Philodendron* varieties \ species were evaluated based on qualitative and quantitative characters to assess the suitability for commercial exploitation. Their suitability for outdoor and indoor landscaping and also for use as cut foliage was evaluated. Thirty two species\ varieties of *Aglaonema* were evaluated for commercial exploitation ie for use as cut foliage \ indoor or out door landscaping. Almost all were attractive. Three types of *Aglaonema* species\ varieties could be noticed based on petiole colour pink, green and white. Based on the qualitative and quantitative characters, the suitability of *Aglaonema* varieties / hybrids in floriculture \ landscaping were also evaluated.Twenty four species/varieties of *Cordyline*/*Dracaena* were evaluated for their use as cut foliage/fillers. Almost all were attractive and their visual scoring and vase studies were also done. Almost all of the species/varieties were having attractive multi coloured leaves. The visual scoring revealed the superiority of *Dracaena fragrans*'Massangeana' among them, followed by *Cordyline terminalis* 'Rainbow', *Cordyline terminalis* 'Carnival', and *Cordyline terminalis*'Surprise'. Maximum vase life was for *Dracaena fragrans* 'Massangeana', followed by *Pleomelereflexa* and *Cordyline terminalis*'Calcutta' and *Dracaena sanderiana.* All of them are very attractive and could be very well used as fillers in flower arrangements and bouquets. Maintained the post quarantine shed and the existing demonstration units and other green houses in the project for keeping the exotic plants. Exotic varieties of high value ornamentals like orchids (*Vanda*, Fragrant vandaceous orchids, *Kagwara*, *Mokara*, *Aranda*, *Renanthera*, *Oncidium*, *Phalaenopsis*,) and *Gerbera* were evaluated. The vegetative and floral characters of the trigeneric orchids viz.,*Kagwara* and *Mokara,* bigeneric

orchids viz *Aranda*, monopodial orchids (*Renanthera*, *Phalaenopsis*) and *Oncidium* were evaluated. Nine *Gerbera* varieties viz, Salvadore, Goliyath, Dana Ellen, Submarine, Jaffana, Balance, Rosalin, Silvester and Intense are evaluated during the period in different containers (mud pot and grow bags) and potting media (sand, soil and cowdung (1:1:1 ) and cocopeat). The vegetative characters and floral characters of the varieties as influenced by containers and media. On compairing growth and yield character performance of gerbera varieties grown in cocopeat in mud pots was better as compared to ordinary potting mixture. Trainings were conducted to unemployed youth and farmers on production technology of new ornamentals, production technology on loose flowers and production technology of dry flowers.

## 7. Domestication and Improvement of Exacum bicolor Roxb

**Domestication aspects -** Treating seeds with either GA 350 µm or KNO3 50 mm for 24 hrs or NaOCl 4%10 mnts are suitable for inducing earliness in seed germination of Exacum bicolor by one week. Seed germination was significantly earlier in coco peat +sand (1:1) , Coco peat + sand (1:1) + AMF, Soil alone, Perlite alone , vermiculite alone, coco peat alone, Vermiculite + perlite (1:1) and Cocoa peat + perlite + vermiculite (3:1:1). However growth score was better in media comprising of coco peat + sand (1:1). No seed germination was observed in any media with FYM as an ingredient. Increased plant height and inter nodal length was the result of GA @ 50 ppm in the treatment. significantly more number of flowers are obtained with micronutrients in *Exacum bicolor*. It is also evident that GA had negative influence on number of flowers.Seasonal evaluation of *Exacum bicolor* revealed thatthe plant is suitable for growing in anyseaso as an ornamental as pot plants as well as for bedding.

**Crop Improvement -** Seeds of 14 genotypes of *Exacum bicolor* were collected from different locations in plains and high ranges of Kerala. Five methods of pollinations viz. open pollination, controlled selfing, controlled crossing, open cross and bagging & selfing were evaluated. It could be concluded that *Exacum bicolor* is strictly an entomophilous cross pollinated plant as there was no fruit set when flowers were bagged or the entire plant was kept in insect proof cages. Major pollinators were *Bombus* sp, *Trigona* sp, *Megachile* sp and *Calliphoride*sp. Fruit set was also not observed in open cross and hence presence of stamen which is an abundant source of pollen is an essentiality for the flowers to get pollinated. Presence of self incompatibility was ruled out as there was considerable seed set in controlled selfing. Likewise male sterility was also ruled out. Capsule weight was significantly higher in both open pollination (0.113 g) and controlled crossing (0.119 g) where as seed weight was the highest in controlled crossing (0.021 g). It could also be inferred that higher fruit and seed weight in controlled crossing as an indication of occurrence of heterosis and possible chances for isolating promising genotypes through planned hybridization programmes. stigma receptivity studies indicated that stigma is receptive even before flower opening. Receptivity reaches the maximum on third day after flower opening as indicated by the capsule weight and seed weight and the time of pollination show an optimum trend in between 8am and 12 noon. Pollen viabilitystudies indicate that pollen is viable day before flower opening and it is maximum on day 1and day 2.

Variation in seedling population were observed in a population of 340 seedlingindicating great scope for crop improvement through selection, inbred development and further hybridization.

## 8. Collection and evaluation of under - exploited ornamentals – AICRP

Fifteen varieties of heliconia viz; *Heliconia stricta* –Bucky, *Heliconia bihai* – Emerald Forest, *Heliconia bihai* – Kamehameha,*Heliconia bihai* – Island Yellow, *Heliconia psittacorum* – Halloween,*Heliconia psittacorum* -Sassy pink,*Heliconia bihai X Heliconia Caribaea* **–** Hot Rio Nights, *Heliconia bihai*x *Heliconia*caribaea- Yamakawa-Chocolate,*Heliconia rostrata, Heliconia chartacea* - Sexy Pink, *Heliconia longissima* -Red wings, *Heliconia orthotrica* - Oriole Orange, *Heliconia orthotrica* - Orange Marmalade, *Heliconia orthotricha* - Macas pink, *Heliconia imbricata x latispatha* -José Abalowere evaluated for growth, flowering and post harvest characters as well as landscape and commercial uses.Variety Red Wingswas superior in terms ofvegetativecharacters like plant height, spread, leaf length and breadth. Petiole length was more in varieties Red Wings, Halloween, Island Yellow and less in varieties Sassy Pink and Maccas Pink.Number of suckers per clump was maximum in variety Oriole Orange. Flower behaviour was different (seasonal / free flowering) among the varieties. July –November was observed to be the main flowering season in all the varieties. ree flowering was observed in varieties Orange Marmalade, Bucky, Red Wings and Island Yellow.Pendent type of inflorescence was observed in varieties *Heliconia rostrata*, Red Wings and Sexy Pink. Inflorescence was erect in all other varieties. Among erect type spike length was maximum in varieties, Hot rio nights and Halloween(43.42 cm and 43.12 cm respectively) and minimum in variety Sassy Pink(13.67 cm). Maximum length of flower stalk was observed in variety Sassy Pink (53.67). Among pendent type, highest spike length and length of flower stalk were observed in variety Red Wings (71.97 cm and 38 cm).Maximum number of bracts were observed in variety Red Wings (16) .With regard to postharvest characters, fresh weight of the inflorescence was maximum in variety Halloween (137 gm).Vase life was maximum(9 days) in varieties Emarald Forest, Jose Abalo, Kamehameha, Halloween, Island Yellow and Oriole Orange. Based on their performance identified heliconias for various purposes.Flowers of varietiesEmarald Forest, Kamehameha, Halloween and Island Yellow can be recommended as cut flower for export. Varieties Bucky, Oriole Orange,Orange Marmalade, Sassy Pink, Hot rio nights and Yamakawa Chocolate have flowers suitable as cut flower for local markets.In landscapes, varietiesOriole Orange, Orange Marmalade and Bucky can be recommended as pot plants, for corner planting etc. and Halloween, Red wings, Hot rio nights, Kamehameha and Emarald Forest for screening purpose in gardens.

## 9. Collection and evaluation of fillers – AICRP

The objective of the study was to evaluate the performance of fillers and to identify those that can be recommended for commercial cultivation in the region. Eleven species of ferns belonging to different genera viz;*Adiantum tenerum, Asplenium nidus, Asplenium longissimum, Asplenium scolopendrium, Diaplazium acrostichoides, Nephrolepis biserrata* 'Furcans', *Nephrolepis exaltata* 'Chidisii', *Nephrolepis exaltata* Botoniensis Compacta, *Nephrolepis cordifolia, Nephrolepis biserrata- Miniata* and *Pteris ensiformis* were evaluated for based on their growth pattern and other attributes for various landscape and commercial uses during 2016-17. Vegetative characters like plant height and spread was more in *Asplenium nidus* and maximum number of leaves were observed in *Adiantum tenerum*. Based on growth pattern they were classified into tall, medium and dwarf. All species evaluated were found to be suitable as pot plants. *Nephrolepis biserrata-Miniata, Nephrolepis biserrata* 'Furcans', *Nephrolepis cordifolia, Asplenium nidus* and *Diaplazium acrostichoides* can be recommended as indoor plants. *Nephrolepis biserrata-Miniata, Nephrolepis biserrata* 'Furcans' and *Nephrolepis cordifolia* can

be used as border plants in landscapes. *Nephrolepis exaltata* Botoniensis Compacta, *Asplenium longissimum, Pteris ensiformis* were observed to be attractive in hanging baskets. *Nephrolepis biserrata-Miniata, Nephrolepis exaltata* 'Chidisii', *Nephrolepis exaltata* Botoniensis Compacta and *Diaplazium acrostichoides* are suitable for bouquet and making in flower arrangements

**10. Effect of organic supplements on growth and flowering of Orchids– AICRP**

The objective of the experiment was to study the influence of different organic manures on growth, flowering and post harvest characters of orchid. The experiment consisted of seven different treatment combinations of organic manures with three replications in CRD. *Dendrobium* variety Burana Jade was used for the study. There was no significant effect for any of the treatments with respect to vegetative as well as floral characters.

**11. Effect of biofertilizers on growth and flowering of Orchids– AICRP**

The study aimed to evaluate the effect of bio fertilizers on growth and flowering of orchids. The experiment consisted of nine different treatments with three replications in CRD. *Dendrobium* variety Ms. Singapore was used for the study. No significantvariation in vegetative parameters could be observed among the treatments. However, a treatment combination of Vermicompost 500 g+ Azospirillum 2g/pot + AMF 2g/pot ($T_6$) was found to be the best for increasing spike length and number of flowers in the spike .

**12. Effect of micronutrients on growth and flowering of Orchids– AICRP**

The experiment was aimed to study the effect of different micronutrients on growth and flowering of orchids. The experiment consisted of thirteen different treatments of micronutrients in various concentrations *Dendrobium* variety Ms. Singapore was used for the study.There was no significant variation in vegetative as well as floral characters during the period of observation. However fortnightly application of Zn @0.05ppm along with weekly spray of NPK @ 30:10:10 was observed effective for improving quality of spikes when compared to other treatments.

**13. Efficacy of media incorporated with Pusa hydrogel on growth and production of quality foliage plants – AICRP**

The experiment intended to assess the efficacy of Pusa hydrogel incorporated in potting media on the quality and performance of *Philodendron xanady*, a foliage plant suitable for both as cut foliage and indoors. Physico chemical characters of the media were observed before planting. Four different levels of Pusa hydrogel (10, 20, 30 and 40 g/pot containing 5 Kg media) were applied. Irrigation was given at four and seven days intervals for each level of pusa hydrogel. Plant characters were observed at monthly intervals. From the analysis of vegetative characters, it could be observed that media incorporated with 30 g Pusa Hydrogel per 5 Kg potting media with four days irrigation interval was found to maintain compactgrowth in *Philodendronxanadu*.

**14. Standardization of glycerinization for increasing shelf life of cut foliages – AICRP**

The experiment aimed to standardize optimum concentration of glycerine solution for increasing shelf life of cut foliage leaves. Leaves *of Cordyline terminalis* was subjected to uptake method with 10%, 20 % and 40 % glycerine solution. Overall acceptance in terms of texture, brittleness, shape, colour retention and glossiness were significantly high in 40 % glycerine solution with a score of 15.90 out of 20.

## 15. Effect of holding solutions on keeping quality of orchid stems– AICRP

The objective of this experiment was to standardize a suitable holding solution for orchids. The experiment consisted of five different treatments *viz*., Control - Distilled water ($T_1$), Sucrose (4%) + 8HQS (100ppm) + Citric acid (150ppm) ($T_2$), Glucose (4%) + 8HQS (100ppm) + Citric acid (150 ppm) ($T_3$), Lime juice (30ml) +Sugar (10g) + NaOCl (0.2% per litre) ($T_4$), Coconut water (50%) + Sucrose (4%) + NaOCl (0.2%)($T_5$). The flower spikes of *Dendrobium* variety Sonia with uniform length and floret number at all bud open stage were harvested and placed immediately in water and then pre-cooled at $12^oC$ for 6hrs.The vase life was evaluated in the above mentioned solutions.The treatment which consisted of Sucrose (4%) + 8HQS (100 ppm) + Citric acid (150ppm) was found to be superior in terms of vase life.

# Project Coordination Group - Aromatic& Medicinal Plants (07)

**Project Coordinator - Dr. Miniraj.N**

**Concluded Projects: 2**
**Ongoing Projects: 9**

## Concluded Projects

### 1. *In vitro* regeneration and conservation of chittamruthu (*Tinospora cordifolia* (Willd.) Miers ex Hook.F.& Thoms)

Single nodal cuttings were used as explants for establishment and multiplication of cultures of *T. cordifolia*. Different combination of cytokinins and auxins were tried for the establishment and multiplication of cultures. Contamination and shoot tip necrosis were the major problems during the establishment of cultures. Contamination could be overcome by surface sterilisation procedures followed by addition of 100 $mgl^{-1}$ of streptomycin sulphate in the media. Shoot tip necrosis could be overcome by the addition of 2.5 $gL^{-1}$ of $CaCl_2$ in the media. A simple protocol with MS (Half strength macronutrients) supplemented with 2 $mgl^{-1}$ BA and 2.5 $gl^{-1}$ $CaCl_2$ could be used for establishment and multiplication cultures. Though *in vitro* rooting treatments did not give efficient rooting, *ex vitro* rooting with pulsing 300 $mgl^{-1}$ NAA for 5 minutes could give efficient rooting. This would effectively reduce the cost of resources and labour involved in *in vitro* rooting and further hardening procedures.

An encapsulation technology for synthesis of artificial seeds/synthetic seeds of *T.cordifolia* has been developed using different combinations of sodium alginate and calcium chloride. Synthetic seeds of *T. cordifolia* using axillary buds of *T. cordifolia* has been developed with liquid MS medium (devoid of $CaCl_2$) supplemented with 3.5% sodium alginate complexed with 75 mM $CaCl_2$. This could be stored under culture room conditions for 4 weeks and under refrigerated condition for 2 weeks. This technology could be utilized for exchange of axenic material between laboratories due to small size and relative ease in handling these structures, or in germplasm conservation with proper preservation techniques.

### 2. Standardization of market oriented production technology of aloe, (*Aloe vera* burm.f.) and promotion of micro-entrepreneurship through value addition

Thirty diverse accessions of aloe were collected from different parts of Kerala and TamilNadu and planted in clay pots filled with potting medium consisting of sand, soil and dried powdered cow dung in the ratio 1:1:1. Evaluation of morphological, anatomical and biochemical characters, leaf and latex yield were carried out one year after planting in the new environment. Accession AV-5 ranked first followed by AV-25, AV-18 andAV-23 for biochemical characters alone and AV-12 ranked first followed by AV-16, AV-13 and AV-6 by considering both morphological and biochemical characters for selection. The accessions AV-16, AV-12, AV-2 and AV-6 were found superior based on morphological characters and morphological and biochemical characters together.

Growth and yield analysis of aloe under different organic nutrient regimes was carried out and the study showed that, application of 37.5kg N in the form of FYM and neemcake in 2:1 ratio along with PGPR mix I ($T_{11}$ - 75 per cent of N as [FYM (50 per cent N) + neem cake (25 per cent N)] + PGPR mix I) was significantly superior in increasing the morphological parameters (plant height, number of leaves, leaf width, thickness and weight) of aloe. The same treatment ($T_{11}$) registered significantly superior fresh leaf yield (4.74 kg $plant^{-1}$ $year^{-1}$), latex yield (18.91 g $plant^{-1}$ $year^{-1}$), improvement in gel quality and highest B;C ratio of 1.8. Application of chemical fertilizers ($T_3$) recorded lesser yields compared to organic manure applied plants.

An experiment was carried out to standardize the stem disc method of macro propagation in aloe. Among the forty eight treatment combinations tried,$T_9$ ($P_1S_3G_1$- *in situ* decapitation, stem segments having three nodes, BA) was the best cost effective treatment with B:C ratio 1.6 for getting higher sprouting percentage, better seedling growth and higher yield characters. By adopting this treatment ($P_1S_3G_1$) within one year nearly 9 suckers can be produced from a single mother plant which is nearly three times higher than the conventional planting material. Hence this method of raising plantlets from aloe stem cuttings can be considered as a rapid method for mass multiplication.

Experiments were conducted for the development of a protocol for the stabilization of fresh aloe gel using different herbal extracts. Fresh aloe gel samples were treated with three forms (decoction, aqueous and alcoholic extracts) of six medicinal plant extracts with reported antioxidant property viz., *Phyllanthus emblica, Curcuma longa, Alpinia calcarata, Glycyrrhiza glabra, Gymnema sylvestre* and *Centella asiatica* in order to find out their efficiency in the stabilization of aloe gel. For standardizing the dosage, 20 ml each of *Aloe vera* juice was treated with graded volumes (1.0ml, 2.0ml, 3.0ml, 4.0ml and 5.0ml) of each form of extract and kept at ambient temperature. Observations on pH, conductivity, T.S.S, vitamin C and microbial load of each sample were recorded at weekly intervals for a period of one month and compared with fresh aloe gel and also with aloe gel treated with a chemical preservative (sodium benzoate) as control. *Aloe vera* gel sample treated with 5ml alcoholic extract of *Gymnema sylvestre, Phyllanthus emblica, Curcuma longa, Alpinia calcarata, Glycyrrhiza glabra,* and *Centella asiatica* could retain the characteristics of fresh gel up to two weeks of storage and was free from microbial contaminants.

Standardized protocols for the manufacture of value added products viz., aloe jam, pickle, ketchup, marmalade, squash, aloe based health drink etc., with reasonable shelf life and with intact active ingredients were developed.

## Ongoing Projects

### 1. Extraction and purification of antioxidant principles from selected medicinal plants

Five extraction techniques were attempted for solvent extraction of antioxidant principles from mango leaf powder and the methods were compared. Soaking in methanol for seven days was found to give comparable yield to Soxhlet extraction for 6.5 hrs, but refluxing with methanol gave highest yield and antioxidant power. Compared to overnight soaking in cold water, extractives yield is higher in decoction of mango leaf powder when boiled continuously for 15 minutes

Extraction Methods devoid of toxic solvents were also attempted. Extraction with ethanol got comparable yield anti-oxidant activity in terms of EC50(µg/g) was higher than methanol.

Dried and finely powdered leaves and roots of *Artanema sesamoides* were sequentially extracted with hexane, chloroform followed by methanol using Soxhlet apparatus for 4 hrs. The methanol extract was subjected to column chromatography over silica gel (100-200 mesh) using isocratic

elution. Pooled column fractions were further subjected to preparative HPLC for the purification of compound

From the mature leaf of *Artanema sesamoides* a compound of molecular mass 594 (ASFP-1) was obtained. On the basis of various spectral analysis (UV, 1D and 2D NMR, Mass and LC-MS/MS) and comparison with the literature, newly isolated compound is identified as Luteolin-7-O-rutinoside**( $C_{27}H_{30}O_{15}$,** Mol mass 594.158**)**. Chemical structure confirmation by C & H NMR has also been done for a few more bioactive compounds i.e., Leucosceptoside A, Martynoside, isoacteoside, Plantainoside C and Artanemoside A isolated from its roots which were earlier tentatively identified based on HRMS, MS/Ms and MSn

Radical scavenging activity of isolated compounds from *Artanema sesamoides* was determined by spectrophotometric method. The activity was measured as percentage inhibition, calculated using the formula: % scavenging = [($A_{control}$-$A_{sample}$)/$A_{control}$] x 100. Ascorbic acid was used as positive control. Experiments were done in triplicate and $IC_{50}$ values were expressed as mean value with standard deviation. Plantainoside C recorded highest $IC_{50}$ value of 113.0±1.45 (µg/ml) followed by Luteolin 7-rutinoside (109.24±11.42 µg/ml) and Aratanemoside A (78.98±0.2 µg/ml)

Quantitative estimation of antioxidant compounds in root and leaf dry powder was done using pure compounds by HPLC method. The root powder contains Acteoside (ASRTF -11) 0.80%, Isoacteoside (ASRTF- 12) 0.31 %, Leucoseptoside A (ASRTF 14) 0.68%, Artanemoside A (ASRTF 21) 1.68%, Plantainoside C (ASRTF 16) 0.12%, and Martynoside (ASRTF 02) 0.1%. The leaf powder contains Luteolin 7-rutinoside (ASFP-1) 0.19%, Acteoside (ASRTF -11) 0.85% and Artanemoside A (ASRTF 21) 9.3%.

## 2. Evaluation of antioxidant activity, cytotoxicity and phenol composition of selected anti-inflammatory plants

Studies on *in vitro* screening against *Ralstonia solanacearum* was carried out. Extraction from dry raw drug powder was done with10 x volume of 90 % methanol for seven days with occasional agitation. The extractives were dried using rotary evaporator and tested against plant pathogenic bacteria, *Ralstonia solanacearum*. Antibacterial Assay was done using Mueller Hinton Agar medium. Assay was done by Disc diffusion method. Methanolic extractives of 30 plants (70 plant parts) were tested of which, 7 extractives showed activity against *Ralstonia solanacearum* at 500 ppm & 1000 ppm concentration. The following are the plants the extracts of which showed activity. Roots of *Aristolochia indica,* rhizomes of *Curcuma aromatic, Curcuma longa, Cyclea peltata,* aerial part of *Datura metel,* fruit of *Garcinia gummi-gutta,* heartwood and leaves of *Caesalpinia sappan* showed antibacterial activity.

Sequential methanolic extractives of *Curcuma angustifolia*, *Acorus calamus*, *Clerodendrum serrate, Bacopa monnieri* and *Momordica charantia* were screened *in vitro* against *Meloidogyne incognita* isolated from banana with 10 nematodes per replication per treatment and with three replications at 100, 200 and 400 ppm concentrations. Observations were recorded at 48 and 72 hours after treatment. *Acorus calamus*, *Bacopa monnieri* and *Momordica charantia* showed high activity against nematodes compared to other extracts. 87.5 % mortality of the nematode was observed in treatment having a concentration of 400 ppm *Acorus calamus* methanolic extractives followed by 60 % in 200 ppm *Acorus calamus* methanolic extractives at 72 h after treatment.

Fractionation and general toxicity evaluation of *Clerodendron serratum* was studied. Sequential methanolic extract (Soxhlet method) of *Clerodendron serratum* root powder showed high general toxicity in brine shrimp assay compared to other extracts. Soxhlet sequential methanolic extract was then separated by silica column chromatography and column fractions were collected and pooled according to the TLC profile into three C1, C2 & C3 and these pooled fractions were tested for general toxicity. One of the three fractions *i.e.*, C2 revealed high lethality in brine shrimp; but when further sub fractionated by preparative HPLC, all subfractions lost activity and on reconstitution by pooling again lethality was restored partially indicating loss of activity when singled out.

## 3. Collection, maintenance and evaluation of germplasm of medicinal and aromatic plants

The existing valuable germplasm collection of aromatic and medicinal plant species maintained and it serves as a demonstration unit. Large number of visitors including students, researchers, farmers and general public make use of the facility. Seeds and planting materials as well as crude drugs were made available from this source. The programme on enrichment of the collection by adding newer species of rare and endangered plants is continuing. Photo documentation of plants as well as observation on their growth and characteristic is continued. Generated information on seed germination, dormancy, viability, vegetative propagation methods of a number of medicinal and aromatic plants.

**Seed treatment techniques were standardised for the following plants.**

1. Hot water treatment: Orila, Moovila , Putharichunda, Cheruvazhuthina, arayal, athi, peral, satavari
2. Dipping in Boiled water: Neelamari, Kurumthotti, idampiri valampiri
3. Con. Sulphuric acid treatment: Manchadi, Kanikonna
4. Soaking seeds in cold water for 7 days: Thanni

## 4. Evaluation of vetiver (*Vetiveria zizanioides*) accessions for superior genotypes - Plan

***a. Non flowering and vigorously growing types – suitable in soil conservation***

29 accessions of vetiver were evaluated for identification of superior genotypes. The accessions showed variation with respect to flowering habit and growth parameters. Ecotypes with better tillering ability, root spread and non-flowering character are considered suitable for hedge planting and in soil conservation programmes. Flowering and seed set can result in spread of the species to neighbouring fields.

Results of the three year observations confirmed that, out of the 29 accessions, Accessions 7, 27 and 31 are non-flowering. Out of these three, Accession -7 was superior with average annual tiller production of 26 tillers /hill and root biomass 102.5 g/hill. Hence Accession - 7 is identified as a non-flowering type of vetiver specifically suited for hedge planting in soil conservation systems.

In the 39$^{th}$ Zonal Research and Extension Advisory Committee meeting of Central zone held at RARS, Pattambi on 28-07-2017, the accession was recommended for POP workshop and it was proposed that demonstration of the type can be undertaken in KAU stations. Accordingly, the

accession was given for multilocational testing at ARS, Chalakudy, ARS, Mannuthy and AICRP (M&AP).

***b. Types with high root and oil yield-*** Evaluation of the accessions is continued to identify types with high root and oil yield.

**b. Demonstration trial of selected vetiver accessions in the coastal sandy tracts of Kerala (Chavakkad & Ponnani Taluks) for identifying superior types suited to the situation**

A survey was conducted in the area and farmers were identified in Palappetty and Ponnani areas in the coastal vetiver area. The selected accessions based on yield per $100m^2$ (Acc. 7, 24, 27 and 33) were multiplied at AMPRS, Odakkali and planted in large area plots in the field of Sri Haneefa, Mannalamkunnu for further evaluation.

## 5. Propagation techniques and *ex situ* conservation of *Coscinium fenestratum* (Gaertn.) Colebr. - an endangered medicinal plant

**A. Collection and *ex situ* conservation of lines/land races from Western Ghats region of Kerala**

Surveys were conducted at Western Ghats region of Kerala. Appropriate site supporting viable populations of the species were located, and the location monitored in order to collect seeds and other reproductive plant parts at the optimum stage of maturity in suitable season. None of the identified plants flowered during this period. Plants collected from the forest were established in the nursery. It is a slow growing plant and will take minimum of one year for transplanting to the field. Representative sample from each location were planted in the field as an *ex vitro* conservatory for the species.

**B. Studies on morphology and floral biology of the domesticated plant**

Studies on flowering behavior, seed structure, dormancy, germination, seed viability of the domesticated plants were undertaken and observations were completed for two seasons. The quantitative characters of stem of the male and female plants showed no significant difference. The type of inflorescence in *Coscinium fenestratum* was found to be a compound raceme, with the globose heads borne on long peduncle developing on old leafless stems in the axils of fallen leaves as cauliflorous clusters. The female inflorescence (11.13 cm) was observed to be longer than the male inflorescence (7.15 cm) showing a significant difference.

Studies on reproductive biology revealed that the flowering season of male plant was noticed from late August to late February with the peak anthesis between 7.00 a.m. - 8.00 a.m. Anther dehiscence was found to occur for a period of 20 and a half hours. The flowering season of female plant was observed from early October to mid-March with the peak anthesis between 7.00 a.m. - 11.00 a.m. The stigma was seen receptive for a period of 26-28 hours. *Coscinium fenestratum* is anemophilous with a pollen fertility of 57.45%. The pollen diameter and exine thickness were measured as 68.95 µm and 5.56 µm respectively.

**C. Standardisation of différent conventionnel propagation techniques and micro propagation technique**

**1. Conventional propagation techniques**

**A. Cuttings:** Vegetative propagation of *Coscinium fenestratum* through cuttings was commonly not effective. Mature hardwood stem cuttings of brownish black colour and about

25cm were used for vegetative propagation. Three different treatments were tried with IBA 100ppm, cow dung and cow urine for root induction. In each treatment, cuttings were dipped for 15 minutes and then planted in polybags filled with different potting media. Among the treatments, cuttings planted in Sand + Coir pith + cow dung + soil(1:1:1:1) after cowdung dip showed root induction and was found during September- October.

**B. Air layering:** Vegetative propagation of *Coscinium fenestratum* through air layering was found to be successful. One year old brown coloured axillary branches of 1cm thickness were selected for air layering. The bark of inter nodal region was removed and tied with potting media. Root initiation depends on the prevailing climate condition. Usually it takes about 7 -9 months. Favorable season for air layering was noted during the period of December to January.

**C. Seed propagation:** In seed propagation, mature fruits of 7 month age were collected and then seeds were obtained after removing the fruit pulp and then thoroughly washed. Later these were dried and then manually scarified. These scarified seeds were later tried with different seed treatments for better germination. Among these treatments $GA_3$ 4000ppm proved to be the best with maximum germination percentage.

**2. Micro propagation technique**

**A. *In vitro* seed propogation. :** Media composition and seed sterilization technique were standardized for the *in vitro* germination of seeds. Media composed of sterile sand found to be the best medium compared to MS basal media recorded a germination percentage of 20%.

**B. Organogenesis:** Different media composition and explants were tried. Cultures without contamination were obtained. It is a slow growing and low response species under natural condition. The same will be shown under i*n vitro* condition also. Among the different media tried for culture establishment, full MS media supplemented with growth regulators kinetin 0.2 ppm and 0.4 ppm proved to be the best with maximum (60%) culture establishment. The period for culture establishment and shoot induction was found to be minimum in these media and also showed a high percentage of leaf emergences.

## 6. AICRP on medicinal plants- PGR management (PGR collection, evaluation, registration and others)

Centre maintains a herbal garden with 400 numbers of medicinal plants including rare and endangered plants endemic to Western Ghats.

**Germplasm maintained in the centre - 7 species as below**

| Sl.No | Common Name | Scientific Name | No: of Accessions | IC numbers |
|---|---|---|---|---|
| 1. | Long pepper | *Piper longum* | 25 | IC 612534 - 612558 |
| 2. | Chitrak | *Plumbago rosea* | 25 | IC 566499 - 566523 |
| 3. | Asoka | *Saraca asoca* | 42 | IC 566454 - 566498 |
| 4. | Brahmi | *Bacopa monnieri* | 29 | IC 566427 - 266455 |
| 5. | Neelamari | *Indigofera tinctoria* | 21 | IC 0613875 - 0613895 |
| 6. | Kattupadavalam | *Trichosanthes cucumerina* | 19 | N/06-141 – IC255388 |
| 7. | Orila | *Desmodium gangetium* | 25 | |

## 7. AICRP on Medicinal plants- crop improvement (entries for MLT, varieties released and others)

**1. Variety released**

*Plumbago rosea* accession TCRPR 521, with high root yield and moderate plumbagin content recommended for variety release in the name SWATHI by the Kerala State Variety Evaluation Committee in this year .

**MULTI LOCATIONAL TRIALS**

**A) Evaluation of promising lines of Lal Chitrak (*Plumbago rosea* ) in MLT**

Plant propagules of two high yielding lines of *Plumbago rosea* identified - TCRPR 516 and TCRPR 521 along with two local checks are under evaluation in MLT by the participating centers *viz*; TNAU and VR Gudam

**B). MLT Evaluation of promising lines from other centres**

**1.Kalmegh (*Andrographis paniculata*)**

MLT evaluation of promising lines of Kalmegh (*Andrographis paniculata)* for high yield and quality was done with 39 entries (AK 1 to AK 39) obtained from DMAPR. Observations on yield parameters like plant height, plant spread, days to reproductive phase, days to 50% flowering, number of primary branches/plant, leaf length, leaf width, leaf/ stem ratio, leaf yield, length of the spike and biomass yield were taken. Entries AK 18 (6408 kg/ha) and AK 9 (6264 kg/ha) performed well with respect to biomass yield under our conditions. Data sheet and dried plant samples were sent to DMAPR for chemical analysis as per the directions.

**2. Long pepper (*Piper longum*)**

Evaluation of promising lines of long pepper was done with three accessions (ALP 01, ALP 02and ALP 03). The observations on morphological and yield parameters like leaf length, leaf breadth, length/breadth, leaf tip, leaf margin, leaf base, leaf colour, internodal length, catkin number, catkin length, catkin breadth, catkin colour and piperine content recorded and data sheet submitted to DMAPR.

**3. Bach (*Acorus calamus*)**

Evaluation of promising accessions of bach (*Acorus calamus*) was done with five entries (AC 01 to AC 05) in 4 replications in a randomized block design. The data recorded on yield attributes like plant height, number of leaves/plant, rhizome weight (g/plant), rhizome length (cm) and rhizome diameter.

**Other crop improvement programmes**

1. **Characterisation and evaluation of *Desmodium gangeticum* germplasm :** Twenty five accessions of *Desmodium gangeticum* were evaluated for morphological and yield parameters. Variations noticed in morphological as well as yield attributes. Biometric observations include plant height, shoot weight, root length, root thickness, number of roots and root weight. Majority of the accessions are medium tall. Among the twenty five accessions tested TCR DG 9, TCR DG 12, TCR DG 14 and TCR DG 24 recorded superior root yield. Experiment is continuing.
2. **Development of DUS descriptors for Lal chitrak (*Plumbago rosea*):** Twenty five accessions of *Plumbago rosea* maintained at the centre were evaluated for morphological and biometric characters. Variations noticed on biometric and morphological characters. Experiment is continuing for flower and root characters

3. **Development of DUS descriptors for Neelamari (*Indigofera tinctoria*) :** The experiment to develop DUS descriptor for the 21 available accessions of *Indigofera tinctoria* in the centre was started during 2015-16. Observations were recorded on general growth characters, leaf characters, inflorescence and flower characters, pod and seed characters, yield and quality characters. Variations noticed in plant height, canopy spread, number of branches, leaflet shape, leaflet base, leaflet colour, leaflet size, indican content, herbage yield, length of inflorescence, number of flowers/ inflorescence, flower colour, number of pods/ panicle and pod shape. Based on these characters the accessions were grouped.

4. **Reproductive biology and pollination studies of bitter snake gourd (*Trichosanthes cucumerina)***

   *Trichosanthes cucumerina* is a highly cross pollinated monoecious vine, entomophilous and honey bees as pollinating agents. Pollination studies were conducted during rainy, summer and winter seasons. Artificial pollination was done by hand. On each plant half the numberof pistillate flowers available were artificially pollinated by hand. Half retained as such for natural pollination. Fruits harvested separately in artificial and natural pollination. Artificial pollination yielded 25.9, 27.6 and 17.1 percent more number of fruits than natural pollination during rainy, summer and winter season respectively.

5. **Development of minimum seed certification standards**

   Minimum clone certification standards of three important medicinal plants (*Saraca asoca*, *Piper longum* and *Plumbago rosea*) of Kerala developed

<table>
<tr><td>Specifications</td><td>Saraca asoca</td><td>Piper longum</td><td>Plumbago rosea</td></tr>
<tr><td>Propagules</td><td>Air layers</td><td>2,3 noded semi hardwood stem cuttings</td><td>2,3 noded semi hardwood stem cuttings</td></tr>
<tr><td rowspan="2">Land Requirements</td><td colspan="3">Free from volunteer plants , Avoid ill drained soils</td></tr>
<tr><td>-</td><td>Provide 30% shade</td><td>Provide 25% shade</td></tr>
<tr><td>Mother Plant</td><td colspan="3">• Should be healthy, true to type and free from pests and diseases<br>• Should be certified for the specific varietal characters by the Certifying Agency<br>• Two/four inspections shall be made for morphological characters, health, genetic purity and pests and diseases</td></tr>
<tr><td>Important diseases</td><td>Die back</td><td>Leaf spot, Leaf blight, Nematodes , Mealy bug, Virus</td><td>Leaf blight, Damping off</td></tr>
<tr><td colspan="4">Foundation clone - Field standards</td></tr>
<tr><td>Isolation</td><td colspan="3">• Fields of other varieties (5m)<br>• Fields of the same variety not conforming to varietal purity requirement for certification (5m)</td></tr>
<tr><td>Spacing</td><td>0.75 m x 1.50 m</td><td>0.5 m x 0.5 m</td><td>0.5 m x 0.5 m</td></tr>
<tr><td>Rotation</td><td colspan="3">Should be rotated to other plots every three years</td></tr>
</table>

| | | | |
|---|---|---|---|
| Specific Requirement | • Off-types maximum (0.1%)<br>• Infested with die back (None) | • Off-types (0.1- 0.2)<br>• Symptoms of leaf spot & leaf blight (0.1 -0.5)<br>• Plants infested with nematodes, mealy bug and virus (None) | • Off-types maximum (0.1%)<br>• Symptoms of leaf blight and die back (None) |
| Size and age of the planting stakes from which cuttings / layers are taken | 6 to 9 months | 7 to 12 months | 12 to 15 months |
| Certified clone standards | • Diameter of layer : 1.0-1.5cm at 10 cm above ground level<br>• Height of the layers:30-50cm | • Diameter of the stem : 0.3 - 0.5 cm<br>• Length of the stem : 6 - 10 cm<br>• No. of nodes : 2-3 | • Diameter of the stem : 0.3 - 0.5 cm<br>• Length of the stem : 20 – 30 cm<br>• No. of nodes : 2-3 |

## 8. AICRP on Medicinal plants- crop production

**Technology recommended for PoP :** Shade requirement for *Indigofera tinctoria* (25 per cent shade to open condition ideal for better yield and quality)

**1. Integrated nutrient management for higher yield and quality of *Indigofera tinctoria***

From the results of three years of experiment, application of FYM 5 t/ha + NPK @ 45:60:45kg/ha can be recommended for better herbage yield, indican yield and B:C ratio. Manurial management with FYM 10 t/ha + NPK @ 45:60:45kg/ha was the next best alternative for better B:C ratio. Compared to plots with integrated nutrient management, the yield recorded from the plants which received inorganic fertilizers alone or farmyard manure alone was very low.

**2. Effect of method of crop establishment and shade level on yield and quality of *Desmodium gangeticum* (Orila)**

The root yield per plant and per hectare was highest when the crop was transplanted under 75 per cent shaded condition. Growing plants under 50 per cent shaded condition by transplanting was the next best alternative for higher root yield.

**3. Standardization of organic production technology for kalmegh**

Combination of farm yard manure with biofertilsers and jivamrut gave higher yield 4173 and 4387 kg/ha during first and second year of study. Among integrated nutrient managed plots combination of NPK at 80:40:20 kg/ha along with biofertilisers and jivamrut gave higher herbage yields. Total alkaloid content was higher in treatment combinations with farm yard manure followed by combinations with castor cake during both the years, while application of vermi compost resulted in lower total alkaloid.

**4. Standardization of organic farming practices for acorus**

The plants which received FYM @ 15 t/ha gave the highest rhizome yield of 1428 kg/ha during first year and 1573 kg/ha during second year. It was on par with vermi compost @ 7.5 t/ha. The plants which received fertilizer NPK @ 45:12.5:12.5 kg/ha recorded the highest rhizome yield of 1772 kg/ha during first year and 1944 kg/ha during second year.

**5. Studies the performance analysis of medicinal plants under banana plantation**

Medicinal plants, *neel* and *bala* performed well under banana intercropping system without any negative effect on yield of either main or intercrop

## 9. Phytochemistry

**1. Experiment title: Comparative quality evaluation of different *Tinospora* species found in Kerala**

Three different *Tinospora* species are commonly found in Kerala namely *Tinospora cordifolia, Tinospora malabarica and Tinospora crispa.* They were collected and grown in our experimental field. The external appearance and morphology of *T. cordifolia and T. malabarica* are almost alike but the stem and leaves of *T. malabarica* are bigger in size. Scanty tubercle protuberances are more in the papery bark of *T. malabarica* compared to *T. cordifolia.* In the very young stage, morphological differentiation is difficult. In the case of *T. crispa* the stem bark is crowded with large blunt protuberances even in very young stages of the plant, hence morphological identification is very easy in *T. crispa*. *T. cordifolia* is found in wide distribution while *T. crispa* and *T. malabarica* are wild and found in limited areas. *T. cordifolia* is preferred by ayurvedic practitioners of Kerala.

The comparative study of three different species showed marked variation in antioxidant activity (AOA), berberine content (active ingredient) and fibre content also. *T. crispa* showed very high AOA and phenol content followed by *T. cordifolia*. Berberine was found more in *T. malabarica* compared to *T. cordifolia*. Berberine was not detected in *T. crispa*. GCMSD analysis also showed variation in the chemical profile of three different species. HPTLC and TLC profiles of these three species reflected variations in chemical composition. Heavy metal analysis of the samples was carried out using ICP-AES method. All three species were free of heavy metals arsenic, cobalt, molybdenum and cadmium whereas the iron, lead, nickel and chromium were found in traces but more in *T. malabarica* followed *by T. crispa*. GCMSD analysis showed variation in the chemical profile of three different species.

Total antioxidant activity and total phenol content was higher in *T. crispa* 12.78 mg AA /g, and 59.71 mg TA/g respectively. Crude fibre content was 24% *T. cordifolia*, 22% for *T. malabarica* and 20 % for *T. crispa.* Berberine content was 0.19% and 0.22 % in *T. cordifolia* and *T. malabarica* respectively. In *T. crispa*, no beriberine was detected.

**2. Quality assessment of traded crude drug *Tinospora* from different markets of Kerala**

Market samples of *Tinospora* raw herbal drug (30 numbers) were collected from various markets of Kerala. Genuine samples of three different *Tinospora* species were also collected from the campus and identified and used for the study as reference standards. Stem samples were used for analysis. A reference TLC fingerprint was developed with genuine samples of three different species of *Tinospora* (chloroform, methanol in Silica gel $60F_{254}$, UV-L). The TLC fingerprints of market samples developed in the same way were compared with the reference

fingerprints to assess the genuineness of the market samples. The result revealed that out of thirty samples analysed so far, 28 samples were found to be that of true type *i.e. T. cordifolia* and the rest two were of *T. malabarica.* No samples proved to be *T. crispa*. This shows that though *T. cordifolia* is preferred by ayurvedic practitioners of Kerala, if not available, *T. malabarica* is used instead as an alternate drug.

# Project Coordination Group - Biotechnology, Biochemistry, Plant Physiology (08)

**Project Coordinator - Dr. M.R Shylaja**

**Concluded Projects: 45**
**Ongoing Projects: 58**

## Concluded Projects

### 1. Accelerated breeding of anthracnose resistance in vegetable cowpea through molecular marker assisted selection

The semi-trailing type vegetable cowpea cv. Kanakamony which is resistant to anthracnose was crossed with susceptible and pole type cv. Sharika. Markers for anthracnose resistance were identified using the $F_3$ population of Sharika X Kanakamony, through BSA. RAPD primer OPA02 and ISSR primers UBC810 and UBC811 have differentiated susceptible as well as resistant genomes. UBC811 marker was anchored on LRR receptor-like serine/threonine protein kinase gene which could be involved in the resistance mechanism. The long poded (>35.0 cm) $F_3$ plants with combined resistance to Cowpea mosaic virus and anthracnose were backcrossed with recurrent parent Sharika. Promising crosses were subjected to background selection using 50 SSR markers. From the BC3F1 population, the lines 10A, 10B and 10D were found to have promising agronomic characters with combined resistance to cowpea mosaic virus as well as anthracnose. The resistance of these lines was confirmed using the UBC811 marker. These lines were selfed to obtain BC3F3 non-segregating and high yielding population with combined resistance.

### 2. Characterization and validation of microsatellite markers for resistance to vascular streak dieback disease in cocoa (*Theobroma cacao* L.)

Twenty resistant and four susceptible genotypes of cocoa were screened using ISSR and SSR markers. BLASTn of UBC811A and UBC811D ISSR nucleotide sequences revealed resistance locus situated in the chromosome V of *Theobroma cacao* genome. BLASTn of ISSR sequence UBC 826A, UBC826B and UBC857 had positioned the resistance loci in chromosome III. ISSR markers UBC 811, UBC 815, UBC 826, and UBC 857 were present in twenty resistant lines but was absent in four susceptible lines. These markers were found to be successful in differentiating resistant and susceptible genotypes of cocoa.

### 3. Validation of molecular markers linked with bacterial wilt resistance in chilli (*Capsicum annuum* L. )

Varieties Ujwala, Anugraha, Pusa Jwala and $F_2$ generation of cross Anugraha X Pusa Jwala were genotyped using RAPD, SCAR, AFLP and SSR primers. Validation of marker linkage with bacterial wilt resistance are checked with BSA. Polymorphism was obtained with RAPD primer was eluted, reamplified and sequenced. *In silico* analysis with BLASTn and BLASTp was done.

### 4. Validation of genes for water stress in rice (*Oryza sativa* L.) mediated by *Pseudomonas fluorescens*

The high yielding rice variety Matta Thriveni (PTB 45) was used with three different treatments Absolute control (T1), water stressed (T2) and water stressed for which *Pseudomonas fluerscence* KAU strain *PfI* was applied (T3). Biometric parameters were measured in three treatments. Significant increase in shoot length, root length, fresh weight, dry weight, yield and 1000 g seed weight was found in T1 plants followed by T3 and T2 . Six differentially expressed genes such as *COI (Cytochrome oxidase c subunit I), PKDP (Protin Kinase Domain containing Protein), bZIPI (basic leucine zipper I), AP2-EREBP (APETALA-Ethylene responsive binding*

*proteins), Hsp 20 (Heat shock protein 20) and COCI (Circadian oscillator component)* were analyzed using real-time PCR. *COI, PKDP, bZIPI, AP2-EREBP, Hsp20* and *COCI* genes were found to have 2.3, 2, 6, 2.8, 4.5 and 4 fold increase in relative expression levels respectively in T3 as compared to control. The results revealed that WRKY, MYB, HSF, bZIP, ARF, AP2/EREBP, bHLH, Trihelix and ABI3/VP1 TF families and their respective regulatory elements were predicted as functionally significant Transcription factor (TF) binding sites.

## 5. Synseed production, in vitro conservation and plant conversion in banana

Standardised the protocol for synseed production in banana variety Nendran and optimised the *in vitro* conservation procedure for getting maximum conversion to whole plants. Beads encapsulated with 4per cent sodium alginate and 100mM calcium chloride gave 66.6 per cent regeneration. The encapsulated shoot tips could be regenerated after 8 weeks of storage at $25^0$C.

## 6. *In- vitro* selection for drought tolerance in black pepper (*Piper nigrum* L.)

The objective was to develop drought tolerance in black pepper var. Panniyur 4 by *in vitro* selection using polyethylene glycol and to characterize the tolerance. The callus survived upto 10 g $L^{-1}$ of PEG. The PEG tolerant calli showed drought tolerance characteristics such as increased proline, soluble proteins and ascorbic acid content as compared to control. RT-PCR analysis showed high expression of *p5cs* (Pyrroline-5-carboxylate synthase) gene in the PEG tolerant calli.

## 7. *In vitro* conservation of chethikoduveli *(Plumbago rosea* L.*)* using encapsulation and vitrification techniques

Protocols were standardized for short term conservation of *Plumbago rosea* using encapsulation technique, long term conservation of *P. rosea* using vitrification techniques of cryopreservation and genetic fidelity of recovered and regenerated plantlets were assessed using molecular markers. In short term conservation, maximum regeneration response after 30 days of storage was obtained with mannitol 10 per cent in encapsulation matrix and liquid MS as storage medium at 25˚C. In simple vitrification and encapsulation vitrification, preconditioned (0.5 M sucrose for 7 days), precultured (0.5 M sucrose for 3days) axillary buds when exposed to vitrification solutions, PVS2 (glycerol 30 per cent, ethylene glycol 15 per cent and DMSO 15 per cent in MS with sucrose 0.4 M, pH 5.7) gave the best response in terms of survival (62.22 per cent) and regeneration (47.78 per cent) on exposure for 30 min after 2 h of cryopreservation *ie.*, storage in liquid nitrogen. The survival and regeneration percentage was found on par with different periods of cryopreservation. Among the cryopreservation treatments, encapsulation vitrification was found to be the best. The ISSR banding profiles generated did not show any polymorphism and was identical to those of control, which indicated the genetic stability of conservation generated plantlets.

## 8. *In vitro* micropropagation protocol for Vanda hybrids with clonal fidelity analysis

Inflorescence segments were the most promising explants for initiating *in vitro* regeneration of two selected *Vanda* hybrids namely Dr. Anek and Sansai Blue. Culture initiation in *Vanda* hybrids were observed in ½ MS + 10 mg $l^{-1}$ BA + 2 mg $l^{-1}$ TDZ + 30 g $l^{-1}$ sucrose + 7.5 $l^{-1}$ agar + 250 mg $l^{-1}$ cefotaxime with an establishment percentage of 80 per cent in Dr. Anek and 60 per cent in Sansai Blue. The medium for multiplication of the shoots was identified as MS + 4.5 mg

$l^{-1}$ BA + 30 $gl^{-1}$sucrose + 7.5 $gl^{-1}$ agar + 250 mg $l^{-1}$ cefotaxime. The micro-shoots produced in the proliferation medium were successfully elongated in hormone free basal MS medium supplemented with 0.5g $l^{-1}$ charcoal. Rooting of healthy and elongated shoots was about 70 per cent in both hybrids of *Vanda* in MS + 0.5 mg $l^{-1}$ NAA + 1 mg $l^{-1}$ IAA + 30g $l^{-1}$ sucrose solidified on 7.5 g $l^{-1}$ agar and fortified with 250 mg $l^{-1}$ cefotaxime. Survival of *in vitro* regenerated *Vanda* plantlets during hardening was 100 per cent in earthen pots with charcoal, coconut husk and brick pieces in 50 per cent shade house. The ISSR primers UBC 808, UBC 811, UBC 826, UBC 835 and UBC 841 were used for genetic stability analysis of *Vanda* hybrids in micropropagation.

## 9. Molecular characterization of katte mosaic virus of cardamom (*Elletteria cardamomum* Maton)

Samples collected from Wayanad and Idukki district of Kerala was used for the study. Protocol for isolation and purification of the virus from the infected leaf samples was standardized and showed 37kDa band in SDS-PAGE analysis. The polyclonal antibody was raised against *Katta mosaic virus* in rabbit and used for detection of *Katte mosaic virus*. The antibody titre was determined using ODD assay and observed that 1:10, 1:100 and 1:150 dilution of primary antibody showed positive reaction with *Katte mosaic virus* coat protein. The *Katte mosaic* virus was detected using indirect ELISA and result showed that 1:100 dilution of primary antibody and 1:200 dilutions of secondary antibody conjugated with APS was able to detect the virus in the crude protein extracted from leaf samples. For detection through RT-PCR, total RNA was isolated and converted into cDNA. Primers were designed to amplify the coat protein region of virus using Primer 3 software. Out of 111 primers, 8 were able to amplify the coat protein region of the virus. Primers CP-9, 10 and 11 were found best for characterization of *Katte mosaic virus. In-silico analysis* showed 80-90 percent similarity with Indian cardamom mosaic virus and phylogenetic analysis revealed that there is no variation in the isolates collected from Wayanad and Idukki district of Kerala.

## 10. Development of a nano biosensor for detection of bract mosaic virus in banana (*Musa* spp.)

For the development of nanobiosensor, gold nanorods (GNRs) at an aspect ratio of 3.03nm synthesized and characteristic features of Gold nanorods were revealed by UV-Vis spectrophotometer and transmission electron microscope (TEM). Antigen of *banana brat mosaic virus* (BBrMV) was added to nanoprobe solution of red colour containing antibody of BBrMV conjugated to Gold nanorods. In the binding process of antigen with nanoprobe, red colour changed to black colour within a period of five minutes and intensity of colour change correlated with concentration of antigen. Examination under UV-Vis spectrophotometer indicated that the original peak of gold nanorods shifted to 700 to 734 nm.

## 11. Development of a nano biosensor for detection of banana bunchy top virus

A solution phase LSPR based gold nanoRod biosensor was developed for the easy and quick detection of banana bunchy top virus. Gold nanorods (GNRs) were synthesized using seed mediated growth method and characterization using UV-Vis spectrophotometry showed two

absorption peaks *viz*., longitudinal plasmon band (LPB) at 679 nm and transverse Plasmon band (TPB) at 515 nm. Surface modification of CTAB capped GNRs was done by ligand exchange method. Functionalization of GNRs with BBTV specific antibody was undertaken by conjugating the antibody with GNRs to make a GNR probe. The interaction of GNR probe with antigen from BBTV infected banana plants characterized using UV-Vis spectrophotometry showed peak shifts and difference in absorption spectrum from plain GNRs solution. The interaction of GNR probe with antigen from infected banana samples also exhibited colour change while no such colour change was notified in healthy samples.

## 12. Molecular cloning and characterization of coat protein gene of banana bract mosaic virus

RT-PCR amplification of coat protein gene was done using gene specific reported primer (B1/B2) and designed primer (BCPF1/R1) which yielded amplicons of size ˜605bp and ˜850bp respectively. Molecular cloning of CP gene was done in *Escherichia coli* (DH5-alpha) and the presences of gene insert in transformed colonies were confirmed by colony PCR. The phylogenetic analysis by the alignment of CP gene sequences of 23 isolates revealed that the present isolate was more similar to KER2 isolate (Kasaragod) and the Indian isolates did not show any relationship based on geographical origin.

## 13. Molecular characterization of candidate gene for pungency in *Capsicum* spp.

SCAR molecular markers specific to pungency character in chilli were used to characterize five pungent and five non-pungent genotypes. The *PunI* specific primers MAPIF/R, *Punl*$^{1}$*fwdl/rev, Punl*$^{3}$*fwd/revl* and *CS* (*Capsaicinoid synthetase*) specific primers CSF1/R2, BF7/R9 were successful to differentiate the pungent and non-pungent genotypes. All the pungency specific markers amplified the regions inside the *Punl* locus because all the loci previously reported for pungency resides there. The markers for pungency from these SCARs were characterized by sequencing. *Punl* locus present in the chromosome 2 of chilli is the major player in regulating the production of capsaicinoids. *CS* gene located inside the *Punl* locus produce capsaicinoid synthetase enzyme needed for the production of capsaicin. Deletion and variation of the sequences inside the *Punl* locus is the reason for varying degree of pungency in different chilli genotypes.

## 14. Molecular docking of antiviral properties of 'paanal', *Glycosmis pentapylla* (Retz.) Correa

*Glycosmis pentaphylla* (Retz.) Correa, locally known as 'panal', was studied for its antiviral properties. The plant material collected was finely powdered, hydroalcoholic extract was prepared and used for LCMS/MS analysis. The mass to charge ratio of various phytocompounds obtained from the LCMS/MS analysis were compared with the masses of phytocompounds reported in literature and these compounds (23 from leaves and 14 from stem and roots) were subjected for the docking studies, using Discovery Studio 4.0. Nineteen proteins responsible for chikungunya, hepatitis, dengue and influenza viral disease were used as targets for molecular docking studies. Phytocompounds were filtered through Lipinski's rule of 5 and Veber's protocol. All 22 ligands from leaf and 13 from stem and roots passed the test indicating that they

have drug likeliness properties. Myricylalcohol failed to pass the test. Out of the total ligands screened, 12 compounds from leaf and 10 from stem and root were identified to be acceptable as drugs with respect to ADMET analysis. Two compounds, isovaleric acid and avicequinone C had shown good interaction with the protein targets of chikungunya, hepatitis, dengue and influenza viral diseases.

### 15. Molecular analysis of phylogeography of cassava mosaic disease

The survey conducted across all districts in Kerala revealed that cassava mosaic disease (CMD) is widespread in Kerala having high symptom severity and increased aggressiveness as compared to earlier years. Maximum intensity of CMD was observed in Wayanad (4.00) followed by Malappuram (3.40), Alappuzha (3.28) and Ernakulam (3.00). Studies using multiplex PCR with all the samples collected during survey showed that SLCMV is widespread in all districts of Kerala while ICMV infection is observed solely as well as combined with SLCMV (mixed infection) in 9 districts namely Thiruvananthapuram, Kollam, Alappuzha, Kottayam, Idukki, Ernakulam, Palakkad, Malappuram and Kasargod. Apart from ICMV and SLCMV, possible occurrence of other cassava mosaic viruses were checked using cassava mosaic Gemini viruses reported in Africa (ACMV, EACMV, Ug-V). Among all, only ACMV (suspected) was detected in samples from Pathanamthitta district. Beta satellite molecules were identified from the Thiruvananthapuram sample having mixed infection, and this may give rise to a situation to increase in disease severity. This is the first report of identification of beta satellite molecules associated with cassava mosaic disease in India.

### 16. Standardisation of virus inoculation method for cassava mosaic disease

The objective of the study was to optimize the virus inoculation procedures for cassava mosaic disease using different methods *viz*., agro-inoculation, biolistic delivery of rolling circle amplification product and white fly transmission. *In vitro* derived virus free cassava plant was used for the study. The protocol involved inoculation of 4-5 leaf stage *N.benthamiana* plants with Agrobacterium strain C58 inoculum, having an initial OD 600 0.5-0.8 and final OD of 4.0 and inoculation at 280c for 6-7 days showed high cassava mosaic virus transmission efficiency in *N.benthamiana* plants 6 days after inoculation, which indicated that this protocol could be used to sceen germplasm for their resistance to cassava mosaic disease.

### 17. Mining of resistance genes associated with anthracnose infection in greater yam (*Dioscorea alata* Linn)

To identify resistant gene analogues (RGA), nucleotide binding site (NBS) type sequences were isolated using degenerate primers. RGS showed similarity to NBS-leucine rich repeat class gene family. Amino acid sequence alignment of the *Diascorea* RGAs grouped them with the non troll interleukin receptor (TIR) subclass of the NBS sequences. Expression profile of RGA'S in tolerant (Sree Keerthi) as well as susceptible (Orissa Elite) genotype in response to anthracnose infection demonstrated that *Dioscorea alata* RGA were upregulated three days after disease inoculation in the tolerant genotype, where as in the susceptible genotype it was observed on the $5^{th}$ day. This is the first report on isolation and expression analysis of *Dioscorea alata* RGAs.

## 18. Genetic diversity analysis of elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson].

Genetic variation in elephant foot yam was analysed the based on morphological and molecular characteristics using twenty- eight accessions from all over the country. Total three clusters were formed in which, cluster I contained only the accession AmH6. Am10 was the only accession in cluster III and all the other accessions were clustered together in Cluster II. Based on the coefficient of variation, the degree of variability was found high for fresh weight of corm, height of corm, length of cormels, number of leaflets, number of corms, number of tertitiary partitions, weight of cormels and number of cormels. The result obtained in the study revealed the level of polymorphism by ISSR primers were very high. An average of 89.21% polymorphism was shown by the primers selected in the study.

## 19. Identification of markers linked to post- harvest physiological deterioration in cassava clones.

The objective was to understand the genetic variability among the PPD resistant and susceptible genotypes and identify the reliable marker linked to PPD resistance. The present study consisted of five PPD resistant and twenty-three PPD susceptible cassava lines. A dinucleotide CA repeat motif (6bp) was identified in the susceptible lines and absent in the five resistant lines, which may be the reason for the difference in polymorphism shown by SSRY 8 marker. This deletion may be due to the change in amino acid sequence conferring resistance to PPD. This unique polymorphism was validated among the five resistant and 23 susceptible lines using DNA-PAGE and the same polymorphism was observed in all genotypes. SSRY 8 marker is a reliable and efficient marker for identification of PPD resistance. Furthermore, sequence based polymorphism was detected producing three potential SNP regions such as two transition SNPs (G-T; C-T) and a transversion SNP (A-T).

## 20. Photosynthesis and enzyme activities regulating starch biosynthesis in different varieties of cassava (*Manihot esculenta* Crantz)

A study on photosynthesis and enzyme activities regulating starch biosynthesis in cassava (*Manihot esculenta* Crantz) was conducted using four varieties/genotypes *viz.*, Sree Vijaya, H165, Sree Athulya and H226. Cassava varieties had shown variation in the morphological and biochemical parameters. Morphological parameters such as number of leaves, leaf area and leaf area index were maximum in the variety Sree Vijaya and minimum in the variety H165. The tuber yield was observed maximum in the variety H226 and minimum in the variety H165. From the study it was observed that the variety Sree Athulya had relatively higher AGPase enzyme activity, SuSy activity, moderate SS activity and lower SPS activity and high starch content in tuber with a total yield of 3.31 kg/plant. The variety H226 has maximum tuber yield and moderate starch content due to decreased SPS activity, moderate AGPase activity and SS activity. The variety H165 had the minimum starch and sucrose content due to decreased SuSy, AGPase activity and SS activity and increased invertase activity. The variety SreeVijaya had the moderate starch content in tuber as it is a short duration variety due to the highest photosynthetic rate, SS activity and moderate AGPase activity.

## 21. Identification of functional markers for thermo sensitive genic male sterile rice (*Oryza sativa* L.)

The main aim of the study was to identify a functional SSR (Simple Sequence Repeats) marker for the selection of progenies obtained from the crosses between Uma and Jyothi with TGMS line (EC720903). The marker identified as RM5897 was situated on chromosome 2 and was very tightly linked to the thermosensitive male sterile gene *tms5*. The identified SSR marker RM5897 is very efficient and it is co-segregating in successive generations.

## 22. Genetic diversity analysis of wild yams of Western Ghats.

The research work aimed to combine morphological, molecular and biochemical data for greater understanding of the extent of genetic variation existing within and among the wild yams species collected from Western Ghats of India. Both ISSR and SSR markers revealed greater similarity of *D. alata* to *D. oppositifolia. D. esculenta (*ISSR*)* and *D. hamiltonni (SSR)* were the divergent wild yams identified in the present study. ISSR data revealed that among the wild yams *Dioscorea vexans* found in Andaman's was a highly divergent one. The cultivated African species *D. rotundata* was highly divergent from wild yams in India. Among the wild yams, *D. pentaphylla* was the highly divergent one. Wild yams are rich in starch, sugar, fibre, fat and protein. The evaluation of nutritive traits in wild yams revealed that *D. belophylla* had higher sugar value than *D. alata*. *D. floribunda and D. bulbifera* had higher protein value than *D. alata. D. belophylla* had higher starch value than *D. alata*.

## 23. Molecular analysis of coconut (*Cocos nucifera* L.) segregants

The major objective of the study was the molecular analysis of coconut genotypes developed from controlled hybridization using RAPD and SSR markers. The experimental material consisted of 120 coconut hybrids in four different controlled pollinations. *i.e.* Komadan x WCT, WCT x Komadan, Komadan x CGD, Komadan x Komadan. Population genetic analysis of RAPD markers revealed the genetic diversity among the four populations. The maximum Nei's gene diversity value was observed in Komadan x CGD population. This indicated that, the population had high genetic diversity. Komadan selfing population showed no genetic diversity. Population genetic analysis of SSR markers revealed the genetic diversity among the four populations. Komadan X CGD population showed high genetic diversity compared to other population because the population exhibited minimum Shannon's index value.

## 24. Photosynthesis and enzyme activities regulating starch biosynthesis in different varieties of sweet potato (*Ipomoea batatas* (L.) Lam.)

Morphological parameters and photosynthetic rate were analysed in four varieties of Sweet potato *viz*., Sree Kanaka, Sree Arun, ST-13 and Kanhangad. Sucrose and starch content were higher in ST-13 and Sree Arun, respectively. Sree Kanaka was observed with relatively higher photosynthetic rate and starch content (13.49±3.04) with a total yield of 0.45 kg/ plant. Enzymes involved in the starch biosynthesis (AGPase, SS, SuSy, SPS and IT) were studied in leaves and tubers of above four varieties. AGPase and SS were more active in tubers and promote tuberization. Invertases were highly active in leaves when compared to tubers. Activities of AGPase were found higher in leaves and tubers of Sree Arun variety and it increased the starch

content or tuber yield in the variety. Higher sucrose and starch accumulation was due to higher photosynthetic rate. It directly influenced the total tuber yield of sweet potato.

### 25. Molecular characterization of cassava chips line CMR-100 and its progenies using SSR markers

The aim of the work was to identify the parents of CMR-100 and to assess the genetic variations among the OP progenies of CMR-100 with selected cassava cultivars using SSR markers. The banding pattern of the alleles in CMR-100, C-129 and C-15 produced by 19 primers were compared for analysing the segregation of alleles. The result showed atleast one of alleles of both C-129 and C-15 were present in CMR-100 in combined form. Two progenies of CMR-100, *viz*., CMR 100/2 and CMR 100/3 were genetically closer to Ambakadan and Narayanakapa. The 3D plot also revealed similar result as in the dendrogram that the progeny CMR 100/60 was genetically closer to CMR-100.

### 26. *Piriformospora indica* mediated response in taro (*Colocasia esculenta* L. Schott) with special emphasis to growth and leaf blight incidence

The objective of the study was to understand the effect of *Piriformospora indica* colonization on growth and leaf blight incidence in taro and to study the differential expression of pathogen related genes in susceptible and tolerant varieties. *P.indica* colonized taro plants were able to delay the onset of leaf blight incidence for a week and could significantly reduce the infection in susceptible as well as tolerant varieties. The differentially expressed genes, which have got functions in the disease defense pathways, were identified. This was the first attempt to exploit the potential of *P.indica* for growth promotion and imparting disease resistance in tropical tuber crops.

### 27. *In vitro* propagation of thermo sensitive genic male sterile rice (*Oryza sativa* L.)

The present study standardized the *in vitro* regeneration protocols for TGMS multiplication through inflorescence nodal segments as explants . This is the first report in male sterile system that utilized nodes of inflorescence as explant for *in vitro* multiplication. Highest shoot induction, shoot length and shoot per culture obtained on MS media supplemented with BA (2mg $L^{-1}$) + NAA (0.5 mg $L^{-1}$).

### 28. Pharmacognostic studies and assessment of anti-inflammatory, antinociceptive, antioxidant potential of 'ellooti' (*Pterospermum rubiginosum* Heyne ex Wt. and Arn.)

Antiinflammatory, antinoeptive, and antioxidant potential of leaves of an ethno medicinal plant *Pterospermum rubiginosum* was evaluated in the present study. Results of the study revealed its significant antioxidant, anti-inflammatory and antinoceptic activities.

### 29. Pharmacognostic studies and evaluation of anti-inflammatory, analgesic and antioxidant potential of 'manjakantha' *Dracaena terniflora* (Roxb.)

Phytochemical screening of roots of *Dracaena terniflora* Roxb, identified the presence of secondary metabolites like phenols, flavonoids, saponins etc. which could be used for various therapeutic efficiency.

## 30. Genetic diversity analysis of greater yam (*Dioscorea alata* L. ) landraces in Kerala

The research work attempted molecular, morphological and biochemical characterization of 45 landraces of *Dioscorea alata* collected from various districts of Kerala. The dry matter percentage ranged from 27.53 to 48.24. The starch content of the accessions ranged from 36.0 to 65.2 and 13.2 to 26.4 percent on dry and fresh weight basis, respectively. Sugar content ranged from 2.4 to 9.6 percent on dry weight basis. Crude protein content on dry weight basis varied from 5.86 to 14.51 percent and Da331 recorded the maximum crude protein content. The genetic diversity analysis usig nine SSR and 15 ISSR markers showed very high polymorphism.

## 31. Molecular characterization of shattering in weedy rice (*Oryza sativa* f *spontanea)* biotypes of Kerala

Objective was to isolate and sequence genes related to shattering *viz*., *sh4* and *qsh1* in weedy rice biotypes and characterisation of genes related to shattering by expression profiling and phylogenetic analysis. *sh4* and *qsh1* are present in both weedy rice and cultivated variety Uma as evidenced from the PCR amplification of genomic DNA. However, the genes responsible for shattering investigated in present study were not expressed in any of the growth stages in cultivated rice variety Uma.

## 32. Identification and characterization of *Suppressor of Over expression of Constants1 (SOC1)* gene in black pepper (*Piper nigrum* L.)

Objective was isolation and sequencing of SOC1, a flowering integrator gene in black pepper var. Karimunda and functional characterization of the gene by studying the expression pattern. The RT-PCR amplified product on analysis showed similarity to MADS box transcription factors. Its expression was found in leaves, shoot and root.

## 33. Identification and characterization of *Flowering Locus T (FT)* gene in black pepper (*Piper nigrum* L.)

The main objective of the study was the isolation, cloning and sequencing of genes homologous to *FT*, a floral integrator gene from black pepper and functional characterization of the gene by studying its temporal and spatial expression patterns. *FT* gene was expressed in the mature spike with berries, mature leaves, immature spikes, spike with flowers, spike with young berries and plagiotropic shoots. *TFL1* gene was expressed in mature leaves and also a slight expression in spike with flowers. This study has identified the flowering time and floral integrator gene (*FT*) and the inflorescence meristem identity gene (*TFL1*) from black pepper for the first time.

## 34. Analysis of differential expression of genes determining inflorescence architecture in black pepper (*Piper nigrum* L.) type 'Thekken'

The objective was to detect the presence and differential expression of RAMOSA family genes (RA1, RA2 and RA3) that determine the inflorescence architecture and to analyse their influence on the branching trait in black pepper (*Piper nigrum* L.) type 'Thekken'. Presence of an integrase core domain in the genome of black pepper was reported for the first time. Differential amplification of cDNA of stage II from 'Thekken' and 'Karimunda' with RA3 primers suggested

that altered expression of the region under study may play a role in the induction of spike branching in 'Thekken'.

## 35. Analysis of *Capsanthin- capsorubin synthase* gene in Byadagi chilli (*Capsicum annuum* L. ) and elucidation of carotenoid metabolic pathway

Seven genetically distinct chilli varieties *ie.* Byadagi Kaddi, Byadagi Dabbi, Ujwala, Anugraha, Vellayani Samrudhi, Vellayani Thejus and CC8-1 accession were used for Ccs gene analysis. Two chilli CCs gene specific SSR primers *viz*., CCs Cds and Ccs promoter were used to amplify the Ccs gene. The Ccs gene was found amplified in all the genotypes including the yellow fruited accession CC8-1. Size of amplified product was 1.5 kb with Ccs cds primer and Ccs promoter, amplified product was 920bp in Byadagi Kaddi, Byadagi Dabbi, Ujwala, Anugraha, Vellayani Samrudhi and 1200bp in Vellayani Thejus and CC8-1. Multiple sequence alignment of the sequences revealed SNP variations in Byadagi Kaddi. Byadagi Dabbi had the same amino acid change at $425^{th}$ position, Lysine (K) was replaced by Glutamic acid (E) and Premature Stop codon UAG was observed in yellow fruited variety CC8-1 at $200^{th}$ position. Multiple sequence alignment of the promoter region could see structural changes in the sequences. Several SNPs in the sequences, a tandem repeat structure, various cis regulatory elements like (HSE), (MYBPZM) and TATA box, and CAAT box could be observed in the promoter region. Elucidation of carotenoid metabolic pathway in *Capsicum annuum* revealed 17 enzymes were present in the carotenoid biosynthesis pathway. Gene regulatory network analysis, using cytoscape showed that network contained 94 nodes and many of the genes were associated with carotenoid biosynthesis processes.

## 36. DNA fingerprinting of promising cocoa (*Theobroma cacao* L.) varieties of KAU

Eight most popular and promising varieties of cocoa were characterized using molecular markers such as ISSR and SSR and DNA fingerprints were developed for each variety. Genomic DNA from each variety was amplified with 10 and 11 selected ISSR and SSR markers respectively. Individual variety fingerprints were developed and using the data, final consolidated ISSR and SSR fingerprints were generated. Unique fingerprints were developed for varieties CCRP 5, CCRP6 and CCRP 9 using ISSR markers. SSR analysis generated variety specific fingerprints for CCRP1, CCRP2, CCRP4 and CCRP9. Banding pattern obtained was further utilized for analyzing relatedness/variability among the studied genotypes using NTSYSpc. Combined ISSR and SSR dendrogram grouped the hybrids CCRS 8 and CCRP 9 in single cluster. The DNA fingerprint developed was good enough to provide varietal identity and the analysis could effectively represented the relatedness/variability among the eight studied varieties. Thus, the DNA fingerprints developed could be utilized for the variety identification as well as for protecting plant breeder's right (PBR) and settling IPR issues.

## 37. Effect of microgravity and high energy radiation on gene expression in relation to growth, yield and quality of medicinal plants and vegetables

The project was envisaged to study the effect of microgravity and high energy radiations experienced in the outer space on gene expression related to growth, quality and yield parameters in four medicinal plants (*Catharanthus roseus, Bacopa monnieri, Plumbago rosea and*

*Indigofera tinctoria*) and two vegetable crops (*Amaranthus tricolor, Solanum melongena).* The project included preflight onground experiments and post flight experiments, after recovering the samples from the capsule. As part of the preflight experiments, basic information was generated on the effect of environmental parameters like temperature and gamma radiation on the viabilty of seeds of medicinal plants and vegetable crops and the growth and physiological parameters of the plants developed from these seeds. Data on the effect of temperature, gamma radiation on regeneration of callus cultures of medicinal plants and their gene expression in relation to irradation were also evolved. The data generated can be utilized in future space biology programmmes. The launch of SREII was not materialized due to some technical problems and the post flight studies could not be conducted due to termination of the mission.

## 38. Biochemical and molecular studies on post-harvest physiological deterioration of Cassava (*Manihot esculenta* Crantz)

There were significant positive correlation between root respiratory flux at 3 and 9 days of storage to the CAT and POX activities studied in different cassava varieties. Roots were treated with various food preservatives at 2 different concentrations (0.5 and 1%). There was a weak but significant reduction in symptom development in butylated hydroxyl touline – (BHT, at 0.5 and 1% level) treated roots compared to other treatments. The roots did not show marked influence to hormone application. High temperature storage of cassava at 40°C resulted in reduced respiratory rate and increased antioxidant scavenging enzyme activity and also reduced the post-harvest physiological deterioration **(**PPD). Differentiation of cassava roots at the metabolites level corresponding to visual symptoms and chemotypic profile of PPD and NIR spectroscopy offer rapid screening tools. Among the different storage treatments, wax coating with antiseptic pre-treatment is most suitable and economical for increasing shelf life of roots. Food Preservatives like BHT and BHA have a significant, albiet marginal influence on PPD symptom development in cassava.

## 39. Nutrio-physiological and molecular analysis and carbon dioxide enrichment studies of coconut palms (*Cocos nucifera*) with foliar yellowing.

The objectives were to analyze the nutria-physiological changes occurring in the palms affected with foliar yellowing and to assess the impact of enhanced carbon dioxide on phytoplasmal response. Palms showing mid whorl yellowing (MWY), root (wilt) affected palms (RW) and healthy palms were selected from two different locations *viz,* the Instructional Farm, College of Agriculture, Vellayani (location 1) and Venganoor region (location 2) in the Thiruvananthapuram district. Physiological and biochemical analyses revealed significant variations in all the parameters studied. The role of phytoplasma in causing MWY was established by molecular and anatomical studies. Sequencing of the PCR product revealed that MWY phytoplasma can be a variant of root (wilt) phytoplasma. The study indicated that the overall health status of the palms with MWY was highly deteriorated. Significant variation in the nutrient profile was noted with significant reduction in the nitrogen, magnesium and zinc content. Accumulation of elements like potassium, calcium, iron and copper was observed in palms with mid whorl yellowing compared to the healthy palms which emphasise the need for proper nutrient management. Sequence analyses of the mid whorl yellowing phytoplasma

revealed 89% similarity to the root wilt phytoplasma. Semi-nested PCR was found more accurate and specific in phytoplasmal detection which can be utilized for phytoplasmal indexing and mother palm and disease free seedling selection. Elevated carbon dioxide showed an improved growth and development and activated defence response to phytoplasma in the infected plants but the $CO_2$ induced modifications in phytoplasmal load was not detected. The results indicated a better tolerance strategy to phytoplasma under changing environmental conditions.

**40. Mitigating the phytotoxic effect of ALS inhibiting herbicides in rice (*Oryza sativa L.).***

The study aimed to mitigate the growth inhibition due to the application of post emergent ALS (Aceto Lactate Synthase) inhibitors, Bispyribac sodium and Azimsulfuron and to improve the productivity of rice. Tank mix application of urea, micronutrients and NAA can be recommended as a booster for mitigating the yield suppression resulting from herbicide application. A 20-24% improvement in grain yield of rice variety Uma was recorded when the plots sprayed with the herbicides azimsulfuron and bispyribac sodium on the $15^{th}$ day was mitigated with Tank mix application of urea, micronutrients and NAA.

**41. Mitigation of solar ultra violet-B radiation induced photo inhibition in photochemistry and photosynthesis of rice (*Oryza sativa* L.)**

The study aimed to understand the photo protective potential of ecofriendly stress mitigating chemicals on photoinhibition in photochemistry and photosynthesis of rice (*Oryza sativa* L.) under solar ultraviolet-B radiation. Among different chemicals used as mitigating treatment combination, fungicide Nativo 70ppm, partially alleviated the yield reduction due to natural solar UV-B radiation. The maximum yield observed when combination fungicide (25WG Trifloxystrobin+ 50WG Tebuconazole) 70ppm was used as the mitigating treatment. Improvement in thousand grain weight and number of spikelet per panicle and photosynthetic rate, less fluorescence emission, more chlorophyll content, catalase activity and reduction in the synthesis of secondary metabolites like flavanoid and xanthophylls were observed in the treatment.

**42. Physiological characterization of thermo sensitive genic male sterility in rice (*Oryza sativa* L.)**

The study revealed that CSP of the TGMS line under study is $26.1^0$C and it could be used as a reliable female parent in rice breeding programme. TGMS red rice under Jyothi background was developed. The presence of higher amount of MDA, SOD, ascorbate, phenol etc. in sterile plants clearly indicates a higher level of oxidative stress experienced by TGMS plants under sterility inducing condition which may be leading to the expression of sterility.

**43. Spectral management for improving photosynthetic efficiency in polyhouse cultivation of vegetables**

The morphological and physiological responses of vegetables, *viz.*, tomato, salad cucumber, capsicum and yard long bean exposed to spectral modification through different colored shade nets were studied. Spectral modifications through shade nets altered morphological and physiological responses and varietal suitability was observed in different shade nets.

Photosynthetic efficiency was also influenced by shade nets and reflected in the yield of selected crops. Red shade net was suitable for capsicum and tomato while white net was ideal for salald cucumber and green for yardlong bean.

### 44. Carbon dioxide enrichment mediated plant- microbe interaction in cowpea *(Vigna unguiculata L.)* under water stress

The objectives were to study the water stress tolerance character and $N_2$ fixation efficiency of cowpea variety Bhagyalakshmy as influenced by microbial inoculants under elevated $CO_2$ condition. The technology used for $CO_2$ enrichment was Open Top Chamber (OTC) system . $CO_2$ enrichment was found to have significant positive influence on water stress tolerance character of cowpea variety Bhagyalakshmy. There was further enhancement of stress tolerance by microbial inoculants, *Rhizobial* sp. and *Perenospora indica*. The underlying tolerance mechanisms were found to be stomatal modifications resulting in reduced transpiration and better tissue water status, activation of antioxidants like ascorbic acid and better maintenance of membrane integrity. Nitrogen fixation efficiency was improved tremendously by elevated $CO_2$ in terms of nodule number per plant and nodule dry weight but leaf nitrogen content and nitrogen use efficiency were reduced by $CO_2$ enrichment. Rhizobial inoculation modified these responses with the positive influence on soil nitrogen status. The outcome of the programme reveals the possibility of improving yield potential and stress tolerance under elevated $CO_2$ by integrating photosynthesis and nitrogen use efficiencies with the application of microbial inoculants like *P. indica*.

### 45. Carbon dioxide enrichment induced drought tolerance responses in tomato (*Solanum lycopersicum* L.) and amaranthus (*Amaranthus tricolor* L.).

The study entitled 'Carbon dioxide enrichment induced drought tolerance response in tomato (*Solanum lycopersicum* L.) and amaranthus (*Amaranthus tricolor* L.)' was undertaken with the objective to study the physiological basis of varietal response of tomato and amaranthus to water stress conditions and to study their modifications under elevated $CO_2$ environments. $CO_2$ enrichment was revealed to have a role in improving the stress tolerance and recovery responses in the case of tomato and amaranthus. Considering all the physiological and biochemical studies carried out in the case of tomato and amaranthus, the better stress tolerance under elevated $CO_2$ was found to be achieved mainly through better photosynthetic rate and activation of defense mechanisms, especially activation of antioxidants. The study also demonstrated the varietal variation existing in $CO_2$ enrichment induced drought tolerance responses in tomato and amaranthus which will help in the selection of suitable varieties for a changing climatic scenario.

## Ongoing Projects

### 1. Centre of Excellence in Biotechnology and Secondary Agriculture at CPBMB

Research on centre of excellence and secondary agriculture focused on development of regeneration protocols in recalcitrant species like coconut and nutmeg, gender identification in nutmeg through molecular marker analysis, *In silico* screening and molecular docking of compounds from nutmeg, pepper, pineapple against major diseases. Somatic embryogenesis from coconut embryo is aimed in the project. With the new generation chemicals and with new

media combinations tried positive response could be observed in Y3 medium supplemented with different levels of auxins and cytokinins. In nutmeg, with the surface sterilization procedure standardized, better culture establishment could be observed. With the media combinations tried 22.83 per cent sprouting could be observed. For gender identification in nutmeg, DNA isolation from tender leaves of nutmeg was done as per the protocol reported by Sheeja *et al*. (2008). Various reported RAPD and ISSR primers were screened for polymorphism. Sixty ligands from nutmeg, 150 ligands from black pepper and 35 ligands from pineapple were selected for molecular docking against cancer, diabetes, arthritis and cardiovascular diseases. The project is in progress.

**2. Metabolome analysis in ginger and product development using gingerol**

The project on PPP mode was launched with participation of KAU- Arjuna Natural Extracts Ltd., Alwaye (ANEL) and DBT-BIRAC, New Delhi. The major activities in the project were gingerol product development using already identified high gingerol yielding somaclones, stability studies for retention of gingerol in the product, analysis and separation of 6 - gingerol from other gingerols, detailed animal toxicity studies of the extract and screening somaclones for gingerol content. Isolated and characterized gingerol at lab level using already identified high gingerol yielding somaclones of KAU and developed ginger extract powder with 8 per cent gingerol. Purification of 6-gingerol was achieved with liquid – liquid extraction and column chromatography. 6-gingerol was found stable in nitrogen atmosphere at low temperature. Acute and subchronic toxicity studies of the developed product in animal models showed no observed adverse effect level. The project is in progress.

**3. Commercial micropropagation of high demand high value crops as per National Certification System for Tissue Culture Plants (NCSTCP)**

The project aimed at developing a well designed commercial micropropagation unit at CPBMB as per NCSTCP, advanced facility for virus indexing at CoA, Vellayani, well designed micropropagation facilities at four satellite centres (BRS Kannara, RRS Vyttilla, RARS Pattambi and CoA Padanakkad), operational capacity building of the units in a revolving fund mode at later stages, need based development of micropropagation protocols on new high demand crops and refinement of already developed protocols for commercial application, capacity building of entrepreneurs on commercial plant tissue culture, virus indexing and clonal fidelity testing. Establishing demonstration plots of tissue culture derived plants at lead and satellite centres are also aimed in the project. Plantlets produced at different centres confirm the standards of NCS-TCP. Quality evaluation of TC banana plants regenerated from male bud showed variability suggesting to look into the mode of regeneration for true to type multiplication. Secondary and micronutrient deficiency of TC banana was corrected by applying '**Ayar'** a preparation made by the Dept. of Soil science, College of Agriculture, Padanakkad

**4. Molecular characterisation of spike branching trait in black pepper (*Piper nigrum* L.)**

The objectives were to identify and functionally characterize the genes conferring spike branching trait in black pepper. Morphological, biochemical, hormonal and molecular analyses of spike branching trait and to hybridise 'Pepper Thekken' with Panniyur variety for transfer of

spike branching trait. Three nucleotide sequences related to floral architecture isolated from branching type black pepper' were isolated and the sequences were deposited in GenBank (Accession Numbers: KX518738-KX518740).

5. **Molecular marker aided selection for novel traits in Komadan coconut palms**

The main aspects of the study included identification of a molecular marker for detection of Komadan characters in Komadan mother palms, evaluation of the segregating progenies from the crosses with Komadan as a parent for analyzing the segregation of Komadan traits, molecular analysis of the segregating population to confirm the marker, along with the long-term objective to evaluate the hybrids with Komadan as a parent . 135 hybrid seedlings developed from the crosess with Komadan as one of the parent in four combinations (Komadan X WCT, WCT X Komadan, Komadan X CGD, Komadan selfing) were planted for long term evaluation. RAPD analysis of the hybrids from the four cross combinations was done with five identified polymorphic pimers OPC20, OPP3, OPP2, OPP5, OPA5 and OPD3 . SSR analysis of the parents and hybrids with 4 SSR primers (CNZ1, CAC10, CnCirH4 and CnCirG11) with specific marker for komadan was done. Development of SCAR marker specific to Komadan is in progress.

6. **Validation of apomixis and transcriptome analysis for detection of the genes related to apomixis in black pepper (*Piper nigrum* L.)**

The objective of the study was to validate apomixis in black pepper varieties Panniyur-1 and Panniyur-2 through controlled pollination studies and to identify differentially expressed genes associated with apomixis through transcriptome analysis.

Attempts were made to confirm apomixes by allowing berry development in controlled condition by bagging of spike initials. Berry development occurred under bagged condition. The upper six berries were considered as apomictic and lower six berries were considered as pollinated. *In vitro* embryo culture resulted in embryo germination and multiple shoot induction in SH medium with hormones. Histological examination revealed that the sexual fertilization occurs in case of pollinated berries, and embryo develops inside the embryo sac in the micropylar end. So, it can be concluded that facultative apomixes exists in black pepper varieties P1 and P2 and the embryo develops parthenogenetically.

7. **Metabolite profiling and gene expression analysis for gingerol production in selected somaclones of ginger (*Zingiber officinale* Rosc.)**

The investigation aimed to completely profile the metabolites in selected ginger somaclones using high throughput analytical platforms and to analyse the gene expression with respect to gingerol production in selected somaclones. Clone to clone variation was observed in the number and quantity of aroma components and pungency principles profiled using GC-MS and HPLC respectively. Aroma and pungency principle accumulation was observed at the rhizome formation stage at five months after planting. Total volatile oil components separated in GC-MS analysis from fresh and dry ginger rhizomes were 148 and 104 respectively. Gene expression studies using quantitative real time PCR is in progress.

8. **Molecular marker analysis for cassava mosaic disease resistance**

The study aimed to identify reliable molecular markers linked with mosaic disease resistance in tapioca. The study is in progress

**9. Validation of antituberculosis activity in selected vegetable crops through docking and *in vitro* assay techniques**

The objective of the study was to validate antituberculosis activity in selected vegetable crops through in *silico* docking of selected phytocompounds against identified targets for tuberculosis and through *in vitro* assay techniques. The study is in progress.

**10. Differential expression of pathogenesis related genes by plant growth promoting rhizobacteria in controlling taro leaf blight**

The study aimed the selection of plant growth promoting rhizobacteria (PGPR) for taro leaf blight (TLB) management, its characterization and study of the differential expression of pathogen related genes in susceptible and tolerant varieties of taro, consequent to application of PGPR. The study is in progress.

**11. QTL mapping for yield traits in vegetable cowpea**

The objective was to map the SSR markers and to identify the quantitative trait loci for yield components in the genome of vegetable cowpea. 30 clearly polymorphic SSR markers were used for genotyping the 94 samples in mapping population and the band patterns were scored. Project is in progress.

**12. Characterization of PR proteins in selected calli clones of black pepper in relation to *Phytophthora* foot rot disease**

The objective was to characterize PR proteins in selected calliclones of black pepper in relation to *Phytophthora* foot rot disease. Detached leaf symptom bioassay at 24, 48 and 72 hours after inoculation revealed that, CKCC 27 showed the least lesion diameter depicting tolerance reaction. β-1,3-glucanase assay showed that, KLCC 89 recorded the earliest (at 24 hours after inoculation) and highest specific activity of β-1,3-glucanase among the 11 calliclones and susceptible variety Panniyur-1. Project is in progress.

**13. DNA barcoding of spider mites (Prostigmata: Tetranychidae) on major crop plants of Kerala**

DNA barcoding of spider mites on major crop plants of Kerala was done using *COI* and *ITS2* loci based primers. The objective of the study was to generate DNA barcode for different species of spider mites on major crops of Kerala and to find out the genetic variability among them. Project is in progress.

**14. Molecular characterization of *Erwinia* species causing rhizome rot in banana**

The study aims to characterize the pathogen causing rhizome rot in banana in terms of phenotypic, biochemical, molecular characters and variability. The rhizome rot pathogen of banana *Pectobacterium carotovorum* was isolated from infected banana samples of 18 locations in Kerala and Tamil Nadu. The variability of the isolates were evaluated by cultural, morphological, biochemical, physiological and molecular methods. The rhizome rot infected samples were collected from banana fields of 14 different locations in the districts Thrissur, Palakkad, Ernakulam, Kollam and Trivandrum of Kerala and also from four different locations in the districts Kanyakumari, Madhurai and Tuticorinof Tamilnadu. Project is in progress.

15. **Genome walking for putative phytic acid (InsP6) unigene in black pepper (*Piper nigrum* L.)**

Objective was to sequence the flanking regions of unigene*Pnc135* coding for Phytic acid ($InsP_6$) by primer walking and validation of the gene and detection and quantification of $InsP_6$ and its derivatives [inositol pyrophosphates (PPx-InsPs)], if any, in black pepper. Three sets of primers (PNC F5/PNCR5, PNC F6/PNC R6, PNC F7/PNC R7) were designed based on the multiple sequence alignment of putative unigene (*Pnc135*) showing similarity to *ipk1* gene. Project is in progress.

16. **Transcriptome analysis of *Phytophthora capsicii* tolerance in black pepper (*Piper nigrum* L.)**

Objective was to understand the differential expression of genes during *Phytophthora* infection in susceptible and tolerant black pepper cultivars through DDRT-PCR analysis on mRNA. Two black pepper varieties, IISR Subhakara (susceptible variety) and IISR Shakthi (tolerant variety) were employed in the study. Total RNA before and after *Phytophthora capsici* inoculation were isolated using TRIzol method and were converted into cDNA using oligo-dT primers and reverse transcriptase enzyme. Project is in progress.

17. **Pyramiding of bacterial leaf blight resistance genes in rice variety Jyothi (PTB39) through Marker Assisted Selection**

The project aimed to pyramid three bacterial leaf blight resistance genes (*xa5 + xa13 + Xa21*) in rice variety Jyothi (PTB 39) using functional STS markers, RG556, RG136 and pTA248 and generate backcross population ($BC_3F_1$ and $BC_2F_5$) introgressed with the resistance genes. Two R genes (*xa5* and *xa13*) pyramided $BC_2F_4$s were identified through foreground selection. Out of 50 Rice Microsatellite (RM) markers, thirty-four background markers exhibited variable banding pattern in the selected $BC_2F_4$s Project is in progress.

18. **Induction of genetic variablilty in *Phalaenopsis* orchids through hybridization and embryo culture**

The objective was to induce genetic variability in *Phalaenopsis* by hybridization and embryo culture. Genetic relationship among the parents was assessed by using ISSR molecular marker system and genetic variability was induced by intervarietal hybridization. Seed culture of the hybrid pods was done by embryo culture technique by using MS and Knudson-C media. Project is in progress.

19. **Bulked segregant analysis for heat tolerance in segregating generation of rice (*Oryza sativa* L.) using SSR marker**

The objective was to identify the SSR markers linked to the gene/s for heat tolerance in rice through bulked segregant analysis (BSA).Two rice varieties, N22 (heat tolerant) and Uma (heat susceptible) and the F3 progenies of the cross Uma × N22 were employed in the study. SSR markers were used to find the polymorphism between N22 and Uma. BSA and single marker analysis were performed to find the linkage between marker and trait. Project is in progress.

**20. DNA barcoding in genera *Benincasa* and *Praecitrullus***

The objective was to assess genetic diversity and interspecies relationship among *Benincasa* and *Praecitrullus* genotypes and to check the species status of *Benincasa* using barcodes. Project is in progress.

**21. DNA fingerprinting of promising selections of jack (*Artocarpus heterophyllus* Lam.) using molecular markers**

To characterize popular jack varieties/ cultivar and six superior jack selections identified by RARS, Kumarakom from Kuttanad tract using SSR and ISSR markers. Popular jack variety Sindhur, cultivar Muttom varikka and six superior jack selections (Veloor varikka-1, Veloor varikka-2, Pathamuttom varikka-1, Pathamuttom Varikka-2, Kavanar Varikka-1 and Chengalam varikka) identified at RARS, Kumarakom from Kuttanad tract were used for the study. Fifty each ISSR and SSR primers were screened with bulked DNA of jackfruit genotypes. Project is in progress.

**22. Tagging of Phytophthora pod rot resistance gene in cocoa (*Theobroma cacao* L.) using ISSR markers**

The objective was to tag the gene(s) conferring resistance to *Phytopthora* pod rot disease and thus enable marker assisted selection for developing pod rot resistant varieties. Based on the detached pod inoculation three resistance and susceptible hybrids were selected. Project is in progress.

**23. *In vitro* synthesis of gingerol and analysis of Expressed Sequence Tags for gingerol production in ginger (*Zingiber officinale* Rosc.)**

The objective was to analyse the synthesis of gingerol under *in vitro* conditions, to characterize the ESTs related to gingerol synthesis and to validate the identified ESTs for high gingerol production in ginger. *In vitro* rhizome bud cultures of three KAU ginger varieties *viz*. Athira, Karthika and Aswathy and two parent cultivars were established. Micro rhizomes were induced from multiple shoot cultures of the varieties and cultivars. The project is in progress.

**24. Development and validation of novel EST-SSR markers in black pepper(*Piper nigrum* L.)**

The objective was to develop EST-SSR markers in black pepper, validation of the developed EST-SSR markers in different genotypes of black pepper and to study the genetic relationship among different *Piper* species. Different genotypes (53 no.) including nineteen varieties and sixteen cultivars of black pepper and eighteen different species of *Piper* were included in the study. Simple sequence repeats (SSR) were mined from the expressed sequence tags (EST) obtained in a previous study about the genes expressed during berry development stage of black pepper. The project is in progress.

**25. Physiological investigations on high temperature induced spikelet sterility in rice (*Oryza sativa* L.)**

The objective was to study the morphological, biochemical and physiological basis of high temperature induced spikelet sterility in rice during anthesis and the role of calcium channel as thermo-sensors. The project is in progress.

**26. Physiological, phytochemical and molecular studies on abiotic stress mediated production of secondary metabolites in the brahmi *Bacopa monnieri* (L.) Wettst.**

The objective was to enhance the production of secondary metabolites in medicinal plant *Bacopa monnieri* (L.) by providing various abiotic stress factors and to study the physiological, biochemical and molecular changes associated with it. The project is in progress.

**27. Identification of macrosatellite markers associated with root traits for drought tolerance in rice (*Oryza sativa* L.)**

The objective was to validate the role of root traits in rice for drought tolerance and to identify the microsatellite markers associated with root traits for drought tolerance in rice. The project is in progress.

**28. Cryoconservation of koovalam *(Aegle marmelos* L. Corr.*)* by encapsulation-dehydration technique**

The proposed research programme aimed at the standardization of cryopreservation protocol using encapsulation and dehydration technique in *Aegle marmelos,* a redlisted medicinal tree of Kerala. The genetic fidelity assessment of plantlets recovered and regenerated from cryostorage will also be assessed using molecular markers. The project is in progress.

**29. Establishment of *in vitro* regeneration systems from callus and protoplast in *Capsicum frutescens* L.**

The objective was to study the establishment of callus culture from different explants in *C. frutescens.* Protocol for protoplast isolation, protoplast culture and plant regeneration from callus/leaf mesophyll will also be established. The project is in progress.

**30. Evaluation of siRNA mediated banana bract mosaic virus (BBrMV) resistance in banana**

The objective was to evaluate siRNA mediated resistance against *Banana bract mosaic virus* (BBrMV) in transgenic banana (*Musa* spp. Var. Nendran) plants developed using ihpRNA construct for replicase gene by artificial infection and to confirm the expression of siRNA products in infected plants. The project is in progress.

**31. Physiological and molecular analyses of flowering response in amaranthus (*Amaranthus* spp.) and cowpea (*Vigna* spp.) under elevated $CO_2$ environment**

The objective was to study the physiological, molecular and biochemical basis of elevated $Co_2$ mediated modifications in the flowering responses of amaranthus and cowpea. The project is in progress.

**32. Somatic embryogenesis in black pepper (*Piper nigrum* L.)**

The objective was to standardize a reliable protocol for somatic embryogenesis in black pepper (*Piper nigrum* L.) var. Panniyur 5. The project is in progress.

**33. Evaluation of systemic acquired resistance and induced systemic resistance on the suppression of foliar blight disease of amaranthus (*Amaranthus tricolor* L.)**

The objective was to study the combined effect of chemical activator Acibenzolar-S-Methyl (ASM) and root colonizing endophytic fungus *Piriformospora indica* on plant growth promotion

and induction of systemic resistance and suppression of foliar blight disease in amaranthus (*Amaranthus tricolor* L.). The project is in progress.

**34. Comparative and functional genomics analysis of starch biosynthesis pathways in cassava**

The objectives were to study the starch synthesis pathways in cassava using data integration and to study on the temporal gene expression pattern in cassava during different growth stages. The project is in progress.

**35. Validation of antiinflammatory, antinociceptive and diuretic potential of neeraral (*Marsilea quadrifolia* L.)**

The objective was to scientifically validate the antiiflammatory, antinociceptive and diuretic potential of whole parts of the ethnomedicinal plant *Marsilea quadrifolia* L. The project is in progress.

**36. *In silico* evaluation of anti-cobra venom activity in selected fruit crops**

The objective was to evaluate cobra (*Naja naja* L.) venom detoxification activity and identification of potential lead molecules in common five fruit crops *viz. Phyllanthus emblica* (L.), *Mangifera indica* (L.), *Punica granatum* (L.), *Syzygium cumini* (L.) and *Tamarindus indica* (L.) using bioinformatics tools. The project is in progress.

**37. Genetic diversity analysis of *Phytophthora colocasiae* using SSR markers**

The objective was to study the genetic diversity of *Phytophthora colocasiae* populations using SSR markers. The project is in progress.

**38. Isolation and characterization of ADP-glucose pyrophosphorylase (AGPase) enzyme in high and low starch variety of cassava**

The objective was to study the AGPase gene sequence variation in high starch cassava variety CMR-129 or BR-105 and low starch cassava variety MNga-1 or M-4. The project is in progress.

**39. Phytochemical diversity of *Cinnamomum verum* J. Presl in South India**

The project aimed to map the phytochemical diversity of *Cinnamomum verum* J. Presl in South India through secondary metabolite profiling. The project is in progress.

**40. Identification of lead compounds with anti-cobra venom activity in common spices through *in silico* methods**

The objective was to identify lead compounds with anti cobra venom detoxification activity in common spices of Kerala *viz. Capsicum frutescens* L., *Cinnamomum zeylanicum* Beryn, *Piper nigrum* L. and *Allium cepa* L. through *in silico* methods. The project is in progress.

**41. Evaluation of direct antagonism by phylloplane bacteria, and induced systemic resistance by *Piriformospora indica* on the suppression of foliar blight disease of amaranthus (*Amaranthus tricolor* L.)**

The objective was to study the combined effect of phylloplane bacteria, and root colonizing endophytic fungus *Piriformospora indica* on plant growth promotion, induction of systemic

resistance and suppression of foliar blight disease in amaranthus (*Amaranthus tricolor L.).* The project is in progress.

**42. Molecular characterization of *Sweet Potato Feathery Mottle Virus***

The objective was to identify the strain and characterize the *Sweet Potato Feathery Mottle Virus* (SPFMV) genome. The project is in progress.

**43. Identification of duplicates in the germplasm of sweet potato (*Ipomoea batatas* (L.) Lam.) using morphological and molecular markers**

The objective was to identify duplicates present in sweet potato germplasam collections at ICAR-CTCRI, Sreekariyam, Thiruvananthapuram using morphological and molecular markers. The project is in progress.

**44. Association mapping for cassava mosaic disease (CMD) resistance in cassava using SSR marker**

The objective was to identify the markers associated with cassava mosaic disease (CMD) resistance in cassava varieties. The project is in progress.

**45. Molecular characterization of rice genotypes having variability in heat tolerance**

The objective was to study the variation in rice genotypes for heat tolerance using microsatellite markers. The project is in progress.

**46. *In silico* analysis of carotenoid biosynthesis pathway in cassava (*Manihot esculenta* Crantz.)**

The objective was to identify the genes involved in the carotenoid biosynthesis pathways in cassava using templates of arabidopsis, tomato, potato and sweet potato. The project is in progress.

**47. Molecular characterization of *Taro Bacilliform Virus* (*TaBV*)**

The objective was to clone and characterize the *Taro Bacilliform Virus* (TaBV) and analyze the phylogenetic relationship with other members. The project is in progress.

**48. Characterization of selected accessions of cassava germplasm using morphological and molecular markers**

The objective was to analyze the genetic variation of cassava based on morphological and molecular characterization. The project is in progress.

**49. Molecular characterization and *in vitro* conservation of taro (*Colocasia esculenta* (L.) Schott)**

The objectives were to analyze the genetic variation of taro (*Colocasia esculenta*) using molecular markers and to establish and maintain taro cultures *in vitro* in slow growth media for medium term conservation. The project is in progress.

**50. Scientific validation of anti inflammatory, antinociceptive and antioxidant potential of malavirinji (*Actinodaphne bourdillonii* Gamble)**

The objective was to scientifically validate the anti-inflammatory, antinociceptive and antioxidant potential of an ethnomedicinal tree *malavirinji* (*Actinodaphne bourdillonii* Gamble). The project is in progress.

**51. Physiological approaches for manipulating male sterility in thermo- sensitive genic male sterile system for hybrid rice seed production**

The objectives were to evaluate the environmental conditions required for complete male sterility of TGMS plants and to manipulate the male sterility by using plant growth regulators and to understand the molecular mechanism associated with TGMS system. The project is in progress.

**52. Physiological, biochemical and molecular studies in medicinal rice (*Oryza sativa* L.) Njavara, as influenced by abiotic stresses**

The objective was to elicit information on the physiological, biochemical and molecular attributes associated with secondary metabolites accumulation due to abiotic stresses *viz.* shade, drought, and UV-B stress in medicinal rice njavara. The project is in progress.

**53. Development of resistance against banana bract mosaic virus in *Musa* spp. var. Grand Naine using small interfering RNA (siRNA)**

The objective was to develop resistance against *Banana bract mosaic virus* in banana var. 'Grand Naine' using siRNA mediated technology. The project is in progress.

**54. Isolation, characterization and evaluation of *PINI* and *BP* genes in relation to inflorescence architecture in black pepper (*Piper nigrum* L.)**

The objectives were to isolate and characterize *PINI* (*PINFORMEDI*) and *BP (BREVIPEDICELLUS*) genes in black pepper (*Piper nigrum* L.) and to evaluate the role of these genes in branching of spikes by studying their differential expression in branching and non-branching varieties of black pepper. The project is in progress.

**55. Evaluation of $CO_2$ enrichment effects on resource utilization in cowpea (*Vigna unguiculata* L.) and amaranthus (*Amaranthus tricolor* L.)**

Objectives of the study are to evaluate the impact of $CO_2$ enrichment on cowpea and amaranthus under varying moisture, temperature and nutrient regimes. Started the experiment on evaluation of plant responses to elevated $CO_2$ under different soil moisture regimes through open top chambers (OTC). Amaranthus seedlings were raised for water stress experiments and work is in progress.

**56. Enhancing morpho-physiological vigour of sesame seedling for improving productivity and weed competitiveness**

The study aims to understand the effect of seed treatments on germination, vigour and productivity of sesame and the influence of early vigour on improving weed competitiveness of sesame. Priming treatments improved the germination, shoot length, root length, vigour index and speed of germination of all the sesame varieties. The varieties Thilak and kayamkulam-II showed maximum response to most of the priming treatments studied. The study revealed that seed priming with MnSO4 or Tank mix can contribute to 30 per cent control of weed growth in crop.

**57. Physiological effects of growth stimulants on yield and quality of okra (*Abelmoschcus esculentus* L.)**

The study aimed to understand the influence of growth stimulants on morpho-physiological changes, yield and quality in Okra (*Abelmoschus esculentus* L.) with respect to soil fertility management. Soil test based nutrient management with growth stimulants application resulted in higher fruit length, fruit diameter, fruit weight and number of fruit per plant than treatments which received standared POP with growth stimulants followed by 50 per cent standard POP with growth stimulants. Regarding the quality parameters like crude fibre, ascorbic acid, mucilage and total protein content of fruit were higher in plant receiving growth stimulants like humic acid, cytozyme and potassium silicate along with soil test based nutrient management system followed by standard POP with growth stimulants and 50 per cent standard POP with growth stimulants.

**58. Identification of microsatellite markers associated with root traits for drought tolerance in rice (*Oryza sativa* L.)**

The objectives of the study were to validate the role of root traits for drought tolerance in rice and to identify the microsatellite markers associated with drought tolerance in rice using BSA. In the first experiment, 35 rice genotypes consisting of improved varieties and landraces were evaluated for their performance for physio-morphological traits under water stress condition. The project is in progress.

**NEWLY SANCTIONED PROJECTS**

1. Isolation and characterization of antioxidant peptides from curry leaf (*Murraya koenigii* L.)
2. Inheritance of molecular markers linked to vascular streak dieback disease resistance in hybrid progenies of cocoa (*Theobroma cacao* L.)
3. Molecular basis of acaricide resistance in *Tetranychus truncates* Ehara (Prostigmata: Tetranychidae) infesting vegetable crops
4. Marker assisted backcross breeding in rice for drought tolerance
5. Molecular cloning and characterization of virus causing leaf curl disease of *Capsicum* spp.
6. Elicitation mediated carotenoid production and *Capsanthin capsorubin synthase* gene expression in Byadagi chilli (*Capsicum annuum* L.)
7. Low cost alternatives in commercial micropropagation of banana (*Musa* spp.)
8. Developing dwarf specific SCAR markrs from WCT inbreds of coconut (Cocos nucifera L.)
9. *In vitro* studies on morphogenesis and plant regeneration in elite clones of cocoa (*Theobroma cacao* L.)
10. Development of doubled haploids for iron toxicity tolerance in rice (*Oryza sativa* L.)
11. Marker assisted backcross breeding for pyramiding genes conferring resistance to bacterial blight in rice variety Uma
12. Standardization of *in vitro* male bud culture in banana *Musa* (AA) 'Kadali'
13. Validation of Temperature Induction Response (TIR) technique for inducing drought and heat stress tolerance in rice (*Oryza sativa* L.)
14. Physiological and biochemical studies on growth, development and yield of ginger (*Zingiber officinale* Rosc.) as influenced by bioinoculants and phosphorus fertilization
15. Enhancement of phenyl propanoid glycosides in *Artanema sesamoides* Benth (vathomvaretti) by hairy root induction

16. Computational prediction of miRNAs in banana (*Musa* spp.) and evaluation of their role in virus infection.
17. Physiological approaches for alleviating the effect of water stress in upland rice (*Oriza sativa* L.)
18. Green synthesized silver nanoparticles for suppression of algal rust pathogen, *Cephaleuros* sp.
19. Efficacy of silver nanoparticles as delivery system in genetic transformation
20. Assessment of water stress tolerance in selectively fertilized coconut (*Cocos nucifera* L.) hybrids.
21. Identification of molecular markers and Quantitative Trait Loci (QTLs) associated with drought tolerant and plant production traits in rice (*Oryza sativa* L.) using association genetic analysis
22. IhpRNA mediated resistance for *Banana bract mosaic virus* in *Musa* spp. by targeting replicase and movement protein genes
23. Evaluation of $CO_2$ enrichment on growth, development and soft rot tolerance in ginger (*Zingiber officinale* Rose)
24. Characterization of selected *Curcuma* species germplasm using morphological and molecular markers
25. Prediction of SSR and SNP markers for anthracnose resistance in yam using bioinformatics tools and their validation
26. Comparative evaluation of gene regulatory network prediction and network reconstruction using genomic data
27. Molecular characterization of pathogens associated with post – harvest diseases in elephant foot yam
28. Evaluation of miRNA prediction tools and *in silico* analysis of micro and long non coding RNAs in sweet potato.
29. Development of infectious clones of *cassava mosaic virus* and their validation
30. Cloning and expression of coat protein gene of *Sweet potato leaf curl virus* (SPLCV)
31. Genetic diversity analysis of sweet potato (*Ipomoea batatas* L. Lam.) germplasm using morphological and ISSR markers.
32. Development of molecular markers for blight disease resistance in taro using bioinformatics tools.
33. Identification and evaluation of endophytes from tropical tuber crops against *colletotrichum gloeosporioides* (Penz.) Sacc. causing anthracnose in greater yam (*Dioscorea alata* L.)
34. *In silico* screening and identification of lead molecules with anti-hepatitis B activity in selected spices.
35. Development of functional SSR markers for D- Limonene content and analysis of genetic polymorphism in cardamom (E*lettaria cardamomum* Maton)
36. Development of functional EST-SSR and analysis of genetic diversity in *Centella asiatica*
37. Genome wide marker assay for the recovery of recurrent parent genome in rice (Oryza sativa).
38. Assessment of antiinflammatory and antioxidant properties of *Chlorophytum laxum* R. Br.
39. Identification of molecular markers for resistance to taro leaf bight in *Colocasia esculenta* L. schott.
40. Identification of molecular markers linked to anthrocnose resistance in greater yam (*Dioscorea alata* L.)
41. Molecular screening of rice genotypes for submergence tolerance

42. Physiological and molecular studies on cyanogenic potential in cassava (*Manihot esculenta* Crantz) in response to nitrogen nutrition, water stress and shade.
43. Population structure analysis of indigenous rice varieties in Kerala using molecular markers.
44. Physiological studies on enhancing growth and yield of ginger (*Zingiber officinale* L.) by Nano-NPK fertilizers and organic management.
45. Physiology and management of *Chara* spp. in wet land rice ecosystem
46. Interactive effect of elevated temperature and UV radiation on rice growth and physiology

# Project Coordination Group - Soil Health and Organic Farming (09)

**Project Coordinator - Dr.K.Ushakumari**

**Concluded Projects: 33**
**Ongoing Projects: 58**

## Concluded Projects

1. **Evaluation of mineral enriched composts for soil remineralisation and crop nutrition**

   The study aimed to evaluate mineral enriched composts and mineral enriched vermicompost by monitoring nutrient release pattern under laboratory conditions and to study their effects on soil remineralization and crop nutrition using yardlong bean as test crop. Based on various physico-chemical and biological characters, fertilizing index and clean index of mineral enriched organic manures were determined and revealed that mineral enriched (rockdust as additive) organic manures were very good sources for soil remineralisation and crop nutrition. It was concluded from the study that 50% N as mineral enriched vermicompost in conjunction with PGPR Mix I helped to increase the yield as well as nutrient uptake of yardlong bean and thus played a vital role in soil remineralization and crop nutrition. It was also evident that the nutrient requirement could be reduced to half the recommended dose if mineral enriched vermicompost was used in conjunction with PGPR Mix I as nutrient source in organic cultivation of yardlong bean.

2. **Biological characterization of Onattukara soils under coconut based cropping system**

   An inventory on the biological characteristics of the major coconut growing soils of Onattukara region in Kerala under different nutrient management practices showed that the maximum values or the most desirable values on biological properties of soils were recorded by soils of the 'very good' productivity class mostly under organic nutrition. But even soils of the 'poor' and 'average' productivity classes receiving organic nutrition recorded values of the 'very good' productivity class highlighting the importance of organic input addition as sources of nutrients in building up the biological health of the soils.

3. **Magnesium and boron nutrition for yard long bean (*Vigna unguiculata subsp. sesquipedalis* (L).Verdcourt) in southern laterites of Kerala**

   The study was conducted to standardize the method and time of application of fertilizers of Mg and B in the Agro Ecological Unit -8 using yardlong bean as test crop. It was concluded that foliar application was significantly superior to soil application for yield and yield attributes. The yield was highest with foliar spray of 2% magnesium sulphate and 0.25% borax at fortnightly intervals plus soil test based package of practices recommendations. Based on B:C ratio, economic yield was obtained when Mg and B were applied twice at first flowering and active flowering stages as foliar spray plus soil test based package of practice recommendations.

4. **Dynamics and interaction of zinc and boron with phosphorus in Ultisol**

   The study was conducted for elucidating the dynamics of zinc and boron as influenced by the phosphorus status of lateritic soil and to optimize the level of P for balanced nutrition of cowpea w.r.t. Zn & B. Among the 100 samples collected from Thrissur, Malappuram and Kozhikode districts and characterized with respect to available P, 18 soil samples were selected and categorized six each from low available P (<3.5 kg ha-1), medium (17 to 20 kg ha-1) and high available P (>35 kg ha) and estimated the physico –chemical parameters. A pot culture experiment was conducted to study the optimum level of P for balanced nutrition of cowpea w.r.t Zn and B.

   The distribution of fraction of inorganic P in the three soils showed that Fe bound P was the dominant fraction contributing to more than 50% of the total inorganic P. Among the fractions of

boron, readily soluble boron recorded the lowest, whereas the contribution of residual boron was the highest. Available P status in soils with low and medium P increased due to the application of P while it decreased in soil with high P. The soil with high P soil showed that the application of phosphorous lead to the fixation of phosphorus in to insoluble forms whereas, if P was not applied there was solubilisation of Fe-P and Al-P resulting in increased availability. Application of Zn was found to reduce Al-P and Fe-P due to the formation of insoluble zinc phosphate. Application of Zn and B reduced the Ca-P, probably due to the formation of zinc phosphate and Calcium borate. In case of zinc fractions, water soluble + exchangeable fraction and organic matter occluded zinc was directly contributing to the available pool. Application of P resulted in adsorption of zinc into specifically adsorbed zinc. With respect to boron fraction, readily soluble boron and oxide bound boron were directly contributing to the available pool whereas binding of boron with organic matter as well as its transformation to residual boron reduced boron availability. Boron application along with P reduced the readily soluble boron. The application of P with and without B reduced the Zn content in plants. Application of P and Zn reduced the boron content in plants and application of boron with and without phosphorus recorded the highest boron content. The highest grain yield was recorded in soil with medium P, while the high P status in soil either due to native P or due to applied P reduced the yield resulting from induced lower uptake of zinc and boron. Thus it was essential to maintain available phosphorus level at medium status with optimizing the levels of other nutrients especially zinc and boron for optimum yield.

5. **Characterization of soil and water of Palakkad Eastern Plains in relation to growth and nitrogenase content of *Azolla* spp.**

   A survey of *Azolla* spp. in the rice growing tracts of Palakkad Eastern Plains (AEU 23) had been conducted to identify soil and water quality parameters congenial for the growth and nitrogenase content of *Azolla* spp. Initially three block panchayaths were taken and from each block, three grama panchayaths were taken randomly from each panchayath 10 samples each of soil, water and Azolla were collected. In this way, 270 samples from azolla growing areas and 180 samples from non-growing areas were taken for the study.

   Among the nine locations studied Nalleppilli panchayath with soil characters (pH- 7.34; EC-0.3 dSm-1; OC – 1.56 % available. NPK- 153.6,63.3 and 191.2 kgha$^{-1}$ respectively; Total Fe-1646.2 mg kg$^{-1}$ ; Mn-234 mg kg$^{-1}$; Zn - 23.3 mg kg$^{-1}$ and Cu - 24.8 mg kg$^{-1}$ ) were found to favour the growth and multiplication of Azolla and the quality parameters of Azolla from the above location were C- 38.6%, N – 2.7 %, C/N ratio 12.58, crude protein 16.95 %, P – 0.174 % and K – 1.39%. A neutral pH(6.8 to 7.5) and low electrical conductivity ( 0.2 to 0.3)dSm$^{-1}$ was preferred by Azolla for its growth.

6. **Nutrient dynamics and transformations in aerobic and flooded systems of rice in lateritic soils of Kerala.**

   A study was conducted on the nutrient dynamics, transformations, availability and absorption in aerobic and flooded systems of rice in lateritic soils of Kerala. Under both the systems, field experiments (two experiments under flooded system and one experiment on aerobic rice) were conducted to standardize the method of sampling and analysis for soil test based application of lime and fertilizers. One was based on sampling and soil testing on wet basis keeping the

anaerobic environment unchanged, while the other was based on routine sampling and analysis after air drying. Under aerobic system major fraction of P was Fe-P which had contributed through Ca-P. Under flooded system major fractions contributing to available pool were Al-P, Fe-P and occluded P but through Ca-P. In the case of Boron dynamics there was not much difference between the two systems except more solubility under flooded conditions. Higher root CEC was noticed under aerobic environment than flooded system. Yield attributes viz., number of tillers per hill, number of panicles per hill were more in aerobic system than flooded system. The data on shoot mass, root length and root volume at active tillering stage indicated that aerobic environment enhanced root and shoot growth when compared to flooded system. This might have contributed to more uptake of nutrients and to yield under aerobic system. The total water requirement of the crop showed almost 57% reduction under aerobic system than that under flooded system. Under both systems, the treatment combination where fertilizers applied as per soil test with lime as per ΔpH (F2-L2) recorded the highest net returns from the crop.

7. **Assessment and management of micronutrient deficiencies in Onattukara**

A study on the assessment and management of micronutrient deficiencies in Ontattukara soils and development of multi micronutrient mixture for balanced crop nutrition revealed the deficiency of B (77%), Zn (66%) and Cu (53%) in the Onattukara region. Micronutrient fertilizer requirement was computed based on the available micronutrient status of the region and crop requirement and developed a multi micro nutrient mixture having a composition of Zn (9.5%) + B (2.6%) + Cu (1.2%) + Mg (2.4%)+N (0.46%). From the investigation it can be confirmed that foliar application of micronutrient mixture@5 kg ha-1 in two splits at 15 DAS and 35 DAS was superior to soil application (@20 kg $ha^{-1}$) in respect of yield, quality and B:C ratio. The study revealed that micronutrient deficiency is one of the yield barriers which can be broken down by including micronutrient fertilizers in the nutrient schedule of crops.

8. **Investigations on the efficacy of biochar from tender coconut husk for enhanced crop production**

The experiment was carried out to characterize biochar from tender coconut husk and assess its effects on soil properties, growth and yield of yardlong bean. Mixing biochar with beneficial microbial consortium like PGPR mix 1 had an additive effect on nutrient availability and plant growth. Application of biochar @20 t $ha^{-1}$ along with 2 % PGPR and NPK as per POP recorded the significantly superior yield of 20.12 t ha-1 with B: C ratio of 1.56 and it also improved physical, chemical and electric - chemical properties of soil and so can be considered as the economically viable and the best treatment. It also significantly reduced the $CO_2$ emission and can be used as an efficient tool for carbon sequestration.

9. **Soil and water quality management for enhancing productivity of coconut based cropping systems in Vilappil Panchayath**

The soil characteristics which represented significant soil quality indicators for the land use systems in the Vilappil panchayath were identified and a Minimum Data Set (MDS) was prepared. The MDS was used to develop a soil-quality index (SQI) for the area. Based on the data obtained from soil analysis, Soil Health Cards were prepared and distributed to the farmers of Vilappil panchayath. Analysis of water quality revealed that the collected samples were neutral or alkaline (pH >6). A higher EC value obtained for water samples may be attributed to

the comparatively high content of K, Na and Cl in the water samples as indicated by their values. The contents of all the other cationic nutrients were negligible in water samples.

**10. Rejuvenation and Conservation of Vellayani Lake -GoK Plan**

The project was undertaken with the objective to prevent encroachment by establishing biofence around the boundary of Vellayani lake, to enhance soil and water conservation, to reduce growth of aquatic weeds, to promote the cultivation of native water plants, to reduce water pollution and to enhance the livelihood security of the local people. As a part of the project activities, biofencing work had been undertaken using native plants and bamboo seedlings in the Kayalkkara of College of Agriculture, Vellayani to prevent encroachment and to demarcate the boundary of Vellayani Lake. Lotus cultivation was undertaken in the lake to reduce the growth of aquatic weeds thereby reduce biomanification and to generate employment and income to the local people. Planting of vetiver around the kayal land in the College of Agriculture was undertaken for soil and water conservation.

**11. Micro nutrient management for sustenance of soil health under intensive cultivation in Western Ghat region**

The study was conducted to develop recommendations of micronutrient fertilizers in banana in laterite soils of Southern Kerala. A formulation of micronutrient fertilizer mixture suitable for banana in the laterite soils of Southern Kerala was developed in the name "Banana micromix" using fertilizer grade ferrous sulphate, manganese sulphate, zinc sulphate, borax and copper sulphate. Experiments conducted in farmers' fields for three seasons using "Banana micromix" recorded significant increase in yield, disease resistance and increased fruit quality in banana variety Nendran. Continuous use of this mixture in banana cultivation do not cause accumulation of micronutrients in soil, plant and water. The dose of application was 10 kg/ha or 4 gm per plant and the mode of application was soil / foliar and time of application was along with the second split doze of NPK as soil application and for foliar application three months after planting as 1% spray by dissolving 4 gm mixture in 400 ml water per plant.

12. **Magnesium and boron nutrition of black pepper (*Piper nigrum* L.) in laterite soils**

The study was conducted to assess the extent of magnesium and boron deficiency in a typical laterite soil of black pepper cultivation, standardizing the dose and method of Mg and B fertilizer recommendation to black pepper and studying its effect on yield and quality of black pepper. The study concluded that soil application of 200 $MgSO_4$ + 20 g Borax or foliar application of 1% $MgSO_4$ + 0.5 % Borax in black pepper in laterite soils resulted in highest yield, yield attributes, nutrient content in plants and highest oleoresin content and maximum piperine content.

13. **Silicon and boron nutrition of rice (*Oryza sativa* L) in wet land soils of northern Kerala**

The investigation carried out under pot as well as field conditions in low land rice ecosystem in laterite derived paddy soils of northern Kerala had shown that the application of potassium silicate @ 0.5 % spray + borax 0.5% spray 3 rounds at 15 days interval significantly improved

the available nutrient status of soil, content and uptake of nutrient by the plant and yield and yield attributes of rice. It was also effective in reducing the toxicity of Fe, Mn and Al in the soil.

**14. Decomposition of leaf litter by Oriculture**

The experiment was carried out to assess the degrading ability of soil dwelling oribatid mites and also to assess the manurial value of the decomposed litter. From the study it could be inferred that among the different litters tried for the isolation and mass multiplication of oribatid mites, jack litter was found to be the best one. Extraction of the mites from soil samples was not possible, instead of that extraction from jack litter was possible due to it's special biochemical composition. The microflora associated with the oribatid mites showed the tannin and lignin degrading ability and also they could able to control the major soil borne pathogens. Among the different biotic enrichments litter alone, litter + cow dung, litter mite, litter + mite + cowdung the biotic enrichment litter + mite + cowdung was found to be the best enrichment in combination with the jack litter in terms of both the nutrient composition and also the decomposition percentage.

**15. Green technology for rice based cropping system in Onattukara**

The experiment was conducted to demonstrate and standardize the management practices for optimum production, to maintain soil health through organic farming and to improve the quality of food produced through balanced supply by organic substitution. The experiment was conducted as per approved technical programme during *virippu* (2011-13), *mundakan* (2011-13) and summer (2012-14). The result indicated that cropping systems and practices as well as their interactions significantly influenced grain yield in *virippu*. Among the cropping system rice-rice-cowpea performed the best and was on par with cropping system rice-rice-groundnut in grain and straw yield. The same trend was observed in *mundakan* also. Package of practices as well as 50% organic +50% inorganic (integrated approach) produced higher grain and straw yield. Sesame, groundnut, cowpea and bhindi were raised during summer 2012, 2013 and 2014. Yield of above crops were influenced by different levels of nutrients.

**16. Income and Livelihood Improvement of Banana Farmers in Southern Western Ghat tract through soil fertility evaluation**

The experiment was carried out in the western ghat panchayats of and Chenkal in the Parassala block of Thiruvananthapuram District with utilization of funds by the Western Ghat Development Cell, Planning and Economic Affairs Department, Government of Kerala. The main objective of the project was to study the feasibility of productivity enhancement in banana in low yielding western ghat tract through the scientific soil fertility interventions including acidity management, application of magnesium and micro nutrient boron. The result of the investigation indicated that the nutrient management with Kerala Agricultural University Package of Practices Recommendation for Nendran banana (NPK @ 190:115:300g plant$^{-1}$ in 6 split doses) along with application of lime @ 1kg per plant at planting , boron @ 10 kg ha$^{-1}$ in two splits ( ½ basal as boraux + ½ at 4-5 months after planting through foliar spray as solubor 0.2 per cent) and soil application of magnesium sulphate @ 80 kg ha$^{-1}$ in two splits ( ½ as basal

and ½ at 4-5 months after planting) resulted in an yield enhancement of 41.75 per cent compared to POP recommendation and 94.24 per cent compared to the farmer practice in southern western ghat tract of Kerala. This treatment also produced the highest net returns (Rs. 11,01,484 $ha^{-1}$ ) and benefit: cost ratio of 2.84 compared to the POP alone (net returns Rs. 6,78,714 $ha^{-1}$ and benefit : cost ratio of 2.20) or farmer practice (net returns Rs. 4,17,238 $ha^{-1}$ and benefit : cost ratio of 1.85). It could be concluded that it is technically feasible and economically viable to enhance the productivity and income from banana cultivation through the soil acidity management combined with soil application of magnesium sulphate and plus foliar application of micro nutrient boron.

**17. Evaluation of a Customized Organic Fertilizer in Relation to Labile Carbon Dynamics, Nutrient Release Characteristics and Productivity of Banana**

The study envisages physico-chemical and biochemical characterization and assessment of maturity parameters of the organic fertilizer obtained from degradable solid waste by rapid thermo chemical conversion technology and evaluation of the customized organic fertilizer in relation to labile carbon dynamics, nutrient release characteristics and productivity of banana in agro ecological unit (AEU) 8 of Kerala

The organic fertilizer produced by thermo chemical treatment was, with a particle size of <4mm, neutral pH, low EC and total organic carbon. Major nutrients were higher secondary and micro nutrients were sufficient and heavy metal content with in safe limit. The humification index were higher and was non phototoxic. Fertilizing Index of 4.7 and Clean Index of 5 qualify it to be a class A marketable organic fertilizer. A field experiment to study the effect of customized organic fertilizer in crop production using Nendran banana as test crop indicated that a steady and constant supply of all essential nutrient to banana and results in profitable net returns, ensuring immediate energy source to rhizospheric microorganisms and promoting long term carbon sequestration in agro ecological unit 8 of Kerala.

**18. Development of custom blended organic fertilizer for vegetables**

Vegetables *viz*., okra, brinjal, chilli, tomato and cucumber were treated with custom blended organic fertilizer made through Suchitha Rapid Waste Processing Technology @ 100, 125 and 150% of POP recommendation. Okra, brinjal, chilli and cucumber recorded the highest yield for the treatment receiving the NPK @ 100% POP in the form of custom blended organic fertilizer (CBOF) in powder form, followed by the same treatment combination in briquette form. The soil test based recommendation followed the above two. For tomato treatment receiving NPK @125% POP in the form of custom blended organic fertilizer in powder form recorded the highest yield followed by tomato treatment receiving NPK @ 150% POP in the form of custom blended organic fertilizer in powder form.

**19. Strengthening and maintenance of Lead Centre for Organic Farming at College of Agriculture, Vellayani**

The established Model Organic Farm at College of Agriculture, Vellayani under the Department of Soil Science & Agricultural Chemistry is being maintained as a permanent field study centre for demonstrations and training purpose in the area of organic farming. Internal training on Organic Cultivation of major crops of Kerala training and demonstration on quality organic manure production were conducted for students, women unemployed youth, farmers and other

public. On-farm preparation, characterization and evaluation of liquid organic manures viz. panchagavya and fish amino acid were conducted. Both the liquid manures were acidic in nature. Fish amino acid registered very high organic carbon content and dehydrogenase activity. E-coli was not detected. Comparative study of soil and foliar application of liquid organic manures conducted on okra and cow pea proved that soil application is more effective for growth and yield. Training programmes on scientific organic farming were conducted for farmers and students visited the model organic farm. Facilities in the model organic farm are being utilized by students of UG and PG programmes and Diploma course for their study purpose. Lead Centre acts as a permanent knowledge and learning centre for all aspects of Organic Agriculture & Agribusiness with a mission to build competence for organizations and individuals which will contribute to ecologically, economically and socially sustainable agriculture and livelihood system.

**20. Micronutrient management for sustenance of soil health under intensive cultivation in Western Ghat region**

Developed two multinutrient fertilizer mixtures for banana and bhindi suitable for southern region of Kerala. Accordingly a formulation of micronutrient fertilizers mixture suitable for Vegetables was developed in the Department of Soil Science & Agricultural Chemistry, College of Agriculture, Vellayani. Experiments conducted in farmers fields using the "Banana micromix" recorded 20 per cent increase in yield in Banana var. Nendran. Disease resistance and improved crop quality was also observed. Experiments conducted in farmers' fields using the "Vegetable micromix" recorded two times increase in the yield, pest and disease resistance and improved crop quality. The mixture can be used either as foliar application or soil application. For foliar application the mixture should be applied @ 5 kg $ha^{-1}$ as 0.5% foliar spray in two splits at 15 days after sowing and 35 days after sowing. Soil application @ 20 kg $ha^{-1}$ can also be done.

**21. A comparative study on soil chemical and biological regimes under coconut ecosystem in red loam and laterite soils of Trivandrum District – A farmer participatory active research**

A general soil resource data of Trivandrum District comprising of 12 block panchayats viz. Parassala, Athiyannoor, Perunkadavila, Nemom, Thiruvananthapuram Rural, Kazhakuttam, Nedumangad, Vellanadu, Vamanapuram, Chirayinkeehu, Kilimanoor, Varkala was generated based on the soil collected in various localities. With respect to soil chemical characteristics of the 12 block panchayats a significant variation in the physical, chemical and biological properties were noticed. In general the soils are found to be moderately acidic warranting application of liming materials. Soil acidification is seen in the soils in vegetable and banana growing soils – application of lime @ 600 kg/ha is recommended. Excessive use of high input acid forming fertilizers and near absence of practice of liming in the soil has resulted in the intensification of soil acidity.

Most of the soils in Thiruvananthapuram being low activity clay soils, it is essential to maintain high levels of organic matter in the soils. The organically treated sites recorded higher values for

soil biological activities thus contributing to nutrient cycling and other improved physical properties. The available phosphorus status in most of the block panchayaths are found to be high which might have been due to the residual effect of the applied phosphorus. The organic matter content of the most of the red and laterite soils are in medium to high range and highest values were noticed in the sites of organic mode of cultivation. No significant deviation in the general trend of K distribution under different cropping systems was noticed. But a general deficiency of soil available potassium was noticed in most of the block panchayats. In the case of secondary nutrients such as Ca & Mg deficiency application of Dolomite or any liming material is recommended. Deficiency of Mn and B was widely seen followed by Cu and in some places Zn. From the assessment of Biological fertility indices of various soils, the highest values were reported with the red loam soils than the laterite pockets. The highest biological fertility index was noticed in sites with highest activity of enzymes viz. dehydrogenase and cellulose. Within the red loam soils, the organically treated plots showed a distinctively higher values than the conventional plots. In general, red loam soils are found to be fertile than the laterite soils. Of the various cropping system studied, Coconut + Tuber and Coconut + Fodder were found to be sustaining the soil chemical properties and physical properties. With respect to soil biological properties coconut + banana was found to be the best in respect of enzyme activities and soil respiratory activity. A correlation between the micronutrients and soil enzyme activities revealed a significant and positive correlation between them and the enzyme dehydrogenase is highly influenced by the availability of micronutrients in soil. Significant and positive correlations between soil available N, and micronutrients such as Fe, Cu, Mn and B are noticed. Among the crops selected for the study coconut + fodder have reported to have improved many of the soil physical and chemical attributes as the quantum of organic matter added or recycled to the soil is more compared to the others.

## 22. Farmer participatory approach to assess the impact of IPNS on soil health and crop yield in a typical laterite soils of Western Ghats

A study was undertaken to understand the integrated use of inorganic fertilizers and organic sources such as fertilizers, manures on soil chemical and biological characters in typical laterite pockets of Vettikkavala Panchayat of Kottarakkara Taluk. About ten locations were identified in the laterite pocket of Western Ghat region. Thirteen treatments involving the combination of inorganics and organics in the form of enriched vermicompost using bonemeal, neem cake, Azospirillum, Vesicular Arbuscular Mycorhizae, phosphobacterins and K solubilizers Freutaria aurantia were tried in the farmer's plots. The experiments were laid out using bitter gourd as test crop. For the soil parameters such as pH, EC, organic carbon and available nutrient status enriched compost using Azospirillum and bone meal was found to be the best. The composting period was also drastically reduced with the application of bio innoculants such as Azospirillum, Freturia aurantia, VAM and phosphobacteria. A reduction in composting period upto 20 days was observed when compared with the addition of organic amendments alone. The most suitable bioinoculant for composting is Azospirullum. From the study, it is inferred that with respect to soil enzymatic activities enriched vermicompost using neem cake and K solubilizer was superior to other treatments. It is observed from the trial that soil urease, phosphatase and dehydrogenase reported a comparatively higher values of 216 ppm of urea hydrolysed $g^{-1}$ of soil $hr^{-1}$, 56 µg of p-

nitrophenyl released $g^{-1}$ of soil $hr^{-1}$ and 356 µg of TPF hydrolysed $g^{-1}$ of soil 24 $hrs^{-1}$ respectively than the other treatments. The substitution of nitrogen with 100% of neem cake enriched vermicompost is possible resulting in improved soil biological properties. With regard to protease activity, it is observed that the application of Azospirillum enriched vermicompost had a significant influence both at 100% and 50% substitution. The highest value for dehydrogenase activity was noticed with the application of vermicompost enriched with neem cake whereby nitrogen is substituted to a rate of 100%.

A higher fruit yield was realized when compost enriched with Pseudomonas (Pseudomonas @ 1%) + NPK fertilizer was applied (15.74 t $ha^{-1}$). The quality of the resultant compost was also influenced significantly by the application of inoculants pseudomonas 1% and 0.5% and Azospirillum (1%). This study thus clearly showed that the judicious use of bioinoculants such as Pseudomonas, Trichoderma and Azospirillum as potential source of enrichment which improves the soil parameters as well as yield of the crops.

## 23. Chemistry and transformations of calcium and magnesium in tropical acid soils of Kerala

Sixty four representative soil samples from 23 agro ecological units under five agro ecological zones of the state were collected and characterized for physico-chemical properties. Among these soils, ninety two per cent were acidic in reaction, of which sixty three per cent were strongly to very strongly acidic (4.5-5.5). Lowlands of Kuttanad, Pokkali and Kaipad were extremely to ultra-acidic. Twenty seven per cent of samples were deficient (<300 mg $kg^{-1}$) in available calcium, while sixty seven per cent samples were deficient in available magnesium (<120 mg $kg^{-1}$). Deficiency was negligible in soils from Attapady hills (AEU 18 and 19), Palakkad central and eastern plains (AEU 22 and 23) and the lowlands of Kuttanad, Pokkali, and Kaipad (AEU 4,5 and 7). The availability of calcium and magnesium increased with pH, cation exchange capacity and decreased with increase in exchangeable aluminium. Forty one soil samples from different agro ecological units were subjected to sequential fractionation. The mean per cent contribution of different fractions to total calcium was in the order exchangeable > mineral > acid soluble > water soluble > organic- complexed. Exchangeable calcium and water soluble magnesium were the sole forms contributing directly to the available pool.

The quantity-intensity relationship of calcium and magnesium in twenty-three soil belonging to different AEUs of Kerala were studied at 25ºC and 40 ºC. The adsorption data of both calcium and magnesium at 25ºC and 40 ºC were best explained by temperature in adsorption isotherm indicating that the affinity for adsorption decreases linearly with degree of saturation. The change in free energy of adsorption for calcium and magnesium was negative in all the soils studied signifying the spontaneous nature of adsorption. The change in enthalpy ($\Delta H^{o}$) was negative in most of the soils indicating the process to be exothermic. The close correlation of enthalpy change with change in entropy proved that as the enthalpy change becomes more negative, stronger is the bond and more orderly is the adsorption. The addition of organic matter improved the supplying power with respect to calcium and magnesium either through mineralization or formation of stable soluble complexes especially at higher pH.

Two field experiments to optimize the level of calcium and magnesium nutrition for rice in low land of north central laterites (Pattambi) revealed the clear role of calcium and magnesium in

improving the yield and yield attributing characters of the crop. Application of dolomite as per ΔpH was found to be effective in increasing the yield and maintaining optimum level of calcium as well as magnesium in soil. Application of lime was not found to influence the *in situ* soil pH. The response of crop to magnesium showed yield improvement to the tune of 1.18 t $ha^{-1}$ by application of magnesium sulphate @ 120 kg $ha^{-1.}$ Residual effect of dolomite had significant influence on the yield of rice whereas no residual effect of applied magnesium sulphate was evident. The correlation studies and path analysis clearly indicated that plant absorption of calcium mainly takes place from exchangeable fraction and that of magnesium from water soluble fraction.

## 24. Major nutrient disorders of banana (var. Nendran) in Vaikom block

Results on soil properties revealed that acidity varied from very strongly acidic to slightly acidic, with normal electrical conductivity and optimum organic carbon status. Available phosphorus (P) was adequate in the soils due to continuous application of Factamphos and bone meal by the farmers but nitrogen (N) and potassium (K) were found to be deficient. A widespread deficiency of potassium (necrosis of leaves starting from the leaf margin and extending towards the midrib in the fields), calcium (yellow-white parallel streaks in the leaf lamina parallel to the midrib accompanied by severe crinkling of leaves) and magnesium (excessive yellowing started from the central zone of the lamina while the margins and midrib area remained green in colour and chlorosis) was observed whereas sulphur (S) content was found to be sufficient. Application of lime was rare and often the quantity applied was less than the crop requirement (<500 g per plant). The analysis data revealed that the soils were found to be deficient in Boron (B), zinc (Zn) and copper (Cu) whereas iron (Fe) and manganese (Mn) content was sufficient. Deficiency symptoms in banana were either due to actual deficiency or induced deficiency. In certain pockets of Vechoor and Thalayazham panchayath, deficiency symptoms were very prominent even when the soils were having optimum boron content. This induced deficiency was observed in areas were higher levels of phosphorus was seen. The symptoms of boron deficiency were prominent and plants showed delayed unfolding of leaves. Uneven and brittle leaf surface with 'ladder like' symptoms were also noticed in these plants. In severe cases leaves and fruit bunches were malformed.

## 25. Regional soil health management under the project – Soil Resource Management and Biological Soil Fertility

Experiments were conducted to monitor soil health parameters in different agro-ecosystems of Kerala, to develop location specific management technologies to improve and sustain soil health and to assess major, secondary and micronutrient status of soils periodically under different AEUs. Soil samples were collected from geo referenced sampling points under intensive agriculture from different panchayats in the districts of Thrissur, Palakkad, Malappuram, Wayanad, Ernakulam, Kollam and Kozhikode. The samples were analysed for different parameters indicating the fertility status of soil. Samples from the same locations were collected after a period of 3 years and analysed for all the parameters related to soil fertility. The analytical data were arranged into different classes based on fertility ratings. The frequency distribution of samples in each class was represented as per cent of total samples analysed with respect to each district for ease in comparing the changes that had occurred over the period.

The changes that had occurred in the soil fertility parameters over a period of three years in the geo referenced sampling points after advocating crop specific soil test based recommendations were studied and the parameters that require prioritized management have been identified for each district. In majority of the districts covered, measures should be taken to alleviate boron and magnesium deficiency. Amelioration of acidity comes as the next factor especially in Malappuram, Wayanad and Kollam districts. Sulphur deficiency is increasing in Wayanad and Kollam districts. Available phosphorus status is abnormally high in all the districts studied. There is every possible chance of phosphorus induced zinc and boron deficiency. Skipping of application of P-fertilizers may be thought of based on soil test results. Wayanad is the district with all the above problems together – acidity, organic matter degradation and nitrogen deficiency, excessive levels of available phosphorus, increased deficiencies of potassium, calcium, magnesium, sulphur, zinc and copper. The present study clearly indicates that soil test based recommendations are showing positive trends where ever it is implemented properly.

## 26. Network Project on Characterization and management of soil fertility with respect to secondary and micronutrients for Agro eco systems of Kerala

The investigation was carried out to identify the critical level of secondary and micronutrients via. Ca, Mg, Zn, Cu and B in soils and in various crops, to study the response of selected crops in identified areas for the adhoc-recommendation available for secondary and micronutrients. The experiment also aimed the standardization of fertilizer recommendations for various crops with respect to secondary and micronutrients, identification of appropriate mode of application of secondary and micronutrients, for each crop and to study the residual effect and interaction effect of application of secondary and micronutrients on soil physical, chemical and biological system. On-farm trials to identify the critical levels of micro and secondary nutrients for the seasonal crops like rice, vegetables (Yard long Bean, Bitter gourd, Snake gourd), ginger, banana and perennial crops like coconut and pepper were laid out by the PIs of the ten centres covering 23 agro ecological units. The experiments were laid to study the response of crops to different levels of the deficient nutrient: providing all other nutrients as per adhoc recommendations based on soil test. Almost 268 numbers of field trial have been conducted and response for application of secondary and micro nutrients and significant yield increase were observed in the fields where deficiency of elements was noticed.

The salient findings are given in the tables.

| **Crop** | **Element** | **Critical level** | |
|---|---|---|---|
| | | **Soil (mg $kg^{-1}$)** | **Plant** |
| Rice | Calcium | 240 | 0.43% |
| | Magnesium | 90 | 0.33% |
| | Boron | 0.45 | 22 mg $kg^{-1}$ |
| | Zinc | 2.5 | 29 mg $kg^{-1}$ |
| Banana | Calcium | 320 | 0.29% |
| | Magnesium | 78 | 0.15 |
| | Boron | 0.4 | 40 mg $kg^{-1}$ |
| | Zinc | 1.3 | 40 mg $kg^{-1}$ |
| Vegetables<br>Snake gourd & Bitter gourd | Magnesium | 118 - 120 | 0.4% |
| | Boron | 0.53 | 30 mg $kg^{-1}$ |
| Vegetable cowpea | Magnesium | 125 | - |
| | Boron | 0.4 | 26 mg $kg^{-1}$ |

| **Recommendations rice** | | | | | |
|---|---|---|---|---|---|
| **AEU (area)** | **Calcium carbonate (kg $ha^{-1}$)** | **Magnesium sulphate (kg $ha^{-1}$)** | **Borax (kg $ha^{-1}$)** | **Zinc sulphate (kg $ha^{-1}$)** | **Copper sulphate (kg $ha^{-1}$)** |
| 1/ southern coastal plain (Thiruvananthapuram to Ernakulam) | | | 12.5 | 25 | 1.5 |
| 3/Onattukara sandy soils (Kollam and Alappuzha) | | | 12.5 | 10-15 | 1 |
| 4/ (Kuttanad soils) | 350 | | | | |
| 6/ (Kole soils) | 850 | 100 | 15 | 10 | 1 |
| 10/ Laterite soils of Thrissur and Palakkad districts | 500 | | 12.5 | 20 | |
| 22/ Soils of Palakkad central plains Alathur and Palakkad thaluks | | | 5.5 | | |
| 23/ Soils of Chittur thaluk | | | 15 | | 1 |

| **Recommendations Banana** | | | | |
|---|---|---|---|---|
| **AEU/Soil type** | **Calcium $CaCO_3$ (kg $ha^{-1}$)** | **Magnesium sulphate (kg $ha^{-1}$)** | **Borax (kg $ha^{-1}$)** | **Zinc sulphate (kg $ha^{-1}$)** |
| 1/ southern coastal plain (Thiruvananthapuram to Ernakulam) | | 120 | 2.5 | 15 |
| 2/ Northern coastal plain (Thrissur to Kasarcode) | | | 10 | 15 |
| 3/Onattukara sandy soils (Kollam and Alappuzha) | | | 10 | 10 |
| 4/ (Kuttanad soils) | | | 5 g/L | 30 |
| 6/ (Kole soils) | | | | |
| 8/ Laterite soils in the southern parts of Thiruvananthapuram district up to Kazhakoottam panchayat | 500 to 850 | | 5 | 15 |
| 9/ Laterite soils extending from Northern parts of Thiruvananthapuram district (from Kazhakoottam panchayat) to Ernakulam district including both | 500 to 850<br>1250 (if pH < 3.5) | | 5 | 25 |
| 10/ Laterite soils of Thrissur and Palakkad districts | 500 to 850 | | 12.5 | 25 |
| 11/Laterite soils of Malappuram, Kozhikode, Kannur and Kasarcode districts | | | 10 | 15 |
| 15/ Northern high hills (high hill areas extending from Thrissur to Kasarcode (excluding Attappady hills) | | 120 | 12.5 | 15 |
| 22/ Soils of Palakkad central plains Alathur and Palakkad thaluks | | | | 25 |
| 23/ Soils of Chittur thaluk | | | 12.5 | |

| **Recommendations Vegetables** | | | | | | |
|---|---|---|---|---|---|---|
| AEU | Magnesium sulphate (kg $ha^{-1}$) | Borax (kg $ha^{-1}$) | Zinc sulphate (kg $ha^{-1}$) | Magnesium sulphate (kg $ha^{-1}$) | Borax (kg $ha^{-1}$) | Zinc sulphate (kg $ha^{-1}$) |
| | Snake gourd | | | Bitter gourd | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1/ southern coastal plain (Thiruvananthapuram to Ernakulam) | 120 | 10 | 20 | 120 | | 30 |
| 3/Onattukara sandy soils (Kollam and Alappuzha) | | 10 | | | 5 | |
| 4/ (Kuttanad soils) | | | 25 | | | |
| 8/ Laterite soils in the southern parts of Thiruvananthapuram district up to Kazhakoottam panchayat | 100 | 5 | | 60 | 5 | |
| 9/ Laterite soils extending from Northern parts of Thiruvananthapuram district (from Kazhakoottam panchayat) to Ernakulam district including both | | 5 | 30 | | | |
| 10/ Laterite soils of Thrissur and Palakkad districts | 120 | 10 to 15 | | 120 | 15 | |

**Recommendations Vegetable cow pea**

| **AEU** | **Magnesium sulphate (kg ha$^{-1}$)** | **Borax (kg ha$^{-1}$)** |
|---|---|---|
| 1/ southern coastal plain (Thiruvananthapuram to Ernakulam) | 120 | 10 |
| 2/ Northern coastal plain (Thrissur to Kasarcode) | 80 | |
| 3/Onattukara sandy soils (Kollam and Alappuzha) | | |
| 8/ Laterite soils in the southern parts of Thiruvananthapuram district up to Kazhakoottam panchayat | 100 | 2.5 |
| 9/ Laterite soils extending from Northern parts of Thiruvananthapuram district (from Kazhakoottam panchayat) to Ernakulam district including both | 60 | 5 |
| 10/ Laterite soils of Thrissur and Palakkad districts | | 10 |
| 11/Laterite soils of Malappuram, Kozhikode, Kannur and Kasarcode districts | 100 | |

## 27. Silicon and boron nutrition of rice (*Oryza sativa* L.) in wet land soils of northern Kerala

The experiment aims at standardizing the dose and method of application of silicon and boron to rice crop in laterite derived paddy soils, its effect on available nutrient status of soil and yield and to study the effect of Silicon in alleviating the toxicity of Fe, Mn and Al in laterite derived paddy soils. The sources of Silicon tried were potassium silicate and calcium silicate and the source for boron was borax. Method of application evaluated were soil application and foliar spray.

The treatments calcium silicate @ 4 g $kg^{-1}$ soil + borax @ 0.5 g $kg^{-1}$ soil and calcium silicate @ 100 kg $ha^{-1}$ + borax @ 10 kg $ha^{-1}$ produced significantly higher available P in the soil compared to other treatments in the case of pot and field experiments respectively. Application of potassium silicate @ 0.5% spray + borax 0.5% spray 3 rounds was superior to other treatments with respect to available K in soil for both pot and field experiments. Soil application of calcium silicate and borax resulted in highest available Ca in soil in both pot and field experiments. Soil application of calcium silicate was superior to foliar application of potassium silicate with respect to available Silicon content in soil. The investigation carried out under pot as well as field conditions in low land rice ecosystem in laterite derived paddy soils of northern Kerala has shown that the application of potassium silicate @ 0.5% spray + borax 0.5% spray 3 rounds at 15 days interval significantly improved the available nutrient status of soil, content and uptake of nutrient by the plant and yield attributes of rice. It was also effective in reducing the toxicity of Fe, Mn and Al in the soil.

## 28. Network Project on Characterization and Management of soil fertility with respect to secondary and micronutrients for Agro Ecosystems of Kerala

As a part of the project soil samples were collected from different areas of Palakkad and Malappuram districts, analysed for nutrients and field trials were done in micronutrient deficient areas. 20 experiments were done at RARS Pattambi and in farmers' fields under different Agro ecological units of Palakkad and Malappuram districts to find out the secondary & micronutrient requirement of the zone.

In banana, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 22,23) in boron deficient areas, magnesium sulphate @ 100 kg/ha in magnesium deficient areas and zinc sulphate @ 20 kg/ha in zinc deficient areas separately along with soil test based management options for other nutrients improved the bunch yield and quality.

In rice, the application of borax @12.5 kg/ha (AEU 10) and @15 kg/ha (AEU 23) in boron deficient areas, magnesium sulphate @ 120 kg/ha in Mg deficient areas and zinc sulphate @ 30 kg/ha in zinc deficient area separately along with soil test based management options for other nutrients improved the grain yield and quality.

In Coconut, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 13) in boron deficient areas, magnesium sulphate ! 120 kg/ha in Mg deficient areas and Copper sulphate @1.5 kg/ha in copper deficient areas separately along with soil test based management options for other nutrients improved the average yield. Ready to use solid micronutrient formulations for rice and banana have been prepared, tested and released for sale for foliar application.

## 29. Establishment of centre for organic farming in Onattukara

During summer sesamum, cowpea, amaranthus and cucumber were raised in the summer rice fallows. The variety used was bhagya and dhanu during virippu and mundakan respectively. The biometric and yield data recorded during virippu and mundakan are furnished below.

| Treatment | Height (cm) | Total tillers (No.) | Productive tillers (No.) | Yield (kg ha$^{-1}$) | |
|---|---|---|---|---|---|
| | | | | Grain | Straw |
| 100% organic | 96.18 | 10.53 | 8.74 | 2425 | 3431 |
| 75% organic | 93.52 | 9.80 | 8.22 | 2388 | 3376 |
| 50% organic | 91.20 | 8.25 | 7.34 | 2200 | 3008 |
| Control | 90.85 | 7.50 | 6.23 | 2210 | 2989 |

The grain and straw yield obtained by the application of 100% NPK and 75% NPK as organic were high. The yield obtained by the application of 50% NPK as organic is comparatively low.

| Treatment | Height (cm) | Total tillers (No.) | Productive tillers (No.) | Yield (kg ha$^{-1}$) | |
|---|---|---|---|---|---|
| | | | | Grain | Straw |
| 100% organic | 103.52 | 10.23 | 7.25 | 2678 | 5448 |
| 75% organic | 100.25 | 9.84 | 6.75 | 2569 | 5100 |
| 50% organic | 100.30 | 8.89 | 5.82 | 2300 | 4427 |
| Control | 100.24 | 9.00 | 5.42 | 2252 | 4335 |

As in the case of virippu the yield obtained during mundakan season is also the same.

## 30. Organic resource integration for sustainable tuber production in the selected agroforestry systems of western ghat tracts of sourthern Kerala

Litter in agroforestry gardens can be exploited as a nutrient source for tuber cultivation after composting. Leaf litter vary in their allelopathic potential and the crops in which they are used for species like jack, cashew and rubber as much exhibited positive allelopathy while Ailanthus wild jack and tamarind recorded negative allelopathy. Elephant foot yam and tannia are better suited as understory crops in agroforestry gardens. Litter compost at 50% N substitution of POP recommendation (100:50:150 kg NPK ha-1) recorded highest yields in elephant foot yam and on par with 100% organic nutrition. The low cost zero energy cool chambers can be used for temporary storage of tubers up to two months without any significant damage.

## 31. Characterization and evaluation of on-farm liquid organic manures on soil health and crop nutrition

The experiments aimed to the characterization of on-farm liquid organic manures viz., cow urine, panchagavya, fish amino acid, vermiwash and jeevamrutha, to monitor the nutrient release pattern under laboratory conditions and to evaluate the efficacy of soil and foliar applications of these manures on soil health and crop nutrition using bhindi as test crop.

Physical, chemical, biochemical and biological characters of on-farm liquid organic manures indicates they are potent nutrient source to improve soil health, crop productivity and quality. This can also be used as potential alternative for readily available nutrient sources for most of the crops. On-farm liquid organic manures in conjunction with fish amino acid followed by cow urine has given the best result with respect to nutrient release.

75% N as EVC + panchagavya 3% foliar application followed by fish amino acid 5% foliar spray and cow urine 10% foliar spray was superior to all other liquid organic manures in promoting yield and quality of bhindi. The recommended dose of inorganics can be substituted with combined application of enriched vermicompost (to get 75% N) and foliar application of 3% panchagavya or foliar spray of 10% cow urine or 5 % fish amino acid at 10 days intervals

**32. Technology refinement for biochar production and evaluation of its on soil health and crop productivity**

The investigation was conducted for the refinement of technology for micro level biochar production from tender coconut husk and evaluation of its effects on soil health, yield and quality of banana (*Musa spp.).* Biochar produced by modified micro biochar kiln had ideal physical and chemical properties that quality it to be used as a good soil amendment which is environmentally safe and contributing to the soil carbom pool. Biochar application in general, and biochar (10kg/ plant) along with 75% soil test based recommendation in particular, enhanced the soil physical properties decreased the soil acidity, promoted rhizospheric microorganisms, increased soil fertility status enabling efficient nutrient use and resulted in higher growth, profitable yield and superior fruit quality of banana.

**33. Phytoremediation of inorganic contamination in Vellayani wetland ecosystem**

The experiment was conducted to track the potential source of contaminants threatening the Vellayani wet land ecosystem and suggest viable phytoremediation technology

The potential sources of contaminants that threatens the Vellayani wetland ecosystems were discharge from automobile workshop and service centres, agriculture fields, domestic waste from hotels/houses/and other solid waste the pesticide residues were not detected in the system. Fe and Al responsible for the degradation of the ecosystem with minor contributions from Pb and Cd. The best phytoextractors/ phytoremediators identified *E. crassipes* for Fe, *M. vaginalis* for Al, *L. flava* for both Pb and Cd. Among the disposal methods of phyto extracted biomas, biochar production was the safest and ashing the least desirable method.

## Ongoing Projects

**1. Germplasm conservation of indigenous rice varieties and ecological restoration of rice soils**

Germplasm raised during virippu 2014 and mundakan 2014 consisting of 76 and 28 entries respectively. All the entries were characterized based on IRRI descriptor. To study drought tolerance, seedling characters of virippu entries were recorded at 20 DAS. The result revealed that varieties Onam, Bhagya,Chingam, Aiswarya, Deepthi and *Santhosh* exhibited good seedling vigour in terms of height, number of leaves, length of root and number of roots . F1 seeds of the crosses *Santhosh* x PTB-8, chuttiaryan x njavara, PTB 8 x *Santhosh*, OM2x bhagya, bhagya x kanchana were planted and F2 seeds were collected. Ten new crosses viz. Njavara x MO-8,Nandiarvattom x Chingam,MO-8 x Vandana ,Njavara x Kunjukunjupriya, Vandana x Njavara,, Nandiarvattom x MO-7, Kunjukunjupriya x Chingam,Njavara x Kochuvithu, Chingam x Njavara . Kochuvithu x Njavara were conducted and the F1 seeds were collected. For molecular studies

DNA was isolated and marker assisted selection started. 104 germplasm lines were characterized. Ten new crosses were made and F1 seeds of five crosses were collected.

2. **Fertility in relation to movements, losses transformations and interactions in different agroclimatic regions of Kerala**

This experiment is a Permanent Manurial Trial to find out the effect of continuous application of N, P, K and lime over incorporation of straw on soil fertility, yield, quality and incidence of pests and diseases.

There was significant reduction in grain yield on avoiding fertilizer application, both in straw incorporated as well as non-incorporated plots. The treatments with N omission had significantly lower yield and was on par with the control plots. Application of fertilisers based on soil test basis (T9 - NPK with dung application based on the organic carbon status of the soil) gave the grain yield as par with the NPK applied plots (T7 and T8). Skipping of K fertilizer alone did not reduce the yield even after 27 years of experimentation and the yield was on par with that in NPK fertilised fields. Straw incorporation in the field might have helped to improve the K status.

The experimental results during the last 5 years revealed severe nutritional deficiency and yield reduction in the N and P omission for the last 27 years. K omission plots (with straw incorporation and NP application) for the last 25 years had almost similar yield as fertilised plots even after 27 years of K skipping, both during Kharif and Rabi seasons. Nitrogenous fertiliser application is essential in Kuttanad paddy fields (inorganic cultivation) due to the anaerobic decomposition of straw and reduced mineralisation of organic carbon.

3. **Classification and characterization of farming systems in district wise agroecological zones of Kerala**

The above project was undertaken with the objectives of identifying major farming systems in each agroecological zones of fourteen districts in Kerala, integration of background databases including natural resource database for each zone at the District and State level and developing agroecological zone based level reports for fourteen districts and consolidated State level Report.

Reports of all Districts have been published. The reports have been prepared after personal interaction with nearly 850 officers of State Department of Agriculture and over 1200 farmers.

The reports will be a critical input for preparing District level and State level plans and will help policy makers of the State in agricultural development in future.

Documents brought out for implementing the Lead Farmer Centred Extension Advisory and Delivery Services (LEADS) programme of the Kerala State Government (based on project work)

1. Background report for Lead Farmer Centred Extension Advisory and Delivery Services (LEADS) in Palakkad and Kollam Districts -An agro ecological zone perspective (2012) were published jointly by Kerala Agricultural University and Kerala State Planning Board.

Documents brought out for implementing the SREP (Strategic Research Extension Plan) and ATMA Plus programme of the Kerala State Government in all Districts (based on project work)

Fourteen chapters based on the project findings in the “Strategic Research Extension Plan (SREP)” based on agroecological units of all Districts of Kerala

Vital information pertaining to the following critical aspects have been generated for all districts of Kerala

- Major cropping/farming systems followed (intercropping, sequential cropping etc.) in each AEU *i.e.* most common crop combinations and livestock components.
- Major Pest/Diseases/Nutritional Disorder of major crops
- Location specific problems that need intervention by the researchers/extension workers
- Status of technology adoption in major crops
- Average yield and yield gap of major crops

**4. Enhancement of production and Productivity of major crops in Onattukara**
**Sub Project Organic nutrition of medicinal rice Njavara in Onattukara**

The experiment was conducted to study the response of medicinal rice Njavara to organic, integrated and inorganic nutrition and to evolve an ideal management package for profitable production of Njavara. The treatments differ significantly in grain yield and straw yield. Highest grain and straw yields (1408 and 1569 kg $ha^{-1}$) were obtained from the plots which received 75% N as FYM and Trichoderma enriched vermicompost in 1:1 proportion with recommended dose of $P_2O_5$ and $K_2O$ as bone meal and ash respectively.

During Mundakan season also the same trend was observed as in the case of Virippu with respect to biometric observation and yield data. From the results it was found that application of 75% N as FYM + *Trichoderma* enriched vermicompost in 1:1 proportion along with $P_2O_5$ and $K_2O$ as bone meal and ash respectively is found to be effective for optimum production of Njavara in Onattukara.

**5. Permanent Manurial Trial of rice in acid Saline soils under flooded condition (Pokkali tract).**

The experiment was conducted to find out the long term effect of application of inorganic fertilizers on the productivity of Pokkali soils and to assess its impact on rice production.

The yield data for 2014 showed slight yield increase for the N and P fertilizer applied plots but there was no significant increase in yield. The percent yield increase was highest 17.09 %) in the plots receiving N and P @ 20:40 kg $ha^{-1}$. The plot receiving NPK application with lime @ 1 ton $ha^{-1}$ has an increase of 5.67% over control. During this year the application of chemical fertilizers have shown a slight increase in rice yield though not to a significant level. The Pokkali fields are highly suited for organic farming. As a permanent manurial trial, the experiment is to be continued.

**6. Utilization of nutrient specific phytoextractors /accumulators for enriched compost production in organic farming**

Experiment was conducted for identification of phytoaccumulators for specific nutrients by extensive sampling and analysis. Production of enriched compost from phytoaccumulators using vermicomposting and field testing of enriched compost under organic farming situation to assess its efficacy.

Collected and analyzed 362 plant samples. Identified 10 hyper accumulators and the conversion efficiency of the nutrients into compost is being analyzed. Identified 10 hyper accumulator plants having high concentration of total nutrients to the tune of about 10% total nutrient contents.

Based on the nutrient content of the prepared compost and other advantages of the plants, 3 plants namely *Amaranthus spinosus, Canna indica and Mirabilis jalapa* are selected for large scale compost production and crop response study is over.

## 7. AICRP on Long Term Fertilizer Experiments

The results of the kharif and rabi crops 2014-15 have been analyzed statistically and soil samples were analyzed for the different parameters. 50%NPK+ *In situ* green manuring /FYM identified as 2$^{nd}$ best alternative which can reduce 50 per cent of the recommended inorganic fertilizer without compromising yield. This experiment has completed 17 years of experimentation and provides an opportunity to evaluate the sustainability of agricultural practices.

## 8. Network Project on Characterization and Management of soil fertility with respect to secondary and micronutrients for Agro Ecosystems of Kerala

As a part of the project soil samples were collected from different areas of Palakkad and Malappuram districts, analyzed for nutrients and field trials were done in micronutrient deficient areas. 20 experiments were done at RARS Pattambi and in farmers' fields under different Agro ecological units of Palakkad and Malappuram districts to find out the secondary & micronutrient requirement of the zone.

In banana, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 22, 23) in boron deficient areas, magnesium sulphate @ 100 kg/ha in magnesium deficient areas and zinc sulphate @20 kg/ha in zinc deficient areas separately along with soil test based management options for other nutrients improved the bunch yield and quality.

In rice, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 23)in boron deficient areas, magnesium sulphate @ 120 kg/ha in Mg deficient areas and zinc sulphate @ 30 kg/ha in zinc deficient areas separately along with soil test based management options for other nutrients improved the grain yield and quality.

In coconut, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 13) in boron deficient areas, magnesium sulphate @ 120 kg/ha in Mg deficient areas and Copper sulphate @ 1.5kg/ha in copper deficient areas separately along with soil test based management options for other nutrients improved the average yield. Ready to use solid micronutrient formulations for rice and banana have been prepared, tested and released for sale for foliar application. Experiments for identification of critical levels of different nutrients are in progress. Micronutrient formulation for rice and banana were released into market.

## 9. Developing systems recommendation for nutrient, disease and insect pest management in major cropping systems of Kerala (Network)

The field experiments at Palakkad and Karamana have been completed. Summer crop was harvested in May 2015. Soil and plant analyses are in progress.

Trend: Present NPK Recommendation can be reduced by 25 % without reduction in yield in the studied cropping systems.

10. **Developing user friendly weather based calendars for various crops in different agro ecological zones of Kerala (part of a Network project on Weather)**

This project was planned to develop user friendly weather based calendars for rice in different agroecological zones of Kerala. Crop calendar preparation has been completed. Final report preparation is in progress.

11. **AICRP Experiments: Development and Validation of On-Station Integrated Farming System models (Four sub projects)**

a. Homestead based IFS model (0.2 ha)

b. Coconut based IFS model (0.2 ha)

c. Rice based IFS model (0.2 ha)

d. Banana based IFS model (0.2 ha)

All the four fully established models are managed scientifically to realize maximum profit. All these models were more profitable than the predominant farming system of the state. The highest net returns per hectare and employment generation were obtained from rice based IFS (Rs.3,02,775 & 699 man days) followed by homestead based IFS (Rs.2,86,550 & 402.5 man days), coconut based IFS(Rs.2,63,905 & 397.5 man days) and Banana based IFS (Rs. 1,01,815 & 437.5 man days ).The predominant farming system existing in the state realized a net income of Rs.53,440/ha. Nutrient generation and recycling was highest in coconut based IFS, followed by rice based IFS, homestead based IFS and Banana based IFS

12. **AICRP Experiments: 1a on IFS mode - Investigating rice based farming systems involving fish through suitable land modifications vis-à-vis conventional rice based cropping systems**

The experiment was conducted to study the performance of different cropping sequences in rice based integrated farming system involving fish component in terms of soil fertility, energetics and economics. The (rice+fish) - (rice+fish) - (culinary melon+fish) system was most profitable (Rs.1, 65,037/ ha) followed by (rice+fish) - (rice+fish) - (fodder cowpea+fish) (Rs.85007/ ha) and (rice + fish) - (rice + fish) - (amaranthus + fish) (Rs.84473/ha). Fish (channa + tilapia) when simultaneously cultured with rice, generated a gross income of up to Rs.334/- from a cent (40 sq.m).

13. **Experiment 2a- Permanent plot experiment on integrated nutrient supply system for a cereal based crop sequence**

The experiment was conducted to develop a suitable integrated nutrient supply system for a cereal based crop sequence involving more efficient use of fertilizers in conjunction with judicious combination of organic manures by their effective recycling technique, without any detrimental effect to long term soil fertility and improving crop productivity. To achieve the economic optimum and highest productivity, 25 per cent nutrient must be substituted as organics during first crop season and 75 per cent nutrient applied as fertilizers during second crop season. The combination of nutrients entirely as fertilizers alone during first and second crop seasons revealed that a reduction of 50 per cent was detrimental for crop productivity. No significant difference was observed in the N, P and K contents of soil at the end of the rabi season for the organic substituted and the purely inorganic treatments. Though the organic

carbon values showed an increasing trend in the organic substituted treatments, the increase was insignificant.

**14. Development of organic farming package for system based high value crops**

The study was conducted to critically evaluate organic farming vis-à-vis farming with integrated nutrient and pest management systems in terms of yield, its quality, soil health and economic advantages. It also envisages to increase manure production using farm wastes, its application for raising crops, and pest and disease management through the use of plant based preparations.

In rice – cucumber – bhindi sequence crop yields and yield attributing characters did not show much variation among the organic treatments and integrated treatment while crop yields were the least in fully inorganic treatments. Grain yield of rice and yield of bhindi were highest in INM and lowest in fully inorganic treatment. Highest cucumber yield and rice straw yield were in the fully organic treatment supplemented with N and P biofertilizers and least in fully inorganic treatment. The REY was highest (22.96 t/ha) in T1 receiving integrated nutrition and least (18.99t/ha) in T7 with full inorganic nutrition. It indicates the benefit of organic + inorganic nutrient combination for cereal based cropping system than fully organic or chemical treatments.

**15. Development of innovative farming practices to mitigate the effect of climate change**

Experiment was planned to design and identify economically viable and efficient farming practices for resource conservation and counteracting adverse effects of climate change and to study the effects of resource conservation technologies on photosynthetic efficiency, biomass production, economic yield, soil hydro thermal regimes and soil health.

The system productivity in terms of rice equivalent yield was better for minimum tillage, crop residue mulch application and where 25 per cent of nutrients were substituted with organics, when compared to conventional tillage, no mulch and full inorganic fertilization respectively. CS3 (Rice- Cucumber- Amaranthus) was found to be the best cropping system with respect to REY. Kharif and rabi crops were successfully taken. During the third crop season pulses viz. green gram and black gram had set fruits but seed setting did not occur due to adverse weather condition. Vegetative growth was also excess.

**16. 'Optimization of organic component in the fertilizer recommendation of amaranthus'**

The experiment was planned to assess the optimum level of organic manure to be recommended for maximum economic yield in amaranthus. From the farmers field trials it was found that the present PoP recommendation of 50 t/ha of farm yard manure for amaranthus could be reduced to 25 t/ha without any significant reduction in yield.

**17. Long range effect of continuous cropping and manuring on soil fertility and crop productivity**

The aim of the experiment is to study the long range effect of crop rotation with high yielding varieties at graded fertilizer levels on the yield stability and soil fertility. From the experiment so far conducted it is revealed that though phosphorus is not generally a limiting nutrient in the acid soils of India, skipping of P fertilization for more than three years affects rice yields even under

sufficient levels of nitrogen application and also affects crop response to N and K. Plant height, total and productive tillers increases significantly with increasing rates of N and P application. Withholding P fertilization for over three years resulted in a decrease in these parameters. In contrast to N, consecutive increase in P up to the third level was found to stimulate growth and tiller production significantly. Withholding phosphorus also increases days to flowering and days to maturity of the rice crop by about two weeks and decreases the uptake of N and K. At equal levels of fertilizer addition the agronomic efficiency was more for P than for N. P levels showed positive influence on the uptake of N and K by both grain and straw. Skipping phosphorus continuously for more than three years considerably reduced the soil P levels.

Though phosphorus is not generally a limiting nutrient in the acid soils of India, skipping of P fertilization for more than three years affects rice yields even under sufficient levels of nitrogen application and also affects crop response to N and K. Plant height, total and productive tillers increases significantly with increasing rates of N and P application. Withholding P fertilization for over three years resulted in a decrease in these parameters. In contrast to N, consecutive increase in P up to the third level was found to stimulate growth and tiller production significantly. Withholding phosphorus also increases days to flowering and days to maturity of the rice crop by about two weeks and decreases the uptake of N and K.

Phosphorus can be skipped for six seasons without any significant reduction in grain yield in riverine alluvium soils of medium to high in available P. P should be applied after a three year skipping period since further skipping detrimentally affects the growth and yield of rice in addition to delaying flowering and maturity for about two weeks even in the presence of adequate levels of nitrogen and potassium.

## 18. Evaluation of a customised organic fertilizer in relation to labile carbon dynamics, nutrient release characteristics and productivity of banana

**1.** ***Characterization of waste and the transformed organic manure*****-** Degradable solid waste from households were collected and manure produced through the rapid thermochemical conversion technology. Representative samples of degradable solid waste and the processed organic fertilizer were collected. Characterization with regard to various physicochemical parameters of both degradable solid waste as well as the manure were done. Heavy metal concentration was also determined. Fertility index and clean index of the organic fertilizer were worked out as per quality standards prescribed by IISS, Bhopal.

***2. Soil test based fortification of the manure with inorganic nutrients for customised application to Nendran banana in AEU 8*** **-** Soil analysis of the representative site of AEU 8 was done and soil test based fertilizer recommendation of Nendran banana as per Package of Practices of KAU was selected. The processed organic manure was then fortified with required inorganic nutrients for customised application to Nendran banana.

***3. Investigations on nutrient release characteristics of the customised organic fertiliser (COF)-*** The laboratory soil incubation experiment to study the nutrient release characteristics of the customised organic fertiliser is in progress. Soil samples are drawn at fixed intervals from the incubation pots maintained at field capacity. Soil analysis to determine the available nutrient status of soil is under progress.

***4. Effect of customised organic fertiliser on labile carbon dynamics and yield of Nendran banana*** **-** The field experiment was laid out at the Instructional Farm, College of Agriculture, Vellayani. Manure and fertiliser application were done as per treatments specified. Soil and foliar samples were drawn and analysed for assessing the nutrient contents before each split application. Field observation of plant biometric characters and yield attributes of banana were also recorded.

## 19. Organic resource integration for sustainable tuber production in the selected agroforestry systems of western ghat tracts of southern Kerala

The project was intended with the main objectives, to assess the biodiversity and tuber cultivation practices in selected agroforestry systems in the western ghat tracts of Kollam, southern Kerala and to examine the potentials of recycling litter as nutrient source for tuber production in the systems. The study based on the informations collected from 165 respondents that tubers are the mainstay in agroforestry systems, preference being in the order Elephant foot yam, tannia, greater yam, cassava, taro and arrow root. Coleus and sweet potato were grown to a small extent alone as these require full sunlight for satisfactorytuber development and yields.

Three agrofrestry systems in the western ghat tracts of Kollam district were selected for the field study and the diversity worked out using Shannon-Weiner index. The maximum value (2.08) was recorded in the agroforestry system at Andoor, Ummanoor panchayat comprising of 40 species crops of which 29 were perennial. The diversity indices in the other two locations (Elampal, Vilakudy panchayayt and Thrikkanamangal, Kottarakkara panchayat) were lower, but had more number of plants per tree species. Litter fall from the tree components in systems ranged from 672 to 592 kg per year excluding those from coconut and rubber revealing its scope for use as organic resource in crop production. The litter were composted using earthworms (*Eisenia foetida*) and the composted material were incubated with biofertiliser PGPR Mix I and used for tuber production. Litter in agroforestry gardens can be exploited as a nutrient source for tuber cultivation after composting. Leaf litter vary in their allelopathic potential and the crops in which they are used for. Species like jack, cashew and rubber as mulch exhibited positive allelopathy while Ailanthus wild jack and tamarind recorded negative allelopathy. Elephant foot yam and tannia are better suited as understorey crops in agroforestry gardens

Litter compost at 50% N substitution of POP recommendation (100:50:150 kg NPK $ha^{-1}$) recorded highest yields in elephant foot yam and on par with 100 % organic nutrition. The two treatments have been found to best based on the crop performance influence of soil properties and ecocnomic returns. The low cost zero energy cool chambers can be used for temporary storage of tubers upto two months without any significant damage

## 20. Phytoremediation of inorganic contaminants in Vellayani wetland ecosystem

***1. Peripatetic inventory of the catchment areas of Vellayani lake*** - Water and sediment samples were collected from the major sites and the tributaries of Vellayani lake. Dominant native macrophytes were identified. Major physical and chemical parameters were analysed including Fe, Al, Pb and Cd content. Both water and sediment samples were subjected to pesticide residue analysis. Total coliform count in water samples were determined using MPN method. Plant density of major macrophytes was determined in the field itself.

***2. Evaluation of native macrophytes for possible hyper accumulation capacity for Al, Fe, Cd and Pb -*** The metal concentration in the collected dominant native macrophytes was estimated using ICP OES. Metal as well as microbial load of the sediments were also determined. Based on the metal uptake by the plants, hyper accumulators were identified.

***3. Performance of selected hyper accumulators under graded doses of toxic metals to identify their retention sites -*** The selected hyper accumulators were raised in pots under varied doses of the toxic metal – three higher doses were given. Plants were grown for a period of 45 days, then uprooted, separated into shoot and root and analysed for metal content. Microbial load in the rhizosphere was also estimated.

***4. Bioavailability of phytoextracted metals and comparison of common disposal methods -*** Vermicompost, ordinary compost, ash and biochar were prepared from the phytoextracted biomass. Pot culture experiment has just been started using these treatments. The test crop taken is amaranthus (variety- Arun).

## 21. RF-STL (Continuation of National project on management of soil health and fertility –Stationary Soil testing laboratory and mobile soil testing laboratory (in RF mode)

Analysed 4314 soil samples and gave fertilizer recommendations. An amount of Rs. 11,94,320/- was remitted to the KAU on this account.

## 22. Pilot plant for rapid conversion of degradable wastes to organic fertilizer.

The project was undertaken to install a pilot plant and demonstrate the process of rapid conversion of degradable wastes to organic fertilizer. Construction of building for housing the Pilot Plant is completed. Procedure for installation of machinery is progressing. Action for fabrication of small scale machine suited to residential flats was initiated.

## 23. Strengthening of Lead Centre for Organic Farming at College of Agriculture, Vellayani- GOK Plan

Strengthening and maintenance of Certified Model Organic Farm (area 3 acres) under the Department of Soil Science & Agricultural Chemistry, College of Agriculture as a permanent field study centre for demonstration and training purpose in the area of Organic Farming. On farm preparation and evaluation of liquid organic manures (Panchagavya and fish amino acid) on vegetables are in progress. Conducted one day training programme on Scientific Organic Farming for farmers of Southern districts of Kerala (Thiruvananthapuram, Kollam and Pathanmthitta) and 100 numbers of farmers attended the programme on 21.03.2015. Experts of College of Agriculture, Vellayani had handled the classes and demonstration on Organic Farming and Organic Certification. Distributed vegetable seeds for promoting Organic Vegetable cultivation in the farmers' fields. Experiments are going on to develop cropping system based PoP on Organic Farming

## 24. A comparative study on soil chemical and biological regimes under coconut in red and laterite soils of Trivandrum Dt – A farmer participatory active research

The project was undertaken to assess the dynamics of soil enzyme, soil physic-chemical characters under different cropping and farming situations in red loam and laterite soils of Trivandrum district. A general soil resource data was generated based on the soil collected in various localities. With respect to soil chemical characteristics of the 12 Block panchyaths a significant variation in the properties were noticed. In general the soils are found to be moderately acidic warranting application of liming materials. The status of available P is high in majority of the soils due to the high input of P fertilizers. From the assessment of Biological fertility indices of various soils, the highest values were reported with the redloam soils than the laterite pockets. Within the redloam soils, the organically treated plots showed a distinctively higher values than the conventional plots. Coconut + Tuber and Coconut + Fodder were found to be sustaining the soil biological health. Excessive use of high input acid forming fertilizers and near absence of practice of liming in the soil has resulted in the intensification of soil acidity.

Deficiency of Boron nutrition is noticed and warrants the application of Boron micronutrient. A correlation between the micronutrients and soil enzyme activities revealed a significant and positive correlation between them and the enzyme dehydrogenase is highly influenced by the availability of micronutrients in soil. Among the crops selected for the study coconut + fodder have reported to have improved many of the soil physical and chemical attributes as the quantum of organic matter added or recycled to the soil is more compared to the others. With respect to soil biological properties coconut + banana was found to be the best in respect of enzyme activities and soil respiratory activity.

## 25. Herbicide mixtures for weed management in direct seeded puddled rice (Oryza sativa L.)

The programme aims to study the bio-efficacy of post emergence herbicide mixtures for weed control in direct seeded rice, its effect on soil microflora and fauna, enzyme activity in soil and weed seed bank. It also intends to assess the *in-vitro* sensitivity of herbicide mixtures to soil borne pathogen (*Rhizoctonia solani*), bio control agents (*Pseudomonas fluorescens* and *Trichoderma viride*) and bio- fertilizer organism (*Azospirillum sp*.) Screening of indicator plants for the herbicides, bispyribac sodium + metamifop and penoxsulam + cyhalofop butyl were carried out separately using the test plants, cucumber, maize and sunflower. The maize plant registered the highest $R^2$ value for all the parameters tested and hence it was selected as the best indicator plant. Among the parameters studied, shoot dry weight recorded the highest $R^2$ value and it was selected as the best parameter for the detection of herbicide residue.

Regarding the herbicide residue in soil, it can be inferred that the herbicide mixture, penoxsulam + cyhalofop butyl would not leave any phytotoxic residue in soil which can cause growth inhibition in maize crop.

## 26. Development of Saltol Sub1 mega rice varieties for flood prone salt affected areas and standardization of production technology

The project was started during 2012-13 with the objective of introgressing abiotic stress tolerant QTL / genes *(SalTol* QTL and *Sub1* gene) into three mega rice varieties which are under wide cultivation in Kerala. The outcome of the project is expected to be an answer to the salinity intrusion and submergence consequent to climate change.

Brief account of results:

1. Hybridization between the recurrent parents (female) – Jaya, Jyothi and Uma each with donor male parents FL 478 (Salinity tolerant) and Swarna Sub1 (Submergence tolerant) were successfully done.
2. Phenotyping assays for salinity and submergence tolerance were done with parents of interest under study.
3. Healthy mature $F_1$ seeds were harvested and dried under the sun for one week and stored under $-20^0$ C.
4. Molecular primers have been designed and selected from public database. These primers were synthesized (sigma) and are optimized for molecular works.
5. Among 247 SSR background markers which were completed for Parental genotyping, 141 showed polymorphism with six rice varieties under study. The background selection using SSR background markers is doing to identify background introgression. The microsatellite markers that revealed fixed (homozygous) alleles at non- target loci at one generation were not screened at the next generation.
6. Biostatistical analysis of background screening using NTSYS pc version 2.0 were completed.
7. Foreground and recombinant selection for salinity tolerant studies were completed.
8. Hybridization between recurrent parent (Jaya) and Jaya F1 was successfully done.
9. Genotypic selection using *Saltol* specific foreground markers SKC 10 and AP 3206 were done with Jaya F1 progenies.
10. Positively selected Jaya F1 progenies were forwarded to hybridization with recurrent parent Jaya.
11. Parental genotyping using 20 Saltol SSR reproductive stage markers were completed. The selection using SSR markers is being done to identify *Saltol* gene introgression. The microsatellite markers that revealed fixed (homozygous) alleles at non- target loci at one generation were not screened at the next generation.
12. Genotypic screening of F1 progeny was done using *Saltol* foreground marker AP3206 and SKC10 to check hybridity The progeny with saltol introgression were selected for backcrossing with Recurrent parent Uma to raise BC1F1 seeds.
13. The panicles of selected progeny were emasculated and cross pollinated with recurrent parent Uma.
14. BC1F1 seeds (For Salinity tolerance) were kept for germination and germinated seedlings were transferred to tray.
15. Seeds of recurrent parents(Uma, Jaya) and BC1F1 seeds positive for *Saltol* locus introgression were germinated and pot planted for raising next generation(BC2F1 seeds).
16. Out of 44 submergence specific foreground primers, genotypic screenings of 25 primers were completed. Amplification pattern of Aiswarya, Jyothi, Jaya, Uma, FR 13 A and Swarna sub 1

with the primers Sub1 BC3, SSR1A were found to be polymorphic and can be used further in the screening of F1 plants.

17. In Jaya and Swarna *sub1* control plants a specific pattern for carbohydrate content was not observed. But in the case of Jaya and Swarna sub 1 submerged plants, a decrease in the carbohydrate content was observed except for 14 th day. So the experiment will be repeated to get a specific pattern for carbohydrate content in both control and submerged plant.
18. BC2F2 seeds (for submergence tolerance) were harvested and dried.
19. Germinated three sets of parents and BC2F2 seeds for raising $BC3F_1$ generation.
20. Background genotyping of BC2F2 plants (*Saltol* introgression) and *Sub1* introgression are being done.

## 27. Permanent Manurial Trial- Tall

The experiment was undertaken to study the effect of continuous application of Cattle manure, green leaves & ammonium sulphate individually and in combination with and without P and K on the yield of Tall Indica rice & the soil properties.

Highest grain and straw yield was obtained from the plots which received integrated nutrient management system. Plots which received inorganic nitrogen in the form of ammonium sulphate recorded the lowest yield. Continuous application of nitrogenous fertilisers alone or NPK in the form of inorganic fertilizers alone were found to have detrimental effect on the growth and yield of rice. Biological parameters analysed indicated that there is no detrimental effects of fertilizers if applied along with enough organics.

PMT (T) has completed 52 years of experimentation and provides an opportunity to evaluate the sustainability of agricultural practices.

## 28. Permanent Manurial Trial- Dwarf

Experiment was find out he effect of continuous application of cattle manure, green leaves and Ammonium sulphate individually and in combination with and without P&K on the yield of dwarf Indica rice and soil properties.

Highest grain and straw yield was obtained from the plots which received integrated nutrient management system. Plots which received inorganic nitrogen alone in the form of ammonium sulphate recorded the lowest yield followed by NPK from chemical fertilizers. Continuous application of nitrogenous fertilisers alone or NPK in the form of inorganic fertilizers alone were found to have detrimental effect on the growth and yield of rice. Biological parameters analysed indicated that there is no detrimental effects of fertilizers if applied along with enough organics.

PMT (D) has completed 42 years of experimentation and provides an opportunity to evaluate the sustainability of agricultural practices.

## 29. Productivity and soil health of rice based cropping systems under organic management

The project aimed to study the soil health and crop productivity under organic rice based cropping systems and it is in progress.

## 30. Shelf life of liquid organic formulations

The project aimed to study the shelf life of liquid formulations by analyzing the chemical and biological properties and to study the effect on growth and yield of cucumber. The experiment is in progress.

## 31. AICRP on Management of salt affected soils and use of saline water in agriculture

1. **Survey, characterization and mapping of ground water quality in the coastal areas of Kerala**

The experiment was carried out to study the chemical composition of ground water as influenced by seawater/ brackish water intrusion, to assess the ground water quality for irrigation and to prepare geo-referenced map of salt affected areas of Kerala. The whole study area falls under eleven districts of Kerala viz. Thiruvanamthapuram, Kollam, Pathanamthitta, Kottayam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragode.

In this study, it was observed that the ground water samples collected from places, which are near to sea, have more salinity. It may be due to intrusion of sea water/brackish water into these places. Salinity can be reduced to a certain level by adoption of proper management techniques such as mixing up of saline water with fresh water/rain water, rainwater harvesting, use of surface or sub-surface drainage systems, bunds to prevent the intrusion of saline water, etc.

2. **Delineation and mapping of salt affected soils in the coastal areas of Kerala**

Objectives include surveying the salt affected soils using GPS, studying the chemical properties of soils and to prepare geo-referenced map of salt affected soils of coastal belts of Kerala. The places which are near to sea are under severe salinity. It may be due to intrusion of saline water into these places. Prevention and reclamation of salt affected soils require an integrated management approach, monitoring and maintenance, implementation of efficient irrigation and drainage systems and good farming practices including proper crop selection and rotation for sustainable development of agriculture in these salt affected areas.

3. **Raised and sunken bed technology for sustainable land use in Pokkali lands**

It was seen that, mulching with polythene sheet is having a significant effect on crop growth and yield of vegetables viz. cauliflower and bhindi at RRS, Vyttila. In case of cabbage and cowpea, the yield was more in treatments without mulch. The cool season vegetables did not come up well in typical *Pokkali* lands. As compared to growth performance and yield of cauliflower, growth of cabbage was very poor and more susceptible to salinity at farmer's field. There is a periodic increase in electrical conductivity of water due to brackish water intrusion. This may increase the salinity of soil and affect the crop growth and yield. By the adoption of proper management techniques to reduce this salinity, sustainable yield of crops can be achieved.

4. **Rice – prawn integration in *Pokkali***

Objectives include evaluating the rice-fish/prawn integration in *Pokkali* lands for maximum productivity, analyzing the changes in soil properties etc. The rice-prawn integration was found to very beneficial and successful in *Pokkali* lands. As the left overs of prawn cultivation become manure for rice cultivation, there would not be any additional application of fertilizers. It may enhance the soil qualities as well as the growth and yield of following rice crop.

**32. Socioeconomic analysis and farmer participatory development of homestead farms of Kerala (Network project)**

The project is going on with the objective to Introduce innovative farming methods to improve production and income from unit area and transform them into beacon home gardens for propagating in the State and to suggest policy initiatives and development strategies for improving homestead farming in Kerala. The selection of homesteads in consultation with ATMA was completed. Various location specific technical interventions following a system approach have been made in consultation with the farm family. The impact of the intervention are being monitored. Some innovative models will be suggested for each region by end of 2015-16. The project is linked to an ongoing State Plan funded Project entitled "*Centre for Studies on technology society interface and policy in agriculture*" operating in the College of Horticulture, KAU, Vellanikkara. The centre is in the process of undertaking the socioeconomic study.

**33. Evaluation and development of pre seeded technology in Direct Seeded Rice**

Organic sheets utilizing waste paper pulp, coir pith compost, dried leaf and aquatic weeds were prepared with 1x1m size and different thickness. Sheets with 0.8 mm thickness is found to be stable in the soil up to 60 days which is the ideal period for weed control in rice which decreased the weed infestation and showed yield advantage. Yield advantage is 1450 kg/ha and in economic terms, it is Rs. 21750/ha. Additional expense in pre seeded sheet is Rs.12,412 and additional return in per seeded sheet is Rs. 21750. Hence the economic advantage is Rs. 9338/ha (21750-12412). If the sheet is provided free of cost the advantage is Rs. 49338/ha. Rolling sheet technology standardized with lesser initial cost.

**34. Capacity building for spatial planning in the agriculture and allied sectors of Kerala.**

The project was undertaken with the objective of establishing pilot training facilities on GIS, GPS and Remote Sensing. Established facilities for GIS training by installing networking facility with a server computer and twenty clients in GIS laboratory. Celebrated GIS day on 14$^{th}$ November by conducting a seminar on applications of GIS in agriculture and released a CD in this connection. Orientation was provided to the PG students and the scientists of COA Vellayani, NARP (SR) Vellayani and the nearby research stations on use of GIS in preparation of thematic map and mapping of various attributes related to soil, climate and crop. Koliyoor micro water shed was selected for characterization of soils using GIS.

**35. Nutrient management for organic rice based cropping system**

The study aimed to develop nutrient schedule for organic rice-rice-vegetable system, to assess the residual effect of organic nutrition, to compute the energetics and economic feasibility and to evaluate the impact on soil health of organic rice based cropping system. Three crops were over and the experiment is in progress.

**36. Impact assessment of landfill on soil health and water quality in a waste disposal site**

The was conducted to assess the impact of dumping Municipal Solid Waste (MSW) on soil and water quality, spatial variability in the level of biological and chemical contamination along the leachate flow zone and identification of a few bioremediators and their possible effectiveness of

decontamination. Various types of samples viz. landfill, leachate, water and soil samples were collected at three consecutive seasons viz pre monsoon, monsoon and post monsoon seasons. The samples were analyzed for pH, EC, BOD, COD, Available N, P, K, organic carbon and heavy metals. Statistical analysis is in progress. Conducted sand culture experiments and pot culture experiments using different flowering plants and *Alternanthera* identified as best hyper accumulator and other works are progressing.

## 37. Establishment of Centre for Organic Farming in Onattukara

The project was undertaken to establish a center for organic farming in Onattukara in a multidisciplinary approach to promote research and extension activities in the field of organic farming and to evaluate the socio–economic status of farming community by income maximization through product diversification and value addition, employment generation and create awareness on participatory approach to make the farmers self-reliant in organic management of crops. Demonstrations were laid out during v*iripp*u and *mundakan* in rice. During summer sesamum, cowpea ,amaranthus and cucumber were raised in the summer rice fallows. The grain and straw yield obtained by the application of 100% NPK and 75% NPK as organic were high. The yield obtained by the application of 50% NPK as organic is comparatively low. As in the case of virippu the yield obtained during mundakan season is also the same.

## 38. KAU – KVASU Collaborative Project on 'Hatchery Waste Disposal and its effective utilization

Hatchery waste for the experiment was collected from the Hatchery unit of the Regional Poultry Farm, Kudappanakkunnu. Different treatments were applied for processing the waste. The technology found feasible consisted of the following steps.

1. Sorting: The collected hatchery waste was sorted into three separate groups (Empty egg shells, dead in shells & unfertilized eggs).
2. A method was developed to separate egg shells and egg shell membranes (ESM) so that they could be used for industrial/pharmaceutical purposes which will fetch high price. The method is being tested repeatedly.
3. A method was developed to produce organic fertilizer from the other two groups (ded-in-shell and unfertilized eggs). The method is being tested repeatedly.
4. The organic fertilizer developed is being tested in laboratory for nutrient content.
5. Plant growth trials are being conducted to study their effect on plants and to test whether any phytotoxicity is expressed.

## 39. Mobile and stationary Soil Testing Lab – Revolving Fund

Soil testing services were extended to farmers, students and researchers on payment basis. During the year, 326 – soil samples, 126 – plant samples, 11 – Manure samples, 3- compost and 1 – water samples were analysed. Soil test based recommendations to various crops were given to farmers. The total income generated through the analytical services was Rs.2, 17,008/- (Rupees Two Lakhs Seventeen thousand and Eight only)

## 40. Solid Waste Management – Revolving Fund

During the year, an amount of Rs.1, 25,390/- was generated through sale of waste processing kits, organic fertilizer, conducting trainings and as university share for installation of 'Suchitha' units.

## 41. Continuation of mobile soil testing service to farmers

Soil testing services were extended to farmers, students and researchers on payment basis. 506 – Soil samples, 7 – Manure samples, 30 – water samples and 1 liming material were analysed. Soil test based recommendations to various crops were given to farmers.

## 42. AICRP on Long Term Fertilizer Experiments

Integrated nutrient management and in situ green manuring with daincha recorded higher grain and straw yields and in situ green manuring was identified as a cost effective and farmer friendly technology. In situ green manuring (Daincha) could save cost of 5 tonnes of farmyard manure. Though there was no significant change with regard to soil pH, the lime requirement of soil got reduced in the treatment which received lime since 1997. The continuous, long term application of lime and organic manures increased the pH of the soil measured in 1 M KCl and 0.01 M $CaCl_2$ after 16 cycles of the rice-rice cropping systems. The NPK balance sheet over eight seasons indicate that the K content in the soil had a negative balance even in treatment which received 150% of the recommended dose of potassium along with other nutrients. In general the soil organic carbon is higher even in control plots which could be attributed to the incorporation of stubbles and weeds into the soil. The soils collected form plots which received differential doses of fertilizers and different organic manures differed in the pools of potassium excepting total potassium. 50% NPK + in situ green manuring/FYM identified as $2^{nd}$ best alternative which can reduce 50 per cent of the recommended inorganic fertilizer without compromising yield.

## 43. Effects of herbicides and chemical characteristics of soil on microbial biomass carbon and enzyme activity

The project was undertaken to determine the impact of pre and post emergence herbicides on microbial biomass carbon and the soil enzymes namely dehydrogenase, phosphatase and urease and also to study the influence of chemical charactersitics of soil on these biotic components.

Data on analysis of soil samples before the experiment revealed that all the physical, chemical, and biological charactersitics which are more favourable for the growth of microflora are exhibited by rice soils of Kole land, Alappad. Based on the organic carbon content, the soils under study can be ranked in the order: Rice field, Kole>non-cropped, Kole>non-cropped, ARS> rice field, ARS. Adverse effect of herbicides on biological parameters can be ranked in the order: pendimethalin>bispyribac-sodium>oxyfluorfen>cyhalofop-butyl.

Chemical charactersitics of the soil viz. pH, electrical conductivity, and organic carbon followed a decreasing trend towards the harvest in all the treatments. Out of the five biological parameters analysed, microbial biomass carbon showed the highest variation from control at all the sampling intervals. Results indicated that the herbicides had negative effect on microbial biomass carbon.

Dehydrogenase activity also showed a decline due to the application of herbicides, but to a lesser magnitude than microbial biomass carbon. The adverse effect was pronounced only at 15 days after application of herbicides and followed the order viz. pendimethalin>bispyribac-sodium>oxyfluorfen>cyhalofop-butyl. The adverse effects were of lower magnitude in the soils of high organic matter content. Microbial biomass carbon, activity of dehydrogenase, urease, acid phosphatase and alkaline phosphatase were higher in S2 (high organic matter soil) compared to S1 (high organic matter soil). All the vegetative and yield parameters of rice were also high in irrespective of the treatment combinations. Organic carbon had highly significant and positive correlation with all the biotic components viz. Microbial biomass carbon, dehydrogenase, urease, acid and alkaline phosphatase activity.

## 44. Influence of weed management techniques on the quality attributes of soil in an Ultisol

The study was carried out with the objective to evaluate the changes in physical, chemical and biological charactersitics of soil in an Ultisol due to different weed management practices in brinjal (*Solanum melongena* L.). The chemical characteristics of the soil viz., pH, electrical conductivity, and organic carbon followed a decreasing trend towards the harvest in all the treatments. Out of the five biological parameters anlaysed, microbial biomass carbon showed the highest variation from control at all the sampling intervals. Results indicated that the herbicides had negative effect on microbial biomass carbon. Dehydrogenase activity also showed a decline due to the application of herbicides, but to a lesser magnitude than microbial biomass carbon. The adverse effect was pronounced only at 15 days after application of herbicides and followed the order viz. pendimethalin > bispyribac - sodium> oxyfluorfen > cyhalofop - butyl. The adverse effects were of lower magnitude in the soils of high organic matter content. Microbial biomass carbon, activity of dehydrogenase, urease, acid phosphatase and alkaline phosphatase were higher in $S_2$ (high organic matter soil) compared to $S_1$ (high organic matter soil). All the vegetative and yield parameters of rice were also high in (high organic matter soil) irrespective of the treatment combinations. Adverse effects of herbicides on the plant characters were minimal. Organic carbon had highly significant and positive correlation with all the biotic components viz., microbial biomass carbon, dehydrogenase, urease, acid and alkaline phosphatase activity.

## 45. Evaluation of soil and water quality in Potta watershed of Pazhayannur block in Thrissur district

pH of the soil samples ranged from 3.47 to 6.80. The highest organic carbon content was recorded in the soil samples of middle reach. The CEC of the soil samples ranged from 4.16 to 8.98 cmol $p^+$ $Kg^{-1.}$ The highest mean available N, P, K, S were recorded for the soil samples of middle reach, whereas the level of micronutrient was found to bethe highest in the upper reach. The pre-monsoon water samples recorded higher pH than post monsoon samples. The EC of water samples ranged from 0.14 to 0.54 d $Sm^{-1}$. The comparison between the quality of water samples collected in pre monsoon and post monsoon samples showed that there was significant difference between them with respect to the contents of calcium (8.24-20.08 me $L^{-1}$) and magnesium (3.14-14.32 me $L^{-1}$) with higher values in post monsoon season. Among the anions,

the content of bicarbonate and chloride were higher than that of nitrates and sulphates. Results of soil analysis revealed that soils in the upper and middle reaches were in the threat of severe loss of nutrients (N, P, K, Ca, Mg, and S) either by soil erosion or by leaching. The quality of irrigation water from all the sources was coming under safe category for irrigation when compared with standard values.

**46. Formulation and evaluation of micronutrient mixture for foliar application in TC banana (*Musa* sp.) var. Nendran**

The hardening studies were conducted in the mist chamber, Department of Plant Biotechnology, College of Agriculture, Padannakkad, Kerala with TC plants of uniform size multiplied from same genotype. The experiment was carried out in completely randomized design with 12 treatments and one absolute control maintaining 3 replications each and there were 4 plants in each replication. The Highest net return (Rs.6, 94, 964) and benefit cost ratio (2:3) was registered with foliar application of 3% micronutrient mixture as three sprays. The quantity of spray solution required for best treatment on projection to one ha is 56 litres, with an additional cost of Rs.160/- litre for the mixture plus Rs.600/- day as cost of labour for application. The positive effects of the micronutrient foliar spray solution indicate the need of these nutrients on banana. This effect can be further evaluated on vegetables and other crops. On the basis of the results thus obtained recommendation can be made on adhoc basis.

**47. Gypsum as a soil ameliorant for black pepper (Piper nigrum I.) in acid soils of Wayanad**

To assess the performance of gypsum as a soil ameliorant in growth and development of black pepper and to evaluate its suitability in promoting root growth in deep soil layers of Central plateau of Wayanad (AEU 20). The results of investigation indicated that application of gypsum as an amendment alone or in combination with burnt lime and dolomite reduced the surface and subsurface acidity and increased the available nutrient status in the surface as well as sub surface soil layers, which might have resulted in better root proliferation favouring vigorous plant growth and development of black pepper in acid soils.

**48. Silicon, boron and zinc nutrition of bittergourd (*Momordica charantia*)**

Both pot culture and field experiment indicated the effect of silicon and boron are more important than zinc in bittergourd. T14 (B-0.6% foliar + Zn-0.2% foliar + Si-40 ppm in the soil found to be performing well under pot culture and field conditions respectively.

**49. Flux and dynamics of iron and aluminium in wetlands of Kuttanad and its management for rice (*oryza sativa* l.)**

The acid sulphate soils of Kuttanad region are having constraints of extreme acidic soil pH and pronounced toxicity of Fe and Al. This can be ameliorated using amendments and can be made more productive. The results of the investigation clearly indicate that application of phosphogypsum along with lime and foliar application of B and Si (phophogypsum + ½ lime @ 300 kg $ha^{-1}$ + protassium silicate 0.25% + 0.25% boron) enhances the grain and straw yield of

rice. This treatment also enhanced the available nutrient status of soil and plant nutrient content. It was very effective in alleviating toxicity of Fe and Al.

**50. Dynamics of iron and aluminium toxicity on rice (*Oryza sativa* L.) in saline hydromorphic soils of Kaipad**

The saline hydromorphic soils of Kaipad are having severe constraints of acidicity, extreme toxicity of iron and aluminium coupled with high salinity. These problems can be ameliorated using combinations of amendments including phosphogypsum, lime and foliar application of boron and silicon (Phosphogypsum @ 500 kg $ha^{-1}$ + ½ lime as per KAU POP, 2011 + potassium silicate – 0.25% boron) to enhance the growth and yield of rice crop. Adoption of aforementioned management strategy could help in improving the soil health and thereby increasing the yield potential of Kaipad rice.

**51. Magnesium and boron nutrition of black pepper (*Piper nigrum* L.) in laterite soils**

The results of the experiment involving soil and foliar application of Mg and B clearly indicated that in the case of soil application, application of 40 g $MgSO_4$ + 4 g borax in pot experiment and 200 g $MgSO_4$ + 20 g borax in field experiment significantly influenced the available nutrient status of soil, yield and yield attributes of pepper. In the case of pot experiment involving foliar application, the use of 1% $MgSO_4$ + 0.5% borax was superior with respect to available nutrient status, yield and yield attributes of black pepper. Application of 0.5% $MgSO_4$ + 1% borax produce on par results. In the case of field experiment, the treatment receiving 0.5% $MgSO_4$ + 1% borax was superior to all other treatments.

**52. Permanent Manurial Trial – Dwarf**

Highest grain and straw yield was obtained from the plots which received integrated nutrient management system. Plots which received inorganic nitrogen alone in the form of ammonium sulphate recorded the lowest yield followed by NPK from chemical fertilizers. Continuous application of nitrogenous fertilizers alone or NPK in the form of inorganic fertilizers alone were found to have detrimental effect on the growth and yield of rice. Biological parameters analysed indicated that there is no detrimental effects of fertilizers if applied along with enough organics.

**53. Management of Calcium, Magnesium, Sulphur and Boron in tissue cultured banana (Musa spp.) Var. Nendran)**

The experiments were conducted to investigate the effect of application of Calcium, Magnesium, Sulphur and Boron in potting mixture for hardening and in field condition banana var. nendran. Both the hardening studies and field experiment indicated the beneficial effect of secondary nutrients and boron on TC banana. $T_{10}$ (150 ppm Ca, 25 ppm Mg, 25 ppm S and 0.5% B) and $T_4$ (75 g Ca + 25 g Mg + 50 g S + 0.5% B) were found to be performing well under hardening and field conditions, respectively.

**54. Herbicide mixtures for weed management in direct seeded puddle rice (*Oryza sativa* L.)**

The best indicator plant selected based on the screening trial viz., maize and its shoot dry weight was used for assessing the herbicide residue of bispyribac sodium + metamifop in soil. Data on

shoot dry weight of maize grown in post experiment soil treated with different doses of bispyribac sodium + metamifop viz., 60,70,80 and 90 g a.i. $ha^{-1}$, bispyribac sodium @ 25 g a.i. $ha^{-1}$, hand weeding twice and weedy check were statistically analyzed. Results revealed that there was no significant difference among the treatments, in shoot dry weight. Hence it can be assumed that, the residues of tested doses of bispyribac sodium + metamifop were not sufficient to cause growth inhibition in the indicator plant maize. The best indicator plant selected based on the screening trial viz., maize and the parameter shoot fresh weight was used for assessing the herbicide residue of penoxsulam + cyhalofop butyl in soil. Data on shoot fresh weight of maize grown in post experiment soil treated with different doses of penoxsulam + cyhalofop butyl viz., 120, 125, 130 and 135 g a.i. $ha^{-1}$, penoxsulam @ 22.5 g a.i. $ha^{-1}$, hand weeding twice and weedy check were statistically analyzed. Results indicated that, there was no significant difference among the tested doses of penoxsulam + cyhalofop butyl and the control treatments in shoot fresh weight. Hence it can be inferred that the herbicide mixture, penoxsulam + cyhalofop butyl would not leave any phytotoxic residue in soil which can cause growth inhibition in maize crop.

## 55. Long range effect of continuous cropping and manuring on soil fertility and crop productivity

The experiments were conducted to study the long range effect of crop rotation with high yielding varieties at graded fertilizer levels on the yield stability and soil fertility. Plant height, total and productive tillers increased significantly with increasing rates of N and P application. Withholding P fertilization for more than 5-6 years resulted in a decrease in these parameters. In contrast to N, consecutive increase in P up to the third level (P80) was found to stimulate growth and tiller production significantly. At harvest, P at 80 kg $ha^{-1}$, produced significantly taller plants during both Kharif and rabi than the different levels of N and K. The growth-enhancing effect of N levels was significant up to N2 (80 kg $ha^{-1}$), whereas further increase did not give any response. The two levels of K did not significantly affect plant growth.

Though phosphorus is not generally a limiting nutrient in the acid soils of India, skipping of P fertilization for more than three years affects rice yields even under sufficient levels of nitrogen application and also affects crop response to N and K. At equal levels of fertilizer addition the agronomic efficiency was more for P than for N. P levels showed positive influence on the uptake of N and K by both grain and straw. Skipping phosphorus continuously for more than three years considerably reduced the soil P levels. Phosphorus can be skipped for six seasons without any significant reduction in grain yield in riverine alluvium soils medium to high in available P. P should be applied after a three year skipping period since further skipping detrimentally affects the growth and yield of rice in addition to delaying flowering and maturity for about two weeks even in the presence of adequate levels of nitrogen and potassium.

## 56. Enhancement of production and productivity of major crops in Onattukara Sub Project: Organic nutrition of medicinal rice Njavara in Onattukara

The project was started during virippu 2012. The treatments differ significantly in grain yield and straw yield. Highest grain and straw yields were obtained from the plots which received 75% N as FYM and trichoderma enriched vermicompost in 1:1 proportion with recommended dose of $P_2O_5$ and $K_2O$ as none meal and ash respectively.

## 57. Permanent Manurial Trial of rice in acid Saline soils under flooded condition (pokkali tract)

The experiment was started during 1979. The results obtained so far indicate that the application of inorganic fertilizers with or without lime do not have any positive influence on grain yield of pokkali varieties. The low fertilizer responsiveness of the pokkali varieties and the high fertility status of the soil can be attributed to this results.

The yield data showed a yield increase for the N and P fertilizer applied plots but there is no significant increase in yield. The percent yield increase was highest 17.09 in the plots receiving N and P @ 20:40 kg $ha^{-1}$. The plot receiving NPK application with lime @ 1 ton $ha^{-1}$ has an increase of 5.67 % over control. During the year the application of chemical fertilizers have shown a slight increase in rice yield though not to a significant level. The pokkali fields are highly suited for organic farming.

## 58. Fertility in relation to movements, losses transformations and interactions in different agroclimatic regions of Kerala

The experiments aimed to find out the effect of continuous application of N, P, K and lime over incorporation of straw on soil fertility, yield and quality an incidence of pests and diseases.

Continuous omission of P resulted in visual deficiency symptoms from the eighth season and consequent significant reduction in grain and straw yield from the $10^{th}$ year onwards. The grain yield obtained in the continuous K omission plots were on par with the treatments with K application even after 29 years. The experiment is continued as per the technical programme for the past 29 years. The experimental data during 2014-17 revealed that crop raised with continuous omission of K fertilizer for the last 30 years, gave on par yield with that fertilized on soil test basis (NPK + lime + cow dung), during both kharif and rabi. Among the different treatments, crop fertilized on soil test basis (T 9) was also on par with that done with POP recommendations (fertilizer alone with lime – T8).

During kharif and rabi seasons, NPK uptake was more in the crop fertilized based on soil test basis (with straw incorporation) and also in fields cropped during alternate seasons. NPK uptake was significantly lower in straw incorporated plots without fertilizer application and in N, P and K fertilizer skip plots. Though the uptake in the plots with zero potassium application, the yield was comparatively high.

Soil test data during the crop season at maturity revealed that nutrient uptake was higher in NPK fertilized plots, low in the respective nutrient skip plots and control plots without fertilizer application. Grain yield during both the seasons were significantly higher in the plots fertilized based on soil test data and NPK applied and NPK with lime application.

It was noticed that the plants in all the treatments including that in the best treatment plots exhibited severe yellowing of leaves with narrow brown spots during both the seasons. The permanent plots show severe chaffing and reduction in the yield during both the seasons over a period of years which may be due to the severee nutritional deficiency including secondary and micronutrients. Depending on the climatic conditions during the season, the field had low to moderate infestation of blast even if prophylactic fugicidal sprays are done.

The experimental results during the last 30 years revealed severe nutritional deficiency and yield reduction in the N and P omission plots from the eighth season and consequent significant reduction in grain and straw yield from the $10^{th}$ year onward. K omission plots (with straw incorporation and NP application) had on par yield as fertilized plots even after 30 years of K skipping. Nitrogenous fertilizer application is highly essential in paddy fields as the mineralization process is slow from the high carbon Kuttanad soils. The crop response in the plot fertilized on soil test basis reveals that INM favours better nutrient absorption and crop yield.

# Project Coordination Group:

# Farming Systems Research and Climate Studies (10)

## Project Coordinator - Dr. Dr. Jacob John

**Concluded Projects:- 3**
**Ongoing Projects: - 11**

## Concluded projects

1. **Developing systems recommendations for nutrient, disease and insect pest management in major cropping systems of Kerala (Network)**

The rice based cropping sequences investigated were rice-rice-daincha, rice-rice-bitter gourd, rice-rice-vegetable cowpea, rice-rice-amaranthus and rice-rice-cucumber with 100 and 75 per cent of the fertilizer recommendation in rice fields of Karamana and Palakkad for two consecutive years. In both the experiment sites, rice yield during *Viruppu* and *Mundakan* in all the cropping sequences were on par under 100 per cent and 75 per cent of the fertilizer recommendation. Soil properties like organic carbon content, available P and available K were also on par. Hence, it can be inferred that a 25 per cent reduction can be brought about in the existing fertilizer recommendation for rice based sequences owing to the incorporation of rice stubbles of the first and second crop and the vegetative residues of the summer crop. The rice-rice-cucumber resulted in more grain yield and was more remunerative.

Coconut based sweet potato-njalipoovan banana-sweet potato sequential cropping system: Integration of 2/3$^{rd}$ of the recommended dose of nutrients for coconut and 100 per cent for the sequential crops (sweet potato - njalipoovan banana – sweet potato) was necessary for maximizing total gross income.

Coconut based cassava-njalipoovan banana- cassava sequential cropping system: Organic basin management of coconut combined with application of 100 per cent of the recommended dose of nutrients for the sequential crops has maximized gross income.

Coconut based ginger-banana-ginger sequential system: Application of 100 per cent of the recommended dose of nutrients both for the main and the sequential crops (ginger – banana – ginger) enhanced gross income. However, integrated application of 100 per cent and 75 per cent of the recommended doze of nutrients both for coconuts and sequential crops, respectively, improved gross returns in a coconut based ginger – banana – ginger sequential cropping system.

The organic basin management for coconut and 100 per cent of the recommended dose of nutrients for turmeric – banana – turmeric sequential cropping system has increased gross income, profit and BCR.

Application of 2/3$^{rd}$ of the recommended fertilizer dose for coconut and 75 per cent of the recommended fertilizer dose for the plant and ratoon crops of TC nendran banana intercropped in coconut gardens enhanced gross income.

Basin management of coconut with *in situ* green manuring, recycling of palm waste, FYM application @ 50 kg + 5 kg ash + 25 g *Azospirillum* per palm per year combined with the application of 75% of the recommended dose of NPK each for the component crops *viz*., noni, banana and long pepper was found worthwhile for sustainable yield index, partial nutrient balance with respect to P & K and profitability for coconut based multistoried cropping systems of the coastal sandy zones.

Fertilizer management schedule for three coconut based cropping systems was investigated for laterite and coastal sandy soils for three years. Recommended doses of fertilizers were calculated on the basis of soil test data. When coconut is intercropped with tuber crops in laterite soils fertilizer levels can be reduced to 1/3$^{rd\ of}$ the recommended dose as per soil test basis for coconut and to 75 per cent of recommended dose for tuber crop. For intercropping Njalipoovan banana with coconut in laterite soils, 2/3$^{rd}$ fertilizer recommendation for coconut and 100 per cent fertilizer recommendation for banana was enough for higher yields. For coconut fodder system, 2/3$^{rd}$ fertilizer recommendation for coconut and 75 per cent fertilizer recommendation for fodder is found to be the best treatment for higher yields. In coastal sandy soils, for coconut cassava system with a fertilizer schedule of 100 per cent for main crop and 75 per cent fertilizer schedule for inter crop can be recommended. From the results it is seen that when coconut is

intercropped with banana in coastal sandy soils, a fertilizer dose of 2/3rd fertilizer recommendation for coconut and 75 per cent fertilizer recommendation for banana can be rewarded. When coconut is intercropped with fodder a fertilizer, dose of 2/3rd fertilizer for coconut and 100 per cent fertilizer for fodder can be recommended.

Management of coffee under 100 per cent of the recommended dose of chemical fertilizer as per the package of practice of KAU in coffee + pepper cropping system was found worthwhile for enhancing the yield of coffee but the yield of pepper was higher when organic recycling was combined with 1/3 rd of the recommended dose fertilizer as per package of practice of KAU under pure pepper system at station trials. Application of 2/3 rd of the recommended dose of fertilizer in coffee and pepper as per the package of practice of KAU in farmers field enhanced the yield of coffee in coffee + pepper cropping system while higher pepper yield was observed when organic recycling was combined with the application of 1/3 rd of the recommended dose of fertilizer in coffee and pepper as per the package of practice of KAU. Significant increase in the soil nutrient status after the experiment was also recorded in the coffee+pepper cropping system.

***Socio-economic analysis***

Coconut based cropping systems *viz*., coconut-arecanut-nutmeg-pepper can be followed wherever possible in order to improve the net income. A combination of coconut and banana is the best in terms of cost and net returns provided the conditions for the cultivation of banana are favourable. The major determinants of technical efficiency of cropping systems are farm size, off-farm income and crop diversification. Smaller farms have an advantage in technical efficiency. Crop diversification is an important determinant of technical efficiency. Despite concerns like rising cost of cultivation and scarcity of labour, these cropping systems can produce reasonable income with relatively low risk in the state.

## 2. Socioeconomic analysis and farmer participatory development of homestead farms of Kerala (Network)

Successful replicable models/enterprise combinations were evolved as follows.

***Urban homesteads***: One of the unique models developed through technical interventions for urban households, was a polyhouse on terrace coverings an area of 3 cents (120 sq.m). The vegetables that were raised successfully in the polyhouse include salad cucumber (var.Multistar and var.Sania), vegetable cowpea (var. Babli Sakata), bitter gourd (Maya East West Seed), snake gourd (var.Kaumudi), bottle Gourd (local variety), amaranthus (var.Arun), brinjal (Sharapova F1-Rijk Zwaan, Nilo F1-Rijk Zwaan and Vengeri). Nearly 1076 kg of vegetables was produced over a period of eight months from the polyhouse. The expenditure incurred was Rs.24000/- while the gross and net return was Rs.55090/- and Rs.31090/- respectively.

***Southern Kerala***: A homestead model of 0.24 ha with crop-livestock-poultry integration with terrace garden and roof water harvesting was developed for southern Kerala. The interventions included scientific management, introduction of newer enterprises and technologies, terrace gardening, water harvesting and vegetable cultivation during summer, improved varieties, good quality planting materials and glass wool wick irrigation in grow bags. The annual net returns before intervention was Rs.98310/- which raised to Rs.127589/- after intervention.

***Kuttanad region***: A model homestead with 0.6 ha in which 50cents (0.2 ha) was covered by channels was developed. Other components include 80 coconut palms, 100 arecanut palms, 100 nos of banana (nendran and njalipoovan), 50 nos of yams and timber trees. Interventions included cultivation of banana in open area receiving more sunlight and Njalipoovan in area having shade, cultivation of tuber crops like short duration cassava hraswa and kalpaka and amorphophallus, raising of tomato, brinjal (Haritha), cowpea (Lola, Anaswara), amaranthus (Arun), snakegourd (Kaumudhi), bitter gourd (Priyanka) and bhindhi (Varsha Upahar,Arka Anamika), planting grafts of mango (mallika) Garcinia and jack, planting materials of mango

ginger, sugarcane, sweet corn and ginger, cultivation of fodder grass var. Co3, azolla cultivation in silpaulin trenches, integrating duck and rearing fish like carps and tilapia in the channels.

***Central Kerala***: A model homestead of 50 cents was developed for Central Kerala. Seedlings like rose apple, papaya, curry leaf and Malaya gooseberry were planted near to the boundary line. Live fencing with glyricidia was also done along boundaries. Cowpea, bhindi, brinjal, tomato, chilli and cauliflower were planted in rows in the model homestead. Fodder grass slips were planted in the model homestead including CO 3, CO 4, DHN 6, and IGFRI 3. Tuber crops such as tapioca, dioscorea, and amorphophallus, rhizomatous spices such as ginger and turmeric and leafy vegetables like amaranthus and cabbage were also included. A silpaulin vermi bed unit was installed for manuring the crops in the model homestead.

***High range zone***: In the homesteads where mono-cropping of coffee was practiced, components like banana, backyard poultry and pepper on arecanut were introduced. This resource rich system is more economical compared to the mono crop-coffee-model. The net income from the integrated system is Rs. 2,17, 812.8/- per annum which was higher than that from the existing mono-crop model. The average net income generated from one hectare coffee mono-crop is in the tune of Rs. 76,115/- per annum. If pepper is added to the system the income from the same land will shoot up to Rs. 1, 58,950/-. Adding banana and backyard poultry will boost up the annual income to Rs. 1, 80,626.8/-. The farmer can realize an addition income of Rs. 37,186/- if the pepper is trailed on arecanut.

***Northern Zone*** : Developed certain low cost user friendly structures for vertical farming in homesteads, terrace and balconies. Minisett planting materials for tuber cultivation is successfully utilized in elephant foot yam, taro, tannia and Dioscorea and can be adopted in grow bags. Low cost drip irrigation for open fields and terrace gardening was emonstrated with nearly 75 % saving of water and reduced labour. Developed a black pepper based cropping system for homesteads involving tuber crops like cassva, lesser yam, elephant foot yam, greater yam and arrow root besides spices like ginger and turmeric and vegetables. Congo signal is found superior to hybrid Napier for intercopping in coconut garden where the soil is silty. Vertical farming with poultry (layers 150 and broiler 1500) and Kada is a cost effective and eco-friendly model for popularization.

Developed organic package for coconut comprising 100 tender coconut husk, 10 small bundles of dried coconut leaves, 50 kg FYM, 50 kg silt, 25 kg well rotten and powdered cowdung and 3 kg dolomite. The above inputs are to be incorporated in coconut basins once in two years besides regular recycling of coconut waste. Demonstrated ratoon cropping of brinjal planted in ridges following ridge and furrow system of planting which improved BCR to the tune of 5.10. Developed a new method of planting cassava by laying one metre long mature cassava stems horizontally in small furrows drawn over ridges after microsite enrichment with FYM and fertile soil. Arecanut based intensive integrated farming system is developed by integrating several components, *viz.,* intercropping nendran banana, hybrid Napier and xanthosoma, establishing azolloa in fish ponds, introducing organic waste disposal methods like vermicomposting and rural composting and animal husbandry units such as poultry and cattle rearing.

Demonstrated the prospects of utilization of hard laterites for successful crop production. Two layers of coconut husks were mulched over the laterites and deposited composted coir pith and red soil to a height of 12 cm and raised vegetables adopting drip fertigation realized a BCR of 5.45 for ash gourd, 2.0 for cowpea, 4.82 for chilies, 6.67 for coccinia and 2.5 for amaranth.

**Socio-economic analysis**: The study on the role of homesteads on food security and livelihood security revealed the following:

The significance of homesteads as a source of food has declined due to various socio-economic reasons

Possibilities of diversification of crops and enterprises in homesteads were found to be less explored by the respondents

Agro biodiversity of homesteads has declined when compared to earlier times and it is mostly due to fragmentation and the reduced reliance on agriculture

Homesteads with an average size of 50 cents were found to meet only 20-30 per cent of the food and nutritional requirement of a family, while there is a possibility of maximising it to even as high as 80 per cent.

Proportion of carbohydrate requirement provided by homesteads is less compared to that of protein requirement.

Institutional support for diversification of homesteads is grossly inadequate.

3. **Allelopathic effect of trees grown in homesteads of Kerala on turmeric (*Curcuma longa* Linn.) - PG**

Leaf extracts of tamarind, mango and teak are inhibitory to sprouting and growth of ginger. Hence, when ginger is planted under the canopy of these trees care should be taken to alleviate the inhibitory effect. Leaf lopping of tamarind is not ideal for mulching in ginger. Leaf loppings of panal, rubber, teak, matty, wild jack and jack enhanced yield and hence, can be recommended to farmers for applying as mulch in ginger @ 15 t $ha^{-1}$(100 g per grow bag of 25 cm height and 30 cm diameter) immediately after planting and subsequently @ 7.5 t $ha^{-1}$ (50 g per grow bag) each at 44-60 and 90-120 DAP. Another interesting observation was that in the control, where newspaper were used as mulch, the yield was high (637 g $plant^{-1}$) and comparable to mulching with panal, rubber, teak, matty, wild jack and jack leaves.

## Ongoing Projects

1. **Development and validation of on- station integrated farming system models--AICRP**

The rice based and coconut based IFS models were found more profitable and generated the highest net returns of Rs.77489/- and Rs.51595/- respectively. The employment generation per hectare was highest for rice (150 man days) followed by coconut based (100), banana based (84) and then homestead based IFS (80). Nutrient generation and recycling was highest in banana based IFS, followed by coconut based, rice based and homestead based IFS.

2. **Investigating rice based farming systems involving fish through suitable land modifications vis-à-vis conventional rice based cropping systems -- AICRP**

The system (rice+fish)-(rice+fish)-(amaranthus+fish) was most profitable (Rs.294005/- per ha) and was on par with (rice+fish)-(rice+fish)-(culinary melon+fish) and (rice+fish)-(rice+fish)-(fodder cowpea+fish) systems. Integration of fish with crops resulted in higher productivity and can be attributed mainly to the nutrient enrichment of soil through recycling of silt from the trenches in which fish was reared. Stability index was higher in the systems where crop and fish was integrated viz., (rice+fish)-(rice+fish)-(amaranthus+ fish), (rice+fish)-(rice+fish)-(culinary melon+fish) and (rice+fish)-(rice+fish)-(fodder cowpea + fish).

3. **Response of nutrients in rice based cropping on farmer's field -- AICRP**
   Application of NPK @ 90:45:45 kg/ha along with zinc sulphate @ 25kg/ha recorded highest rice equivalent yield of 12998 kg/ha/year and the increase was 12 % and 251 % over farmers' practice and unfertilized control respectively. Balanced nutrition with NPK and Zn recorded the highest net income of Rs. 1.40 lakh/ha and B:C ratio of 1.98.

4. **Diversification of existing farming systems under marginal household conditions**
   An average net income of Rs. 134626 was realized due to technological interventions made in integrated farming system of holding size 0.44 ha and it was higher by 373 % over benchmark. Crop + Hort + Poultry was the predominant farming system with average net income of Rs.100989. Paddy contributed 36 per cent, coconut and banana 57 per cent and poultry 7 per cent of net income. Crop +Hort + Dairy+ Pisciculture was found to be the best farming system which recorded highest average net income of Rs.226545 compared to benchmark of Rs.56491.Paddy contributed 18 %, coconut and banana 38 % dairy 35 % and pisciculture 9 % of net income.

5. **On Farm evaluation of farming system modules to improve the profitability and livelihood of small and marginal farmers.**
   Hort + Diary was the predominant system in marginal farm holding size of 0.88 ha and generated net income of Rs 219477/- which was higher by 128 % over benchmark. Coconut and banana together contributed 63 per cent and dairy contributed 30 per cent of net income. Crop + Hort + Dairy was the predominant system in small farm holding size of 1.43 ha and generated net income of Rs. 293159 during 2016-17 which was higher by 139 % over benchmark. Paddy contributed 21 %, coconut and banana together contributed 43 % and dairy contributed 24 % of net income.

6. **Soil $CO_2$ emission under different tillage practices in red loam/ laterite, clay and coastal sandy soils of Kerala**
   Tillage with rotovator in any type of soil contribute the minimum CO2 to atmosphere. This contributes a significant reduction in emission of CO2 when it considered globally.
   Modelling is suitable for studying carbon dynamics in soils under rice and teak ecosystems. It highlights the potential of CENTURY model over Roth-C model in terms of simulation of soil carbon.

7. **Spatiotemporal distribution of aquatic invasive plants in Kuttanad wetland ecosystem**
   The spatiotemporal variations in aquatic invasive plants showed a cyclic trend in its distribution. Among the months taken for the study, monthly mean aquatic weed distribution was maximum in the month of September with a value about 5.4 $km^2$. In the seasonal distribution, the southwest monsoon season (5.4 $km^2$) had the maximum aquatic weed distribution, followed by the winter season (4.0 $km^2$), Northeast monsoon season (3.4 $km^2$) and summer season (2.3 $km^2$).

8. **Impact of heat and nutritional stress on adaptive capability of bucks**
   When two stressors occur simultaneously, they may have severe impact on adaptive capabilities of Osmanabadi bucks as compared to that would occur individually. Osmanabadi bucks possess the capability to adapt to the detrimental effects of environmental stresses which is evident from the significant interaction of treatment and experimental dayson majority of the parameters studied.

9. **Impact of heat and nutritional stress on rumen fermentation characteristics and metabolic activity in bucks**

When two stressors occur simultaneously, they may have severe impact on rumen fermentation characteristics and metabolic activities of bucks as compared to that would occur individually. The study established the adaptive capability of Osmanabadi bucks to the detrimental effects of environmental stresses to alter their fermentation and metabolic activities.

10. **Phenology of medicinal snake gourd (*Trichosanthes cucumerina* l.) under different seasons**

During winter, summer and rainy seasons snake gourd grown under rain shelter recorded highest vine length, number of branches, maximum leaf area and number of male and female flowers produced, herbage yield per plant and dry yield per plant than open condition whereas pollen fertility, pollen viability and fruit weight were found to be highest in open condition than in rain shelter during summer season and found more in rain shelter during winter and rainy seasons. Highest herbage yield per plant, fruit yield per plant and total yield per plant were recorded under open condition during summer season. But during rainy season it is higher under rain shelter when compared to open field.

11. **Impact of heat and nutritional stress on the growth and reproductive performance**

When nutrition is not compromised Osmanabadi bucks were able to withstand heat stress. This is evident from the non-significant difference on various growth and reproductive parameters studied between C and HS groups. Osmanabadi bucks possessed superior adaptive capability to combined stresses simultaneously.

# Project Coordination Group - Crop Pests and Beneficial Insects(CPBI) (11)

**Project Coordinator - Dr. D. Ambika Devi**

**Concluded Projects: 9**
**Ongoing Projects: 47**

## Concluded Projects

### 1. Isolation and characterization of biocide molecules from potential plant sources- RKVY

Among 100 plants screened for pesticidal property, crude aqueous extracts of *Chromolaena odorata, Lantana camera, Clerodendron infortunatum, Hyptis suaveolens, Samadera indica, Adathoda vasica, Tithonia diversifolia, Andrographis paniculata, Pongamia pinnata, Capsicum fruitescens, Calotropis gigantea, Gloriosa superba, Annona squamosa, Wedelia trilobata, Phyllanthes nirurii, Cipadesa baccifera, Quisqualis indica, Simarouba glauca, Sweietenia mahogany* and *Mikania micrantha* showed pesticidal properties under in vitro condition. Based on the results, flowers of *Q. indica*, *S. glauca, S. indica* and *M. micrantha* were selected for fractionation and isolation of bioactive compound. Among the different fractions collected by silica gel chromatography, the methanolic extract fractions of all the plant species showed maximum bioactivity. Extraction by using ASE 150 was significantly superior to cold extraction and soxhlet extraction methods. The fractions which showed maximum bioactivities were used for the GC MS analysis. The GC MS analysis results revealed the presence of numerous insecticidal molecules in the extracts of *Q. indica, S.indica, M. micrantha* and *S. glauca*.

GC MS analysis of ethanol extract fraction XX of *S. indica* revealed the presence of compound glaucine, which has insecticidal property. Ethanol extract fraction VI of *S. indica* revealed the presence of two compounds while its methanol extract fraction XV revealed the presence of compound 4- heptanone, semicarbazone, which has insecticidal property. The methanol extract fraction XIV and XII of *S. indica* revealed the presence of two compounds having insecticidal property while methanol extract fraction IV of *S. indica* revealed the presence of compound 2, 4-Dimethyl-6-(2-methylphenyl) pyridine-1-oxide. The ethyl acetate extract fraction XI revealed the presence of a compound Vinyldimethyl (hydroxymethyl) silane, having insecticidal action.

GC MS analysis of *M. micrantha* chloroform extract fraction VII revealed the presence of compound 1-Methyl-D3-1,2,4-Triazole, which have insecticidal property while the ethyl acetate extract fraction IX and XI of *M. micrantha* revealed the presence of two compounds of insecticidal property. The methanol extract fraction VI of *M. micrantha* showed the presence of compounds 1, 2-Ethanediamine, N, N, N'- trimethyl- and 2- Decyl methyl phosphonofluoridate and the methanol extract fraction XXII revealed the presence of compound having insecticidal property 2-Phenylsulfonyl-4-methylcyclohexanone. The methanol extract fraction II revealed the presence of compound Trifluoromethyl t-butyl sulphide having insecticidal property. The results of the study revealed excellent insecticidal activity of extracts of *Q. indica, S. indica, M. micrantha* and *S. glauca*.

### 2. Evaluation of alternate management technologies against tea mosquito bug (*Helopeltis antonii* Signoret) in cashew

The results on the effect of insecticides on tea mosquito bug damage on laterals showed that λ-cyhalothrin recorded the lowest damage score. On panicles, the damage was not uniform before spray and hence the covariance analysis done revealed that the insecticide treatments were on par among each other and superior to control in all the post spray observations. In third spray, the treatments including control were on par among each other with respect to damage on laterals. Same trend was observed on panicles also. This was due to the natural decline in tea mosquito bug population after flowering phase of the crop. Nut yield data revealed that the treatment, KAU POP in which quinalphos was sprayed twice as second and third spray, recorded highest per tree nut yield. However, the treatment λ-cyhalothrin and thiamethoxam

was on par with KAU POP in nut yield. Evaluation of bioagents and botanicals on Tea mosquito bug damage score revealed that there was no significant difference among treatments except for 7th days after second spray with respect to damage on laterals. However, with respect to damage on panicles, there was significant difference that all the botanical and bioagent treatments were superior to control and was on par with KAU POP treatment in which quinalphos was used during flowering phase. Nut yield data revealed that KAU POP recorded the highest nut yield followed by *Beauveria bassiana* and these two were on par with each other. The lowest nut weight was in control.

**3. Evaluation of entomopathogenic fungi against tea mosquito bug (*Helopeltis antonii* Signoret) in cashew**

After first spray no fresh attack was observed in POP treatment in which lambda-cyhalothrin was sprayed, inspite of damage before spray. After 15th and 30 days, fresh attack was observed in *Beauveria & Metarhizium* treated trees and all the treatments including control were on par among each other. No fresh damage was observed on lambda-cyhalothrin treated trees up to 30th day. At 7th day after 2nd spray, least damage was observed on quinalphos treated trees and was superior to control. On 15th day, no fresh attack was noticed on quinalphos treated trees and *Beauveria* was on par with quinalphos. This was followed by *Lecanicillium*. During third spray at 7th day after spray there was no significant difference observed among treatments including control. However, at 15th day, all the treatments were superior to control. No fresh attack was observed in case of Quinalphos treated trees. Nut yield data revealed that the treatment, *Beauveria bassiana* recorded maximum yield followed by POP in which lambda cyhalothrin , quinalphos and quinalphos was sprayed in that sequence and they were on par with each other. However, the treatments *Metarhzium* and *Lecanicillium* were on par with control with respect to nut yield.

**4. Development of alternative technologies for management of Pest / Disease Problems in Banana: Management of Fusarium wilt disease of banana- RKVY**

Sucker treatments were given prior to planting corresponding to different treatments. Consecutive drenching was given 1st, 3rd and 5th month after planting. Per cent wilt index were calculated on 4th, 5th and 6th month after planting based on the observations on the external symptoms taken according to the score chart. The study revealed that in the initial stage of crop growth, there was no significant difference between the treatments. At five month after planting sucker treatment with *Pseudomonas fluorescens* (50g/l) followed by drenching *Pseudomonas fluorescens* (20g/l) was found to be better. In the six months stage all the treatments are found to be superior to control. The plants having sucker treatment with *Trichoderma viride* (50g/l) + drenching *Trichoderma viride* (20g/l) were having lesser external symptoms. It was followed by the treatments having Trichoderma as one of the components. The extent of discolouration of the rhizomes was noted at the time of death of plant or at the time of harvest. Per cent vascular wilt index was calculated based on the score chart. All the treatments were superior to control. The control plants recorded more days for harvest of bunch compared to other treated plants. Yield was found to be maximum for the plants treated with *Trichoderma viride* (20g/l). The number of hands in a bunch and number of fingers in a bunch were superior in all treatments compared to control. The plants treated with fluzilazole showed minimum percent wilt index followed by carbendazim and plants drenched with fluzilazole. All the organic treatments were found to be superior to the control plants. Per cent vascular wilt index was minimum for plants treated with fluzilazole followed by carbendazim and for plant suckers treated with *Pseudomonas* and drenched with fluzilazole. Among the organic treatments biocontrol agent *Trichoderma* was found promising. Yield was found to be higher in plants treated with fluzilazole. Study showed

that fusarium wilt can be effectively managed by the application of fungicide fluzilazole by sucker treatment followed by soil drenching. The biocontrol agent *Trichoderma* can also be used for managing the disease especially in organic crop which gave substantial yield also.

## 5. Characterization and management of insecticide resistance in *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae).

Bioassays were conducted with the respective test insecticides and the *S. litura* population collected from Kovilnada and Palappur were found to be resistant against chlorpyriphos, quinalphos, lambda-cyhalothrin and cypermethrin whereas, Alappuzha population was found to be susceptible. Biochemical analysis study revealed the role of esterases and GSTs in case of OP resistance and esterases and MFO for pyrethroid resistance. Tested synergists are effective in breaking the resistance and found to be effective alternate in resistance management programs. Spraying/rotation of new generation chemicals like emamectin benzoate or indoxacarb or chlorantraniliprole or flubendiamide could effectively manage the resistant population of *S. litura*. Dissipation study revealed low persistence of chemicals like indoxacarb and emamectin benzoate at field level and thus recommended for safe vegetable cultivation.

## 6. Diversity of leaf hopper fauna in rice and vegetable ecosystems - PG

A total of 17 species of leafhoppers were collected from rice and vegetable ecosystems belonging to three subfamilies, eight tribes and 12 genera. Seven species of leafhoppers were collected from rice plants *viz, Cofana spectra* (Distant), *C. lineata* (Distant), *Nephotettix nigropictus* (Stal), *N. virescens* (Distant), *Exitianus indicus* (Distant), *Maiestas dorsalis* (Motschulsky) and *Hecalus porrectus* (Walker). Another two species, *viz., H. lutescens* (Distant) and an unidentified species of leafhopper in the genus *Doratulina* were collected from the weed *Eragrostis tenella* Linn. associated with rice ecosystem. Occurrence of *Hecalus lutescens* (Distant) is a new record from Kerala. *Cofana lineata* and *Hecalus porrectus* are new records on rice in Kerala.

The survey on leafhopper fauna associated with vegetable ecosystem revealed the presence of eight species belonging to three sub families. These leafhoppers were found associated with six major vegetable crops. *Amrasca biguttula biguttula* (Ishida) on brinjal and okra, *Empoasca (Empoasca) kerri* Pruthi on cowpea, *E. (E.) motti* Pruthi on bitter gourd, *Seriana jaina* (Distant) on cowpea, *Tautoneura (Tautoneura) mayarami* Mathew and Ramakrishnan on lab lab bean, *Kolla ceylonica* (Melichar) on brinjal, okra and cowpea, *Hishimonus phycitis* (Distant) on brinjal and an erythroneurine species (unidentified) on brinjal and ash gourd. Infestation of *K. ceylonica* (Melichar) on brinjal, okra and cowpea is a new record for Kerala. Based on the characters studied and species identified, a dichotomous taxonomic key was prepared for the identification of leafhopper species associated with rice and vegetable ecosystems.

## 7. Bioefficacy of entomopathogenic fungi against rice bug *Leptocorisa oratorius* Fab. (Hemiptera: Alydidae) - PG

The superior treatment obtained in pot culture experiment was *Beauveria bassiana* at $10^8$ spores/ml with 97.77 % mortality of *Leptocorisa oratorius*. *Metarhizium anisopliae* at $10^8$ spores / ml also caused significant reduction in rice bug population (71.16 %). The per cent damage due to rice bug infestation was significantly less in plots treated with *B. bassiana* @ $1x10^8$ spores/ml. There was no significant variation among treatments with respect to rice yield.

**8. Bionomics and management of root mealybugs on black pepper.**

The results showed that three root mealybug species, *Formicococcus polysperes, Dysmicoccus brevipes* and *Pseudococcus* sp. were found to be infesting the black pepper in Wayanad and Idukki districts leading to yellow discolouration of leaves. They were also associated with four different species of ants and a coccinellid grub of *Horniolus* sp. was predatory on root mealybugs. The root mealybug population was negatively correlated with soil temperature with its peak in cooler months (November and December) and lowest population in rainy months (June and July). Pepper varieties showed variation in susceptibility to the root mealybugs and Panniyur-2 was highly susceptible followed by Panniyur-1 and the least susceptible was Karimunda. Among the different entompathogenic fungi evaluated against root mealybugs, *L. lecanii* @ 2x $10^8$ spores/ml was the most effective whereas in chemicals, imidacloprid 17. 8 SL at 25 g a.i/ha and chlorpyriphos 20 EC at 300 g a.i/ha were superior.

**9. Eco-friendly management of pineapple mealy bug *Dysmicoccus brevipe* (Cockerell) (Hemiptera: Pseudococcidae)**

Survey conducted at selected localities of Ernakulam, Idukki and Thrissur districts of Kerala revealed five species of insect natural enemies and a fungal pathogen from mealybug colonies *viz., Cacoxenus perspicax* (Drosophilidae), *Spalgis epius* (Lycaenidae), *Scymnus* sp1 and 2, a parasitoid *Chartocerus* sp. (Signiphoridae) and fungus *Apergillus* sp. Apart from the natural enemies, ant species *Camponotus mitis* (Smith) (Formicidae: Formicinae) and *Technomyrmex albipes* (Smith) (Formicidae: Dolichoderinae) were also found associated with *Dysmicoccus brevipes.* At the highest concentration of $1x10^9$ spores $ml^{-1}$, mortality of 66.67 per cent was recorded with *Lecanicillium lecanii*, followed by *B. bassiana* (60 %) and *M. anisopliae* (40%). Quinalphos and azadirachtin treatment showed drastic population reduction of 96.73 and 87.75 per cent, respectively. *M. anisopliae* treatment resulted in reduction of mealybugs (59.29 %), followed by *B. bassiana* (30.13 per cent) and *L. lecanii* (17.26 per cent). Reduction of fruit quality in terms of TSS was observed to be directly related to infestation level as the TSS was 8.74° Brix in heavily infested compared to 9.93° Brix in moderately infested fruit, indicating the importance of mealybug infestation on quality of fruits.

## Ongoing Experiments

**1. Response of selected okra [*Abelmoschus esculentus* (L.) Moench] cultivars root knot nematode *Meloidogyne incognita* (Kofoid& White) - PG**

Thirty okra cultivars comprising twentyone accessions from NBPGR Regional Station, Thrissur, eight released varieties and a highly susceptible check (Arka Anamika) were screened for their reaction to root knot nematode *M. incognita.* The moderately resistant cultivar IC 117238 recorded the lowest root knot number (19.66) followed by IC 111507 (22.66) whereas the highly susceptible cultivar Susthira recorded highest root knots of 266.00. Highest nematode population was recorded from IC 218900 with an average of 486.00 / 10 g root followed by Susthira (485.33), Aruna (480.33) and IC 329360 (478.33).

**2. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala. Sub project - management of nematodes in polyhouse grown salad cucumber- RKVY**

Soil application of neemcake @ 200g/$m^2$ three weeks prior to sowing +soil application of *Purpureocillium lilacinum* @50g/$m^2$ at sowing recorded reduction in soil nematode population by 80 per cent and yield increase by 66 per cent over untreated control in salad cucumber under polyhouse condition.

3. **Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala. Sub project - management of nematodes in banana - RKVY**

Results of the farm trials conducted at 10 locations using carbosulfan @16.6 g/plant showed that carbosulfan application was effective in reducing the nematode population by 58 to 84 per cent and increasing the yield upto 60 to 78 per cent over untreated control in banana.

4. **Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala. Sub project - management of pests and diseases of vegetables - RKVY**

a) **Management of sucking pests of chilli -** Farm trials were conducted with two doses of Thiamethoxam 25 WG and biopesticides against the sucking pests of chilli in farmer's field. Thiamethoxam 25 WG @ 25g ai/ha was found superior in controlling the pests with minimum pest population. It also recorded significant reduction in damage to the leaves and the yield was also high in plots treated with Thiamethoxam 25 WG 25g ai/ha compared to control plot

b) **Management of sucking pests of brinjal -** Farm trials conducted with two doses of Acetamiprid 20 SP and biopesticides against the sucking pests of brinjal in farmer's field showed that Acetamiprid 20 SP 10 g ai/ha was superior in controlling the pests with minimum pest population and highest yield in treated plots compared to control.

c) **Management of sucking pests of cowpea (aphid and pod bugs) -** Farm trials were conducted with two doses of Thiacloprid 21.7 SC, Acetamiprid 20 SP and biopesticides against the Sucking pest of cowpea in farmer's field. Thiacloprid 21.7 SC 30g ai/ha and Acetamiprid 20 SP 10g ai/ha recorded minimum aphid population. The yield was found higher in the plots treated with Acetamiprid 20 SP 20g ai/ha compared to control plot.

d) **Management of leaf caterpillars (pumpkin caterpillar and snake gourd caterpillar) of Snake gourd -**Farm trials were conducted with two doses of Spinosad 45 SC against the leaf caterpillars of snake gourd in farmer's field. Spinosad 45 SC 75 g ai/ha was found superior in controlling the pests with minimum pest population. The yield was high in plots treated with Spinosad 45 SC 75 g ai/ha compared to control.

e) **Management of leaf feeders of Amaranthus -** Three farm trials were conducted with insecticides and biopesticides against the leaf feeders of Amaranthus in farmer's field . Chlorantraniliprole 18.5%SC 30g ai/ha and Flubendiamide 20 WG 50 g ai/ha were found superior in controlling the pests with mean population of 4.33/plant and 2.62/plant. Chlorantraniliprole 18.5%SC 60g ai/ha and Flubendiamide 20 WG 100 g ai/ha were also effective for the pests with mean population of 3.44/plant and 2.13/plant. Biopesticide, fish amino acid 10ml/litre was also found effective with a population of 2.68/plant. The yield was also high in plots treated with Flubendiamide 20 WG 100 g ai/ha (31.41kg/plot) and Flubendiamide 20 WG 50 g ai/ha 28.34kg/plot(20 $m^2$)compared to control (11.74kg/plot).

f) **Management of shoot and fruit borer of brinjal -** Farm trials were conducted with pesticides and biopesticides against the shoot and fruit borers of brinjal in farmer's field. Spinosad 45 SC 75 g ai/ha was found superior in controlling the pests with minimum pest population. Biopesticide, Oxuron 5ml/litre and Fish amino acid 10ml/litre were found equally effective. Significant reduction in fruit damage was observed in plots treated with Spinosad 45 SC 75 g ai/ha. The yield was high in plots treated with Spinosad 45 SC 75 g ai/ha compared to control plot.

g) **Management of Epilachna beetle of bitter gourd -** Farm trials were conducted with pesticides and biopesticides against the leaf caterpillars of Bitter gourd in farmer's field. Chlorantraniliprole 18.5 SC 30 g ai/ha and Indoxacarb 14.5 SC 150g ai/ha were found superior in controlling the pests with a mean population of 4.34 /leaf. The yield was high in these plots, being 34.98 kg / plot ($20m^2$) compared to 5.45kg / plot obtained from the control plot.

h) **Management of shoot and fruit borer of bhindi -** Farm trials were conducted with pesticides and biopesticides against the shoot and fruit borers of bhindi in farmer's field. Spinosad 45 SC 75 g ai/ha was found superior in controlling the pests with minimum pest population 5.71/plant. Biopesticide, Oxuron 5ml/litre and Fish amino acid 10ml/litre were found equally effective with shoot infestation of 12.99 and 12.62/plant respectively. Damage to the fruits was also reduced significantly in plots treated with Chlorantraniliprole 18.5 SC 30 g ai/ha as indicated by the percentage of fruits infestation of 12.84. The yield was high in plots treated with Chlorantraniliprole 18.5 SC 30 g ai/ha 38.19 kg/plot ($20m^2$) compared to 24.60 kg/plot control plot.

i) **Management of sucking pests of bhindi (leaf hoppers, aphid) -** Farm trials were conducted with pesticides and biopesticides against the sucking pest in farmer's field. Acephate 75 SP 292 g ai/ha was found superior in controlling the **aphid and hopper** with minimum pest population. Fish amino acid 10ml/litre and Oxuron 5ml/litre were found equally effective. The yield was high in the plots treated with Acephate 75 SP 292 g ai/ha compared to control plot.

5. **Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala. Sub project - Development of alternative technologies for pest and disease management in coconut and arecanut - RKVY**

a) **Rhinoceros beetle -** Pooled analysis of four centres (COA Vellayani, RARS Kumarakom, CoH, Vellanikkara, RARS Pilicode) revealed that, based on reduction in spindle damage and leaf damage Carbosulfan 6G 20g + 200g sand and Cartap hydrochloride 4% G 20g or 10g + 200g sand were the best treatments followed by Chlorantraniliprole 0.4 G 10 g + 200 g sand and Fipronil 40g + 200g sand. Crown cleaning followed by the above treatment thrice a year could effectively manage the pest.

b) **Red palm weevil -** Analysis of data from 3 centres (COA Vellayani, RARS Kumarakom, ORARS Kayamkulam) revealed that, based on presence of adult and larvae or bore holes, Cartap hydrochloride 4G, 20g + 200g sand and Chlorantraniliprole 0.4 GR 25g + 200g sand were the best treatments followed by Carbosulfan 6G 20 g + 200g sand and Spinosad 45 SC 5 ml/L.

6. **Evaluation of biointensive technologies in the management of tea mosquito bug *Helopeltis antonii* Signoret in cashew**

Among the aqueous extracts and botanical oil emulsions tested against tea mosquito bug, *Helopeltis antonii* on cashew under laboratory conditions, pongamia oil at 5% concentration has shown both insecticidal and antifeedant property. Vayambu rhizome powder has shown antifeedant property at 5 % concentration and exhibited both antifeedant and insecticidal property at 10 % concentration.

7. **Exploitation of bionematicide from potential plants of Western Ghats.**

The findings of *in vitro* experiments showed that methanol extract of *Andrographis paniculata* and *Chromolaena odorata* 0.1% resulted in maximum mortality of *M. incognita* juveniles. Hence

these two plants were selected for standardizing the appropriate preparation and method of application *viz*. soil application of extract adsorbed charcoal in granular form, soil application of dried powder, seedling root dip and soil drenching of crude extracts under pot culture condition. Observations on biometric characters and nematode population characteristics in ginger, turmeric and pepper revealed that application of dried powder of *A. paniculata* @10g/kg soil and Chromolaena dry powder @25g/kg soil were effective in reducing the nematode population.

8. **Research on new molecules of plant protection chemicals.**
   **Sub Project 1- Screening of new generation insecticides, bio-pesticides and other nonchemical insecticides for the management of pests of cole crops.**
   Experiments carried out in two different agroecosystems of Idukki and Thiruvananthapuram during two consecutive years revealed that Spinosad and Chlorantriniliprole are the best insecticides for *Spodoptera litura.* Trials to standardise the effective dose of each insecticides revealed that Spinosad (0.1%) and Chlorantriniliprole (0.05%) are the effective doses for managing the pest. These insecticides were validated under polyhouse condition too, the results of which are being analysed. Among the biocontrol agents, *Lecanicillium* @ 2% was effective in managing white flies, *Trialeurodes* sp. under polyhouse condition and Sl NPV or Garlic extract 4 % in managing *Spodoptera litura*. The major pest in hills, the DBM could be managed by Chlorantraniliprole (0.05%) or Spinosad (0.1%). The aphids *Lipaphis erysimii* and *Brevicoryne brassicae* could be managed by Acetamirid or *Lecanicillium* sprayed at fortnightly intervals.
9. **Research on New Molecules of Plant protection chemicals.**
   **Sub Project 2: To evaluation of pesticides for the management of nematodes attacking cabbage and cauliflower.**
   - **Cauliflower -** Cartap hydrochloride 4G@ 1kg ai/ha was the best treatment in increasing the yield (18.65t/ha) of cauliflower followed by the application of Thiamethoxam 25WG @100g ai/ha (16.33t/ha). Among the biocontrol agents, *Trichoderma viride*@2.5kg/ha was the best treatment in increasing the yield (18.23t/ha). Cartap hydrochloride 4G@ 1kg ai/ha was the best treatment in reducing the population of nematode in 200cc soil (123) and 5g of root (79.33).

   - **Cabbage -** Cartap hydrochloride 4G@ 1kg/ai/ha was the best treatment in increasing the yield (20.5t/ha) of cabbage followed by the application of Thiamethoxam 25WG @100g ai/ha (18.8t/ha). Among the biocontrol agents, *Trichoderma viride* @ 2.5kg/ha was the best treatment in increasing the yield (18.23t/ha). Cartap hydrochloride 4G@ 1kg ai/ha was the best treatment in reducing the population of nematode in 200cc soil (123.3) and 5g of root (77.0).

10. **Research on new molecules of plant protection chemicals**
    **Sub Project 3: Evaluation of insecticides, for the management of pests of coccinia and tomato.**
    In tomato, three experiments were conducted against whitefly (*Bemisia tabaci*), serpentine leaf miner (*Liriomyza trifoli*) and leaf caterpillar (*Spodoptera litura*). Chlorantraniliprole 18.5% SC 30 g ai/ha was found effective against leaf caterpillar, *Spodoptera litura.* Acetamiprid 20% SP 10 g ai/ha and Thiamethoxam 25%WG 25 g ai/ha were found effective against whiteflies and leaf miner.
    Three experiments were conducted in coccinia against leaf caterpillar (*Spodoptera litura*), epilachna beetle (*Epilachna septima*) and aphid (*Aphis* spp.) Flubendiamide 20%WG 50g ai/ha and Chlorantraniliprole 18.5% SC 30g ai/ha, were found effective in reducing the infestation of

leaf feeder, *Spodoptera litura* and epilachna beetle, *Epilachna septima* in coccinia.
Thiamethoxam 25%WG 25 g ai/ha was found effective against aphids in coccinia followed by Imidacloprid 17.8% SL 20 g ai/ha.

**11. Research on New Molecules of Plant protection chemicals**

**Sub Project 4: Newer and safer chemicals and biopesticides for the management of Pests of mango.**

The lowest rate of leaf webber, *Orthaga exvinacea* infestation was recorded in the treatment Oxuron @ 5 ml/l. Among biopesticides *Beauveria bassiana @ 20* g /l was also effective. Chlorantraniliprole @0.3g/l and emamectin benzoate @ 0.4g/l obtained significant reduction in the leaf webber (*Orthaga exvinacea*) count. Reduction in the incidence by hoppers, *Idioscopus* sp and *Amritodus* sp. was observed when Spinosad 0.3 ml/l, Emamectin benzoate@ 0.4 g/l Buprofezin @ 0.2 ml/l Thiomethoxam @ 0.3 g/l were used for the management of these pests. Among botanicals, Oxuron @ 5ml/l, Azadirachtin and biopesticides *Beauveria bassiana @ 20 g /l.* were found effective.

**12. Survey on emerging insect pests of banana - AICRP**

Weevil pests of banana viz., pseudostem and rhizome weevils were observed to infest banana in almost all districts of the state. Nendran, Red banana and Robusta were highly susceptible. The variety Popoulu recorded very high susceptibility to fruit fly attack. In addition to fruit flies, 5 different types of flies (Order: Diptera) were also collected from the Popoulu fruits. Heavy incidence of slug caterpillar *(Miresa decendens)* were observed in Nendran. Root mealy bug *Geococcus sp., and Dysmicoccus sp.* were recorded in many parts of the state. Infestation of mealy bug (*Ferrisia virgata)*, and white flies *(Dialeurodicus disperses)* were high at hilly terrains of Idukki, Wayanad, Kannur and Kasargod districts. Severe infestations of banana spittle bugs (*Phymatostetha deschampis)* was recorded from Pathanamthitta and Idukki districts. The intensity of red spider mite attack was high compared to previous year. Skipper butterfly infestation were seen in the districts of Idukki, Wayanad, Kannur and Kasargod especially in Nendran. Slug caterpillar *(Miresa decendens)* is emerging as a pest of concern, which was observed at Thrissur, Wayanad, Idukki, Alappuzha and Kottayam districts on cv. Nendran and Njalipoovan.

**13. Integrated management of banana pseudostem weevil (*Odoiporus longicollis*) - AICRP**

Swabbing chlorpyriphos 0.05% and pseudostem trapping with EPF, *Beauveria bassiana* were found effective for the integrated management of pseudostem weevil in banana.

**14. Survey, identification, pathogenicity and control of banana nematodes - AICRP**

Major banana nematodes *viz*., *Radopholus similis, Meloidogyne incognita, Helicotylenchus dihystera, Pratylenchus penetrans* and *Heterodera oxyzicola* were recorded in various banana tracts of Kerala. Severe incidences of *Meloidogyne incognita* was observed in banana monoculture or in banana plants intercropped with tubers ( *Dioscorea* ) and vegetables at Wayanad, Idukki, Thrissur, Ernakulam, Kottayam and Alapuzha districts. The incidences of *Radopholus similis* was more at Wayanad district closely followed by Kottayam district. Banana spiral nematode, *Helicotylenchus multicinctus* was more at Palakkad. The incidence of *Pratylenchus* sp. was more at Idukki, Kottayam and Wayanad districts which are the hilly tracts and also in Alappuzha district a coastal district. Scattered incidences of banana cyst nematode, *Heterodera oryzicola* was identified from the soil samples collected from Kollam district.

**15. Biological control of banana nematodes - AICRP**

Combined application of bio-control agents *viz., Pseudomonus fluroscens* @ 12. 5 g/$m^2$ + *Paecilomyces lilacinus*@ 12.5g/$m^2$ was effective in reducing the nematode population (54.23 per cent reduction of population of *M. incognita*) in soil under pot condition.

**16. Biorationals for the management of nematodes of banana - AICRP**

Application of cartap hydrochloride @ 10g/$m^2$ effectively reduced the nematode population followed by *Paecilomyces lilacinus* @ 25g/$m^2$.

**17. Biological control of banana stem weevil (Odoiporus longicollis) - AICRP**

Application of Entomopathogenic fungus, *Beauveria bassiana* @1x$10^7$ spores/ml, spray at $5^{th}$, $6^{th}$ and $7^{th}$ month after planting + stem trapping and stem trap swabbed with *Heterorhabditis* sp. were effective in reducing the various stages of the pseudostem borer of banana and its management.

**18. Management of banana skipper butterfly, Erionota torus - AICRP**

Foliar application of Chlorantranilipole 18.5 SC effectively reduced infestation of banana, skipper butterfly, *Erionota torus*. Among the biological control methods, foliar application of *Bt* @ 3ml/l (1x$10^8$cfu) proved better in the skipper butterfly management.

**19. Survey for new and emerging insect pests of jackfruit**

Lepidopteran and Coleopteran defoliators/ stem borers were observed sporadically with severe incidences in jackfruit growing locations. Severe incidence of leaf eating cerambycid beetles (*Olenecamptus bilobus)* was observed during the monsoon period. *Glenea multiguttata*, a cerambycid beetle caused damage to Jack leaves by severing the veins leading to drying of leaves and young shoots. Incidence of *Oberea artocarpi* was recorded from Central zone (Thrissur and Palakkad districts) mainly from trees less than 5 years old. Jack fruit aphid (*Greenidia artocarpii)* caused crinkling of leaves in young shoots. The spittle bug (*Clovia lineaticollis*), which is a mild but regular pest appeared whenever new shoots were formed. Defoliation by grass hopper and leaf caterpillar was of regular occurrence. Infestation by the tingid bug was wide spread but of mild nature. Bud weevil (*Ochyromera artocarpi)* heavily feed on young and tender jack fruits. Rodents like 3 banded common squirrel, Malabar giant squirrel, and birds had special preference for ripening fruits. The combined attacks of these pests caused appreciable yield loss.

**20. ICAR Consortium research platform on borers in network mode**

About 16 species of cerambicid borers belonging to family Cerambicidae and two subfamilies, *viz*., Laminae and Cerambicinae prioninae were found to occur in the surveyed homesteads. The major Cerambycid borers collected during the survey were *Cerosterna scabratrix* (F.), *Olenocamptus bilobus*(F.), *Pterolophia* sp. Indet, *Apomecyna* sp. Indet, *Nupserha dubia* Gahan, *Celosterna scabrator* (F), *Aeolesthes holosericea* (F), *Macrochenus isabellinusAurivillus, Epipeotes uncinatus* Gahan, *Stromatium barbatum* (F), *Glenea multiguttata Guerin* – Meneville, *Nupserha* sp., *Batocera rufomaculata* (Deeger), *Batocera rubus* (Linee), *Ceresium* sp, *Acanthophorus* sp. Among these, *Nupserha dubia* Gahan, *Epipeotes uncinates* Gahan and *Glenea multiguttata Guerin*– Meneville, are reported for the first time in Kerala, through our studies. *Batocera rufomaculata* (F.) in addition to the hosts like mango, jack, cashew found to be in close association with the important perennial crop, *Moringa oleifera* and caused significant damage to the crop.

## 21. Studies on mite pest management – AINP on Agricultural Acarology

- **Management of chilli mite, *Polyphagotarsonemus latus* in polyhouses -** A significant reduction in mite population was recorded in all the treatments, three days after application. Ten days after treatment, spiromesifen emerged as the superior treatment against chilli mite. However, the acaricide molecules, difenthiuron and fenpyroximate were found to be on par with spiromesifen. Fenazaquin was found to be inferior to these three molecules.
- **Management of rice leaf mite, *Oligonychus oryzae* -** Spiromesifen and fenazaquin caused significant reduction in mite population by third day of application. By seventh day, azadirachtin and wettable sulphur also showed significant reduction in mite population which was on par with spiromesifen and fenazaquin. By fifteenth day, complete reduction in mite population was recorded in these treatments.
- **Bioefficacy of the acaropathogen, Acremonium zeylanicum against *Tetranychus truncates* -** The study clearly indicated that the acaropathogen, *A. zeylanicum* can cause significant mortality of the spider mite, *T. truncatus*. The acaropathogen, proved to be more effective against adult mite compared to the egg stage. Mortality of the mite increased with increase in concentration of *A. zeylanicum* and the concentration, $1\times10^8$ spores/ml recorded highest mortality (78.19%) in the laboratory.
- **Evaluation of *N. longispinosus* against *T. urticae* on cucumber -** The results indicated that the predator, both deutonymph and adult showed significantly higher preference towards eggs at all the prey densities tested. At lower prey density of 5:5:5, no preference was noticed by the predator, deutonymph between larva and nymph of the prey. However, at higher prey densities of 10:10:10 (30) and 15:15:15 (45), the predator deutonymph preferred larva over the nymph. The preference of adult predator towards larva and nymph was similar at densities of 5:5:5 and 10:10:10. But the predator adult preferred larva over nymph at a higher prey density of 15:15:15

  At a release rate of 20 predators for 100 prey mites, no prey and predator were recorded in the experimental arena on the seventh day, where as in control, 756.00 prey mites were recorded on the seventh day. On tenth day, a drastic reduction in the number of prey mites was recorded in all the treatments. At predator densities of 1, 2, 3, 4 and 5, prey mite counts recorded were 171.00, 45.00, 17.33, 6.33 and 2.66, respectively. However at densities of 10 and 20, prey mites were zero. In control, 561.00 prey mites were recorded on tenth day. The predators recorded a population of 67.33, 35.33, 41.33, 47.33, 67.00 and 23.66 at densities of 1, 2, 3, 4, 5 and 10, respectively.
- **Optimum predator prey ratio in the polyhouse**

  The prey counts at five days after the first release of the predator were significantly lower at the ratios of 1: 20 (1.86 mites/$cm^2$) and 1: 25 (1.91 mites/$cm^2$) which were on par with each other. However, the prey population recorded at 1: 33 (4.21 mites/$cm^2$) was significantly higher compared to 1: 50 (3.34 mites/$cm^2$). Ten days after the first release of the predator, significantly lower prey mite population was recorded at the ratios of 1: 20 (3.36 mites/$cm^2$) and 1: 25 (3.31 mites/$cm^2$) which were on par with each other. On this day, the prey mite count at the ratios 1: 33 (4.83 mites/$cm^2$) and 1: 50 (4.81 mites/$cm^2$) were on par with each other. On fifteenth day after the first release of the predator, 4.99 and 5.61 prey mites were recorded per $cm^2$ leaf area at the ratios 1:20 and 1:25 which were on par with each other. The ratio of 1: 33 (11.12 mites/$cm^2$) recorded significantly higher prey mite population compared to the ratio 1: 50 (12.05 mites/$cm^2$). However, all these ratios were significantly superior to the control (13.86 mites/$cm^2$) in reducing prey mite population.
- **Population of prey after second release of the predator**

  The laboratory study indicated that at a narrower predator: prey ratio of 1: 5 and 1: 10, the predator could eliminate the prey population in seven days and ten days, respectively.

However, at these ratios, a drastic decline in the predator population was also noticed probably due to the insufficiency of food to sustain the predator population. At wider ratios (1: 20 to 1: 100), total elimination of prey population could not be effected upto ten days after predator release. In the polyhouse, the best predator: prey ratio identified were 1: 20 and 1: 25 to suppress the pest population. The present study suggests that *N. longispinosus* can be an efficient biocontrol agent against spider mites.

- **Diversity of the predatory coccinellid, *Stethorus* spp. associated with phytophagous mites**

  Studies on morphological characterization of the specimens revealed that the collection includes ten species of *Stethorus* collected from 14 different host plants across three South Indian states of Kerala, Karnataka and Tamil Nadu. Among the ten species recorded, identity of only four species could be established viz., *Stethorus keralicus, S. pauperculus, S. parcepunctatus* and *Stethorus rani*. *S. keralicus* and *S. parcepunctatus* were collected on *Raoiella indica* infesting arecanut. *S. rani* was found in association with *Tetranychus* sp. on cardamom. The prey range of *S. pauperculus* included *Oligonychus* sp. and *Tetranychus* sp.

## 22. All India Network Project on Vertebrate Pest Management Agricultural Ornithology

- **Extend of depredatory damage in rice**

| Crop | Stage | Mean damage in observational area (%) | 2016-17 |
|---|---|---|---|
| | | Depredatory bird | |
| Rice | Nursery bed and direct sown crop | Baya weaver | 4.25 |
| | | Blue rock pigeon | 6.00 |
| | | Common teal | 1.00 |
| | Vegetative stage | Purple moorhen | 18.50 |
| | Filling stage | Streaked weaver | 2.25 |
| | | Baya weaver | 1.00 |
| | Maturity stage | Munia | 0.25 |
| | | Plum headed and rose ringed parakeets | 2.25 |
| | Lodged rice | Teal | 0.25 |

| Crop | Stage | Mean damage in observation area (%) | 2016-17 |
|---|---|---|---|
| Cow pea | Pod maturation | Depredatory bird | |
| | | Pea fowl | 4.25 |
| Banana | Fruiting stage | Rose ringed parakeet | 4.50 |
| | | Small green barbet | 3.00 |
| | | Crow | 1.50 |
| | | Koel | 3.00 |
| | | Tree pie | 0.25 |
| | | Common myna | 0.50 |
| Okra | Maturity stage | Rose ringed parakeet | 9.00 |
| | | Small green barbet | 2.50 |
| Mango | Fruiting stage | Rose ringed parakeet | 0.25 |
| | | Crow | 1.25 |
| | | Common myna | 1.00 |
| Papaya | Fruiting stage | Small green barbet | 2.00 |
| | | Koel | 4.25 |
| | | Flame back wood pecker | 0.25 |
| | | House crow | 1.00 |

- **Eco-friendly bird management practices**

| Crop | BPM Technique | Depredatory bird | Effectiveness (%) |
|---|---|---|---|
| Cow pea | Reflective ribbon | Parakeets and pea fowl | 85.0 ± 12.0 |
| Plantain | Banana leaf trash cover | Barbets, parakeets, koel, babblers, crow, myna, bulbuls | 90.0 ± 5.0 |
| Plantain | Polythene sheet | Barbets, parakeets, koel, babblers, crow, myna, bulbuls | 98.0± 1.0 |
| Rice | Methyl anthranilate based feeding repellent | Weaver birds and munia | 45.0 ± 4.0 |
| Rice | Metallized reflective ribbon | Rose ringed and plum headed parakeets | 65.0 ± 12.0 |
| Pulse | Reflective ribbon in maturing crop | Parakeets and peafowl | 65.0 ± 7.0 |
| | Teak leaf protection | Parakeet and spotted dove | 95.0 ± 5.0 |
| | Nylon rope and metalized reflective ribbon fencing | Peafowl | 90.0± 5.0 |
| Mango | Greasing the drip irrigation pipes against the bird pricks | Birds of various kinds | 92.0 ± 6.0 |

| | | | |
|---|---|---|---|
| Pumpkin and ash gourd | Cloth bagging of developing fruits | Pea fowl | 99.0 ± 0.50 |
| Pumpkin and ash gourd | Paper bagging of developing fruits | Pea fowl | 25.2 ± 8.0 |

- **Studies and management on vertebrate pest of crops - Effect of wild boar management technique on coleus yield**

| SL. No | Treatment | Area damaged (m2)/ acre | | Yield of coleus tuber kg/acre | | Mean yield (kg) |
|---|---|---|---|---|---|---|
| | | Location A | Location B | Location A | Location B | |
| 1 | Nylon net | 0 | 0 | 5814 | 5626 | 5720 |
| 2 | Olfactory repellent 1 | 0 | 0 | 5350 | 5500 | 5425 |
| 3 | Control | 800 | 480 | 4740 | 4980 | 4860 |

## 23. AICRP on Honey bees and Pollinators.

Studies on the pollinator diversity in cashew revealed that honey bees are the dominant visitors in their flowers. They include *Apis cerana indica, Apis florea, Apis dorsata* and the stingless bee *Tegtragonula (Trigona) iridipennis*. Other flower visitors in cashew were ant, *Camponotus* sp., a social wasp *Polistes*sp. and flies. Whereas in coffee, *T. iridipennis i*s the major insect visitor in coffee flowers. The honey bee species *viz.,Apis cerana indica, Apis florea* and *Apis dorsata* were also observed in addition to *Amegilla* sp.

With regard to the stock improvement studies through selection and multiplication of better performing colonies, two colonies revealed significant difference in bee strength, brood development, pollen/honey storage and honey yield which were selected for queen rearing, queen grafting and for stock improvement. The experiment is being continued.

Five feral colonies were transferred to wooden hives (1960 cc) designed by this centre. Observations on brood development, pollen and honey storage at fortnightly intervals revealed a gradual increase in brood from February to May and a decline after that, pollen storage was maximum during May and least during January. It was also observed that the number of honey pots was maximum during April and the mean honey yield was 375.50 g/hive.

Identified the enemies of stingless bees viz., nitidulid beetle, mites and predatory spiders during the period under report.The stingless bee foraging plants (4 Nos.) which provide pollen/ nectar to stingless bees were also identified during the period under report.

The brood of Indian bee apiaries of AICRP on Honey Bees and Pollinators as well as beekeepers of Kerala was found to be infected with a bacterial disease. During the period under report, preliminary trials were conducted with botanicals to find an alternate treatment for antibiotics. The results revealed that when the colonies fed with garlic @ 10 g per 10 litre of sugar syrup (@ 250 ml/colony/week) for consecutive three weeks showed cent percentage recovery of the disease incidence.

## 24. Rodent Control - AINPVPM

*Mus saxicola saxicola* Elliot, 1839 adult was trapped for the first time in protected cultivation. *Vaneleurla oleracea olearcea* (Bennet) sub adult female was trapped for the first time in polyhouse condition. Recapturing of *Rattus ranjiniae* Agarwal and Ghosal (confirmed the identity by the Zoological Survey of India), from rice field for the first time after 1966.

## 25. Supervised field trial

- **Supervised field trial on dissipation of Imidacloprid 70 WG in Tomato** - The study on dissipation of residues of imidacloprid 70WG in tomato was carried out at the Instructional Farm, Vellayani, Thiruvananthapuram, Kerala during February-April, 2016. The study on the dissipation of residues in tomato was carried out from the date of the third application. Soil samples were analyzed at 15 days after the third application. The mean initial deposit of imidacloprid in tomato at recommended and double the recommended dose were 1.46 and 2.36 mg $kg^{-1}$ respectively. The residues dissipated with time and reached below detectable level of 0.01 mg $kg^{-1}$within 15 days in recommended and within 25 days in double the recommended dose. The half life values of imidacloprid in tomato at recommended and double the recommended doses were 1.95 and 2.31days, respectively.
- **Supervised field trial on dissipation of residues of PIM 014 (tebufenpyrad) in tomato** - The study on the dissipation of residues of PIM 014 (tebufenpyrad) in tomato was carried out at the Instructional Farm, Vellayani, Thiruvananthapuram, Kerala during Dec. 2015-Feb. 2016. PIM 014 20 % WP was sprayed on tomato plants at two concentrations, *i.e.* 100 g $ha^{-1}$ (X), and 200 g $ha^{-1}$ (2X). The mean initial deposits of tebufenpyrad in tomato fruit at the recommended and double the recommended doses were 0.85 and 1.91 mg $kg^{-1}$, respectively. The residues of tebufenpyrad at 1, 3, 5, 7, 10 days after spraying were 0.56, 0.39, 0.26, 0.24 and 0.12 mg $kg^{-1}$ in recommended dose and residues dissipated with time and reached below detectable level of 0.05 mg $kg^{-1}$ within 15 days. In double the recommended dose, the mean residues detected were 1.71, 1.63, 0.93, 0.74, 0.10 and 0.06 mg $kg^{-1}$ after 0, 1, 3, 5, 7, 10 and 15 days, after spraying respectively, and the residues dissipated with time and reached below detectable level of 0.05 mg $kg^{-1}$ within 20 days.

  The mean initial residues of tebufenpyrad in loamy sand soil at the recommended and double the recommended dose were 1.19 and 3.66 mg kg-1, respectively . The residues of tebufenpyrad dissipated to 0.82, 0.65, 0.62, 0.55 mg kg-1 after 3, 7, 15, 30 days of application in recommended dose. In double the recommended dose, the residues dissipated to 1.45, 1.13, 1.12 and 1.03 mg kg-1 after 3, 7, 15 and 30 days after spraying.

  The mean initial deposits of tebufenpyrad in sandy loam soil at the recommended and double the recommended doses were 1.72 and 1.85 mg kg-1, respectively. The residues of tebufenpyrad dissipated to 0.89, 0.71, 0.58, 0.38 mg kg-1 after 3, 7, 15, 30 days of application in the recommended dose. In double the recommended dose, the residues dissipated to 1.70, 1.34, 1.16 and 0.87 mg kg-1 after 3, 7, 15 and 30 days after spraying.

  The mean initial deposits of tebufenpyrad in black soil at the recommended and double the recommended dose were 0.95 and 1.99 mg kg-1, respectively. The residues of tebufenpyrad dissipated to 0.87, 0.49, 0.45, 0.42 mg kg-1 after 3, 7, 15, 30 days of application in the recommended dose. In double the recommended dose, the residues dissipated to 1.87, 1.26, 1.1 and 0.94 mg kg-1 after 3, 7, 15 and 30 days after spraying.

The mean initial deposits of tebufenpyrad in clay soil at the recommended and double the recommended dose were 2.76 and 4.28 mg kg-1, respectively. The residues of tebufenpyrad dissipated to 2.67, 2.65, 2.58, 2.53 mg kg-1 after 3, 7, 15, 30 days of application in the recommended dose. In double the recommended dose, the residues dissipated to 4.27, 4.21, 4.10 and 4.02 mg kg-1, respectively, after 3, 7, 15 and 30 days after spraying.

The mean initial residues of tebufenpyrad in water (pH 4) at the recommended and double the recommended dose were 0.59 and 1.0 mg kg-1, respectively. The residues of tebufenpyrad dissipated to 0.48, 0.46, 0.32, 0.31 mg kg-1 after 3, 7, 15, 30 days, respectively, of application in the recommended dose. In double the recommended dose, the residues dissipated to 0.9, 0.89, 0.86 and 0.48 mg kg-1 after 3, 7, 15 and 30 days, respectively, after spiking.

The mean initial deposits of tebufenpyrad in water (pH 7) at recommended and double the recommended dose were 0.38 and 1.0 mg kg-1, respectively. The residues of tebufenpyrad dissipated to 0.37, 0.30, 0.26, 0.23 mg kg-1 after 3, 7, 15, 30 days, respectively, of application in recommended dose. In double the recommended dose, the residues dissipated to 0.9, 0.88, 0.82 and 0.79 mg kg-1 after 3, 7, 15 and 30 days after spiking.

The mean initial deposits of tebufenpyrad in water (pH 9) at the recommended and double the recommended dose were 0.51 and 0.88 mg kg-1, respectively. The residues of tebufenpyrad dissipated to 0.47, 0.41, 0.37, 0.32 mg kg-1 after 3, 7, 15, 30 days of application in the recommended dose. In double the recommended dose, the residues dissipated to 0.82, 0.80, 0.79 and 0.36 mg kg-1 after 3, 7, 15 and 30 days after spiking, respectively.

- **Supervised field trial on dissipation of residues of fosetyl aluminium in tomato -** The study on dissipation of residues of Fosetyl aluminium in tomato was carried out at the Instructional Farm, Vellayani, Thiruvananthapuram, Kerala during November 2016-January 2017. Fosetyl Aluminium 80% WP was applied to tomato plants (as basal drenching) at two concentrations, *i.e.* 2.4 g a.i. $L^{-1}$ (3 g $L^{-1}$) (X), and 4.8 g a.i. $L^{-1}$ (6 g $L^{-1}$) (2X). First drenching was done at initiation of fruit setting on 02-12-2016 and second on 09-12-16 at 7 days interval. The study on the dissipation of residues in tomato was carried out from the date of the second application. Soil samples were analyzed at 15 days after the second application. The mean initial deposits of fosetyl aluminium in tomato fruits at recommended and double the recommended doses were below Limit of Quantification (LOQ). The residues of fosetyl aluminium in tomato fruits one day after drenching was 0.053 mg $kg^{-1}$ in recommended dose and 0.067 mg $kg^{-1}$ in double the recommended dose. The residues of fosetyl aluminium in subsequent days were also below Limit of Quantification (LOQ). The mean residues of fosetyl aluminium in soil collected at $15^{th}$ day after second application were below Limit of Quantification (LOQ) in recommended and double the recommended doses, respectively.
- **Supervised field trial on dissipation of Nativo 75 WG (Trifloxystrobin 25 % + Tebuconazole 50 % WG) on cowpea** - The study on dissipation of residues of trifloxystrobin, its metabolite (CGA 321113) and tebuconazole after application of Nativo 75 WG (Trifloxystrobin 25 % + Tebuconazole 50 % WG) on cowpea was carried out at the Instructional Farm, Vellayani, Kalliyoor, Thiruvananthapuram, Kerala during March-May, 2016. Nativo 75 WG was sprayed twice on cowpea plants at 10 days interval at two concentrations, *i.e.* 87.5+175 g a.i./ha (350 g $ha^{-1}$) as X dose, and 175+350 g a.i./ha (700 g $ha^{-1}$) as 2X dose. First spraying was done at pod formation stage on 26-04-2016 and second on 05-05-16 at 10 days interval. Control plots were sprayed with water. The study on the dissipation of residues of trifloxystrobin, its metabolite and tebuconazole in green pods of cowpea was carried out at 0, 1, 3, 5, 7 and 10 days after last application. The residues of

trifloxystrobin, its metabolite and tebuconazole were also analyzed in mature pod, seed and soil at harvest (15 days after last application). The residues of trifloxystrobin, its metabolite and tebuconazole were analyzed by GC-MS method with Limit of Quantification (LOQ) as 0.05 mg/kg. The mean initial residues of trifloxystrobin in green pods of cowpea at the recommended and double the recommended doses were 0.46 and 1.51 mg/kg, respectively. The residues of trifloxystrobin on the first day after last spraying were 0.09 mg/kg in the recommended dose and the residues dissipated with time and reached below LOQ at 3 days after last spraying. In double the recommended dose, the mean residues were dissipated to 0.55, 0.25, 0.11 and 0.06 mg/kg after 1, 3, 5 and 7 days, after last spraying, respectively, and the residues reached below LOQ at 10 days after last spraying.

The mean initial residues of trifloxystrobin metabolite (CGA 321113) in green pods of cowpea at the recommended and double the recommended dose were 0.10 and 0.39 mg/kg, respectively. The residues of metabolite dissipated to 0.09 mg/kg after one day of last spraying in the recommended dose and reached below LOQ at three days after last spraying. In double the recommended dose, the residues dissipated to 0.37, 0.29 and 0.10 mg/kg after 1, 3 and 5 days after last spraying, respectively, and reached below LOQ at 7 days after last spraying.

The initial residues of tebuconazole in green pods of cowpea at the recommended dose was 0.78 mg/kg and the residues dissipated with time and reached below LOQ at 5 days after last spraying. The mean residues of tebuconazole were 0.12 and 0.08 mg/kg after 1 and 3 days of last spraying in recommended dose, respectively. Whereas, in double the recommended dose, the initial residues of tebuconazole was 2.7 mg/kg and the residues dissipated to 0.74, 0.27, 0.15 and 0.11 mg/kg after 1, 3, 5 and 7 days of last spraying, respectively, and the residues dissipated with time and reached below LOQ at 10 days after last spraying.

The half life values of trifloxystrobin in cowpea at the recommended and double the recommended doses were 0.255 and 2.098 days, respectively. The half life values of trifloxystrobin metabolite (CGA 321113) in cowpea at these doses were 0.250 and 1.30 days. The half life values of tebuconazole in cowpea at recommended and double the recommended doses were 0.704 and 1.234 days, respectively.

The mean residues of trifloxystrobin, its metabolite and tebuconazole in mature of pods, and seeds of cowpea and soil collected at harvest (15 days after last application) were below LOQ (<0.05 mg/kg) at both recommended [87.5+175 g a.i./ha (350 g $ha^{-1}$)] and double the recommended [175+350 g a.i./ha (700 g $ha^{-1}$)] doses.

- **Supervised field trial on dissipation of residues of chlorpyriphos in brinjal** - The study on dissipation of residues of chlorpyriphos in brinjal was carried out at the Instructional Farm, Vellayani, Thiruvananthapuram, Kerala during May-September, 2016. Chlorpyriphos 20 % EC was sprayed on brinjal plants at two concentrations, *i.e.* 200 g a.i $ha^{-1}$ (X), and 400 g a.i $ha^{-1}$ (2X). First spraying was done at initiation of flowering stage on 17-08-2016 and second on 26-08-16 at 10 days interval. Control plots were sprayed with water. The study on the dissipation of residues in brinjal was carried out from the date of the second application on 26-08-16. Soil samples were analyzed at 15 days after the second application. The mean initial deposits of chlorpyriphos in brinjal at the recommended and double the recommended doses were 0.08 and 0.10 mg $kg^{-1}$, respectively. The residues of chlorpyriphos on the first day after spraying were 0.07 mg $kg^{-1}$ in the recommended dose and the residues dissipated with time and reached below detectable level of 0.05 mg $kg^{-1}$ within 3 days. In double the recommended dose, the mean residues were dissipated to 0.09 and 0.06 mg $kg^{-1}$ after 1 and 3

days, of spraying respectively, and the residues reached below detectable level of 0.05 mg $kg^{-1}$ within 5 days.

The half life values of chlorpyriphos in brinjal at the recommended and double the recommended doses were 0.283 and 0.799 days, respectively. The mean residues of chlorpyriphos in soil collected at $5^{th}$ day after second application were 0.12 and 0.16 mg $kg^{-1}$ in the recommended and double the recommended doses, respectively.

- **Supervised field trial on dissipation of residues of chlorpyriphos in paddy -** The study on dissipation of residues of chlorpyriphos in paddy was carried out at the Instructional Farm, Cropping System Research Station, Kerala Agricultural University, Karamana, Thiruvananthapuram, Kerala during July – November, 2016. Chlorpyriphos 20 % EC was sprayed on paddy plants at two concentrations, *i.e.* 375 g a.i./ha (X), and 750 g a.i./ha (2X). First spraying was done at tillering and booting stage and second at 15 days interval. Control plots were sprayed with water. Harvested samples of paddy grain, straw and cropped soil were collected from the field. The residues of chlorpyriphos in grain and straw at the recommended doses were 0.33 and 0.07 mg $kg^{-1}$ and double the recommended doses were 0.36 and 0.18 mg $kg^{-1}$, respectively. No residue of chlorpyriphos was detected from soil at the lower and higher doses.

## 26. Pesticide Residues - AINP

1. The Summary of GAP trials conducted during 2016-17 is given below

| Sl. No | Crop | Pesticide | Formulation | Dosage (g ai./ha) | Initial concentration (mg $kg^{-1}$) | Days taken to reach BDL | LOQ (mg $kg^{-1}$) | Half life (days) |
|---|---|---|---|---|---|---|---|---|
| 1 | Bitter gourd | Lambda cyhalothrin | Karate 5 EC | 15 | 0.15 | 5 | 0.05 | 0.701 |
| | | Spiromesifen | Oberon 22.9% SC | 96 | 0.87 | 5 | 0.05 | 0.517 |
| 2 | Cucumber | Lambda cyhalothrin | Karate 5 EC | 15 | 0.12 | 3 | 0.05 | 0.265 |
| | | Spiromesifen | Oberon 22.9% SC | 96 | 0.13 | 1 | 0.05 | - |
| | | Imidacloprid | Confidor 200SL | 20 | 0.10 | 3 | 0.05 | 0.265 |
| 3 | Okra | Lambda cyhalothrin | Karate 5 EC | 15 | 0.14 | 3 | 0.05 | 0.239 |
| 4 | Brinjal | Lambda cyhalothrin | Karate 5 EC | 15 | 0.08 | 3 | 0.05 | 0.308 |
| | | Imidacloprid | Confidor 200SL | 20 | 0.11 | 3 | 0.05 | 0.25 |
| 5 | Chilli | Spiromesifen | Oberon 22.9% SC | 96 | 0.92 | 15 | 0.05 | 1.378 |
| 6 | Cabbage | Lambda cyhalothrin | Karate 5 EC | 15 | 0.15 | 5 | 0.05 | 0.782 |
| | | Spiromesifen | Oberon 22.9% SC | 96 | 0.96 | 10 | 0.05 | 1.042 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Imidacloprid | Confidor 200SL | 20 | 0.21 | 5 | 0.05 | 0.679 |
| 7 | Cauli-flower | Lambda cyhalothrin | Karate 5 EC | 15 | 0.39 | 10 | 0.05 | 1.363 |
| | | Spiromesifen | Oberon 22.9% SC | 96 | 1.32 | 15 | 0.05 | 1.22 |
| | | Imidacloprid | Confidor 200SL | 20 | 0.56 | 15 | 0.05 | 1.806 |

**27. Bionomics and distribution of banana leaf roller *Erionota* sp. (Lepidoptera: Hesperiidae) - PG**

Survey was conducted at monthly intervals in seventeen blocks of Thrissur district to study the distribution and seasonal incidence of banana leaf roller, *Erionota* sp. and also to record the varieties infested by the banana leaf roller. The highest infestation of 15.30 per cent was recorded in August followed by September (11.1%), October (9.6) and November (8.2%) in Thrissur district. The per cent infestation was very low in December 2015 to February 2016 (3.6 –0.9%) however, the infestation was absent during the months of March, April, May and June and the infestation was again recorded in July 2016 (3.8 %). The highest percent infestation was recorded from the variety Nendran (73.04%) which was followed by the varieties robusta, poovan, palayankodan, kadali, and with a percent infestation of 15.24 %., 2.97%, 2.6%, and 1.67%.

Biology of banana leaf roller was studied. The total larval period ranged between 18 to 27 days, pupal period lasted for 8 to 12 days. Adult longevity ranged between 1 to 6 days. Laboratory evaluation of entomopathogens and insecticide was carried out in the laboratory of Dept. of Agrl. Entomology, College of Horticulture. The efficacy of chemical flubendiamide and entomopathogens *Bacillus thuringiensis, Beauveria bassiana,* and *Metarhizium anisopliae* were evaluated against banana leaf roller. Flubendiamide and *B. thuringiensis* was found to be the best treatments which achieved 100 per cent mortality after second day of application. Among the entomopathogenic fungi, *Metarhizium anisopliae* 1 x 108 spores/ ml was the best effective treatment. The best two treatments chemical Flubendiamide and *B. thuringiensis* were tested in the field. Flubendiamide caused a highest percent mortality of 70 per cent after third day of application whereas *B. thuringiensis* caused a mortality of 40 per cent after fourth day of application.

**28. ICAR Network Project on Insect Biosystematics: Biodiversity studies in *Curculionoidea*.**

Field trips were conducted South India and other parts of India. The main places of survey works carried in Kerala. Karnataka, Tamil Nadu, Andaman and Nicobar Islands, Manipur, Meghalaya and Arunachal Pradesh. During the reporting period, an insect collection room was set up at this college under this project and named as Malabar Insect Collection (MIC). The MIC has more than 300 weevils under different subfamilies collected from different geographical regions of India including Andaman and Nicobar Islands. The collection from Andaman island includes 2 genera and about 3 species which need to be determined.

**29. Establishment of pest and diseases surveillance and forewarning units in southern zone of Kerala.**

Recorded data from the selected farmers fields (19 lead farmers) and IF, Vellayani. Details of pest incidence in the respective area were collected. Appropriate management measures were suggested for existing problems. Correlation of Epilachna beetle (*H. vigintioctopunctata*)

population with weather parameters were worked out which showed significant positive correlation with maximum temperature + 0.84*, + 0.83*, + 0.91* for egg mass, grub and adult respectively, and with +humidity for egg mass and grubs.

**30. Establishment of pests and diseases surveillance and forewarning unit in northern zone of Kerala.**

Pests and diseases on banana during 2017 (February and March, 2017) revealed that Leaf feeding caterpillar, Sigatoka, and whitefly have caused considerable damage to the crop. The data revealed that there is a high degree of positive correlation exists for leaf feeding caterpillar (Erionota sp) with maximum and minimum temperatures and minimum relative humidity. There exists negative correlation with regard to rainfall. It may be predicted that when the temperature increases the damage of leaf feeding caterpillar increases. There was a positive correlation in the incidence of Sigatoka disease, with that of relative humidity (both maximum and minimum).

Maximum temperature showed a positive correlation (0.69771) to that of whitefly incidence. It can be predicted that when the temperature increases whitefly population increases. There was a positive correlation for temperature and relative humidity (Maximum). Leaf miner showed positive correlation for the maximum relative humidity and negative correlation for temperature (both maximum and minimum). Stem borer showed positive correlation for maximum and minimum temperature and negative correlation for relative humidity both maximum and minimum. Colletotrichum leaf blight showed negative correlation for temperature (maximum and minimum) and positive correlation for relative humidity (maximum and minimum). From this it may be concluded that Tea mosquito bug increases with increase in the relative humidity.

**31. Production and Marketing of Safe to Eat, vegetables, fruits and food products for sale through Govt. outlets**

**a) Monitoring of pesticide residues in vegetables collected from markets and farmer's field**

As decided in the steering committee chaired by Agriculture Production Commissioner, forty samples representing various vegetables (bitter gourd, snake gourd, ivy gourd, vegetable cowpea, amaranthus (red and green), salad cucumber, melon (oriental pickling), smooth gourd etc.) were collected every month from the farmers fields of various districts and sixty samples from various markets (Horticorp, Big Bazaar, Niligiris, Agricultural wholesale market (Urban and Rural), organic vegetable shops (Aroma fresh-Nandancode, Aroma fresh-Kesavadasapuram, Aroma fresh -Sasthamangalam, Welgate Kowdiar), and other local markets in Trivandrum, Kasargod and other districts. Total number of 1385 samples were analysed during April 2016 to March 2017 and the results were published in the official web portal of Govt. of Kerala. Results are summarized below:

- Data on the extent of pesticide contamination in vegetables collected from markets and farmgate showed that, out of 990 vegetable samples 57 were contaminated with pesticides.
- Data on the extent of pesticide contamination in fruits collected from markets showed that, out of 84 fruit samples only 3 samples were contaminated with pesticides, and the rest (81) were safe to eat.
- Data on the extent of pesticide contamination in spices that collected from markets clearly showed out of 263 spice samples 89 samples were contaminated with organophosphate & pyrethroid insecticides.
- Data on the extent of pesticide contamination in dry fruits collected from markets clearly showed that, out of 37 dry fruit samples only + samples were contaminated with pesticides, and the rest were Safe to Eat.
- A total of 11 food product samples were collected and analysed from various markets in Kerala which did not show contamination of pesticide residues, in any of the samples tested.

- Seven periodic reports No' 25, 26,28, 29, 30,31 and 33 relating to open market, organic shops and farmers fields were published in the government web portal www.kerala.gov.in and the findings were disseminated to public through Malayalam/English dailies and leading TV channels. Analysed 188 samples collected by Food safety authorly during onam season and published a special report (Report No' 2712016) just before onam holidays, indicating the safety of "OnaSadhya" vegetables' This special testing was done as per instruction of Hon'ble Minister for Agriculture.
- Analysed vegetable samples from Ecoshops attached to Krishi Bhavans, organic and GAP farmers of Trivandrum, Idukki, Kollam, Waynad, Palakad and Kasargod districts and issued "Safe to Eat" certificates to producers, through agricultural officers of Krishi Bhavan concerned.
- A special report on Home Remedy package has been published for the awareness of decontamination of high risk vegetabes, from pesticide residues.
- Continuous analysis and reporting of pesticide residues in food commodities under this project "safe to Eat" resulted in notable depreciation in the pesticide usage in food commodities when compared to the previous years as shown below. During the initial year (2013) the pesticide contamination percentage was low, and now it is reduced.
- Overall analysis of the data generated during the period (April 2016 to March 2017) under report revealed that of the out of 1385 samples, 153 samples were found to be contaminated with different insecticide.

**b) Removal of residues/contaminants from vegetables:**

- Conducted decontamination studies in selected vegetables and published a package of decontamination practices in Govt. web portal and other publications, through print and electronic media for household application.
- Based on these studies, a formula for the removal of pesticide residues (ss-gs% of external residues) from vegetables and fruits (KAU-veggie wash) was developed at the pesticide residue laboratory and was standardised by the post graduate students & research fellows.
- Forty seven firms dealing with household and herbal products in Kerala have entered on MoU with the Registrar, KAU and paid the fee for permission to use the technology for three years on nonexclusive basis.
- Thirty firms have already launched their product 'veggie wash' in different brand names, which are marketed through shops and also through horie uased direct market.

## 32. Management of tea mosquito bug (*Helopeltis antonii* sign.) in cashew using red ants *Oecophylla smaragdina* (F.)

Life cycle and biology of red ants, host plants and insect fauna that support red ants on cashew, competition between other ant species, management techniques for harbouring red ants on cashew, effect of red ant harbouring on yield of cashew plants were studied and recorded.

In red ant harboured plants the yield was two times higher than that of red ant non-harboured plants. This is very significant as the appreciable yield increase is clearly attributable to the effect of red ants in warding off cashew pest attack especially Tea Mosquito Bug. The trend is same in the previous years also. But augmentation of the population of red ants by providing food such as chicken offal or fish waste is required to keep the population of red ants high for effective biological control. Moreover, the population of yellow crazy ants (*Anoplolepis sp.)* which is the greatest natural enemy of red ants is to be kept under check. This requires constant effort by the farmers.

**33. Characterization of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), for genetic variability, endosymbionts and vector-virus interactions in cassava.**

- **Morphological characterisation of Cassava whitefly, *Bemisia tabaci* (Gennadius)**
  **Sampling of *Bemisia tabaci* population -** Surveys were conducted in different agro-ecological zones of Kerala and whiteflies were collected from cassava plants. Samples collected from different agro-ecological zones of Kerala- Manaloor, Vellanikkara, Viyyur (Thrissur), Chittoor (Palakkad), Ambalavayal (Wayanad), Sreekariyam (Thiruvananthapuram), Kannur, Thiruvalla (Pathanamthitta), Sadanandapuram (Kollam), Chettikulangara (Alappuzha), Pala (Kottayam) and Thodupuzha (Idukki) and live samples were collected using aspirator. Morphometric variability studies and genetic variability studies (ISSR marker) of whiteflies were conducted.
- **Molecular characterization of *Bemisia tabaci* adults - Isolation of genomic DNA –**
  Protocol for genomic DNA isolation from *Bemisia tabaci* was standardized in the Centre for Plant Biotechnology and Molecular Biology (CPBMB), All India Network Project on Agricultural Ornithology (AINPAO) laboratory, College of Horticulture, Vellanikkara.
  Adult whiteflies were collected with an aspirator and placed live into 70 per cent ethanol in the field. Samples were stored at -20 °C. The killed adult was washed in double distilled water. The genomic DNA was isolated using modified cetyltrimethyl ammonium borate (CTAB) method (Milligan, 1998).
  Virus free *B. tabaci* cultures were maintained separately. Behavioural responses of the *B. tabaci* on the above varieties were studied for its dispersal, feeding, fecundity, longevity and life cycle.

**34. Exploitation of indigenous bacterial antagonists against root-knot nematode, *Meloidogyne incognita* (Kofoid and White) - PG**

Soil samples were collected from rhizosphere of nematode infested plants and isolation of bacteria is under progress.

**35. Entomopathogenic fungi for the management of banana rhizome weevil (*Cosmopolites sordidus* Germar) - PG**

Field collected mycosed cadaver of adult weevil was identified to be infected with *Fusarium solani* (VI-1). Pathogenicity of the fungus was proved and morphological characters of the fungi were also studied. *Metarrhizium anisopliae* (Ma4) @$10^8$spores/ml treated on 3$^{rd}$ instar grubs of banana rhizome weevil caused cent per cent mortality on 10DAT. Mortality of adult weevils treated with the same caused only 35% mortality even on 20 DAT. *Beauveria bassiana* (Bb5)@$10^8$spores/ml treated on 3$^{rd}$ instar grubs caused maximum (85%) mortality even after nine days of treatment. In case of adults, maximum mortality was 25% which was obtained 20 DAT. *Beuveria bassiana* (ITCC 6063) @$10^8$ spores/ml was treated on 3$^{rd}$ instar grubs of weevil and maximum 46.66% mortality was obtained even after 5DAT.In case of adults, the mortality was very less. 3$^{rd}$ instar grubs treated with *Paecilomyces lilacinus* (ITCC6064) @$10^8$ spores/ml caused maximum 85% mortality on 8DAT. Adult weevils treated with *P. lilacinus* caused maximum 20% mortality even after 20DAT.

**36. Bioecology of small hive beetle and assessment of their damage from stingless bee colonies of Kerala- PG**

Highest incidence of hive beetle incidence was recorded from Kollam district (19 %) followed by Thiruvananthapuram (16%) and Pathanamthitta (3%) districts.The damage symptoms recorded from infested colonies was tunneling through honey pots, pollen pots and brood cells and caused fermentation and discolouration of honey due to the feeding and defecation by the

beetle larvae and finally a light brown coloured undistinguished mass of hive contents. The small hive beetle infesting the stingless bee colonies of Kerala is identified as *Epuraea latissima* Erichson. Other pests such as black soldier fly *Hermitia illucens* L., Tenebrionid beetle *Palorus* spp, pollen mite and ants were also documented from the apiaries. Four species of root knot nematode viz., *M. incognita, M. javanica, M. arenaria* and *M. chitwoodi* were described from brinjal, bhindi, tomato and banana from 3 districts (Thiruvananthapuram, Idukki and Trissur) of Kerala. The percentage of *M. incognita* was higher in Thiruvananthapuram district whereas *M. javanica* and *M. arenaria* was higher in Idukki and Thrissur respectively. *M. chitwoodi* was described from Kattakada of Thiruvananthapuram district from bhindi.

**37. The Lamiinae (Coleoptera: Cerambycidae) of southern India.**

The flat faced long-horned beetles were collected from the following localities in southern India. Kerala: Ponmudi, Peringamala, Kazhakkuttam, Vidhura, Pondipath, Pampadumpara, Myladumpara, Ernakulam, Kumaragam, Kasaragod and surrounding places of Vellayani. Tamil Nadu: Chidambaram. Karnataka: Mudigere, Mangalore.The information on distribution, host plants, behavior etc. has been generated. The collected specimens were identified using the relevant literature and the identity was cross checked with the holotypes wherever available.

**38. Characterization, evaluation and formulation of *Beauveria bassiana* (Bals.) strains against rice bug *Leptocorisa* spp. (Hemiptera: Alydidae).**

Surveys were conducted in the rice growing tracts of Alappuzha, Ernakulam Thrissur, and Palakkad districts of Kerala. Total genomic extracted from the mycelia of strains of *B. bassiana. In silico* analysis of the amplicon was carried out using BLAST to characterize the entomopathogen. Assessed compatibility of *Beauveria bassiana* with insecticides.

**39. Microbial consortium for the management of insect pests of bitter gourd (*Momordica charantia* L.)**

Mycosed cadavers of *Diaphania indica* and *Epilachna septima* were collected from field and was identified to be infected with *Fusarium verticilloides* and *Fusarium equisett.* Koch's postulates was proved. Host range of *F.verticilloides* was conducted and was found to be pathogenic to *Aphis gossypii* and *D. indica.* Based on the compatibility between various microorganisms tested, *Metarhizium anisopliae, Beauveria bassiana, Lecanicillium lecanii and Paecilomyces lilacinus* and the mortality percentage of test insects, a microbial consortium was developed. The consortium offered cent per cent mortality for various test insects such as *Diaphania indica, Epilachna septima, Bactocera cucurbitae and Leptoglossus australis.* 5% dose of the talc formulation was found to be effective against the various test insects and shelf life studies of the developed formulation are going on.

**40. The Eumolpinae (Coleoptera:Chrysomelidae) of southern India.**

The eumolpine leaf beetles were collected from following places in southern India. Kerala: Vellayani campus and nearby regions like Poonkulam, Pachalloor etc. Peringamala Agri Farm, Kumarakon bird sanctuary, Vaikom, Pandipath Bonakkad, Thrippunithura, Pampadumpara (CRS), Mailadumpara (ICRI). Tamil Nadu: Chidambaram. The information on host plant was gathered in all possible cases. The specimens were identified in consultation with the relevant literature. The life cycle study of *Tricliona* sp. is ongoing.

**41. Dissipation and risk assessment of select insecticides used for pest management in cabbage and cauliflower -PG**

Method validation for pesticide residue analysis in cabbage and cauliflower has been carried out. Field trial on dissipation of select insecticides used in pest management of cabbage and cauliflower at Thiruvananthapuram (plains) and Cardomom Reseach Station, Pampadumpara (hills) has been completed. Studies on the effect of pesticides on soil microbial activity *viz.*, urease, phosphatase and dehydrogenase enzyme are ongoing.

**42. Seasonal incidence of predatory wasp (*Vespa* spp.) in Indian bee apiaries and evaluation of bait traps -PG**

The predatory wasp collected from the field was identified as *Vespa tropica.*The incidence of honey bee pests other than wasp (spiders, ants, wax moth, eagle, monkey and lizard) and their mode of attack were documented. The spiders predating on bees were identified as *Argiope anasuja, Hersilia savigyni* and *Thomisus lobosus*. The predatory wasp incidence was recorded only during fifteen weeks ($35^{th}$ week to $50^{th}$ week) of the year, from August to December (brood rearing season of Indian honey bee). The peak incidence of wasp was recorded in the $44^{th}$ week (November). The bees were found predated by the wasps only for five weeks ($41^{st}$ week to $45^{th}$ week), with a maximum of 18 wasps per week. Of the ten apiaries selected purposively, highest wasp incidence was recorded at Kuriathi, Nedumangad. The predatory strategy of bees and counter attack by bees were also documented. Studies on the evaluation of bait traps (protein and carbohydrate based) revealed that they were not effective against wasps. More number of bees (46 Nos.) were caught in carbohydrate based trap (pineapple molasses trap), rather than the adult wasps (2 Nos.).

**43. Population dynamics, biology and management of mealy bug, Phenacoccus solenopsis Tinsley (Hemiptera: Pseudococcidae) on okra.**

The main objective was to study the population dynamics, biology and management of *Phenacoccus solenopsis* Tinsley and characterization of its endosymbionts. Preliminary surveys were conducted during 1st week of April and mealybugs have been collected for rearing under laboratory condition. Culture of mealybugs being maintained on pumpkin in rearing cages. Application of *Paceilomyces lilacinus* and neem cake reduced the plant parasitic nematode incidence in cucumber considerably. Application of glyricidia leaves and marigold also reduced the parasitic nematode in the crop. To manage the red spider mite in the polyhouse, spiromezifen, botanicals like neem oil soap (2%) and neem oil and entomopathogenic fungi like *Lecanicillium & Beauveria* were used. Spiromezifen was effective against red spider mites. Botanicals *viz.*, neem oil soap (2%) and neem oil were moderately effective against mites. Entomopathogenic fungi *viz., Lecanicillium & Beauveria* were moderately effective against mites.

**44. Severity of mealybug studies in Kerala**

Roving survey conducted throughout Kerala from April 2016 to March 2017 and the survey showed that mealybug population was highest in summer season compared to rainy season. On various host plants, 37 mealybug species were recorded and got identified from NBAIR, Banglore, of which 3 were root mealy bugs

The dominant mealybugs are *Phenacoccus solenopsis, Paracoccus marginatus, Planococcus lilacinus, Nipaecoccus viridis, Ferrisia virgata, Dysmicoccus brevipes, Rastrococcus iceryoides, Coccidohystrix insolita. Phenacoccus solenopsis* collected from almost all districts of Kerala and its infestion was high on Malavaceae and Asteraceae species.

Significant finding of the survey is the collection of root mealybugs on colocasia cowpea, balsam, okra and coleus *Plectranthus rotundifolius* (koorka) apart from banana and pepper; it appears a relation between the mealybug and the root knot nematode in *Plectranthus rotudifolius*

Twelve predators *viz*., *Hyperaspsis maindroni* Sicard, *Rodolia amabilis* Kapur, *Scymnus castaneus* Sicard, *Scymnus latemaculatus* Motshulsky**,** *Scymnus latemaculatus* Motshulsky, *Scymnus nubilus* Mulsant, *Cacoxenus perspicax* Knab, *Cryptolaemus montrouzieri* Mulsant, *Spalgis epius* Westwood**,** *Rhizobius foresieri* Mulsant, *Orius sp, Reuteria marqueti* Puton on mealybug *viz., Planococcus lilacinus, Planococcus citri, Nipaecoccus viridis, Phenacoccus solenopsis* and *Paracoccus marginatus*

Twenty six parasitoids, including *Aenasius arizonensis* (Girault) and *Prochiloneurus pulchellus* Silvestri apart from *Acerophagous papayae* were recorded on mealybugs and got identified from Aligarh Muslim University, UP; out of six identified parasitoids one hyperparasitoid also recorded from *Nipaecoccus viridis i.e* . *Prochiloneurus pulchellus* Silvestri. An Apanteles species recorded on *Ferrisia virgata* belonged to the genera of Microgastrinae, a new record on mealybug

Trichomes provide a foot hold for mealybugs and trichome-mealybug interaction was studied on host plants of mealybug. A positive correlation was found between trichomes and *Phenacoccus solenopsis, Coccidohystrix insolita* and *Maconellicoccus hirsutus* infestation; a negative correlation was found between trichome density and the population of *Paracoccus marginatus, Pseudococcus longispinus Planococcus lilacinus, Pseudococcus jackbeardsleyi, Rastrococcus iceryoides, Icerya seychellarumm, Icerya aegyptiaca, Rastrococcus invadens* and *Ferrisia virgata*

Population of *Dysmicoccus brevipes* was recorded on pineapple, banana, pepper and *Ludwigia*.

Peroxidase activity, total phenol and poly phenol content showed a marked difference in the infested and un-infested plants indicating that the mealybug infestation broken up the host plant's inherent resistance against the herbivore

Among the different insecticide tested to manage the dominant mealybugs (*P. solenopsis*), imidacloprid was more effective than chlorpyriphos and thiomethoxam. Buprofezin and fipronil were not effective against *Phenacoccus solenopsis*.

## 45. Potential of the natural biopolymers, chitin and chitosan in pest management -PG

The project was aimed to evaluate the insecticidal properties of the natural biopolymers, chitin and chitosan for utilization in crop pest management.

Chitin, chitosan, chitosan gel @ 7% and commercial formulations (Bioboost and Biorakshak) @ 2% caused mortality on *Epilachna vigintioctopunctata, Aphis craccivora,* plant parasitic nematodes *Meloidogyne incognita*, *Rotylenchulus reniformis*, and antifeedant activity against *Diaphania* indica, *Myllocerus viridanus*

Chitin @ 7% caused cent percent mortality of *A. craccivora* on 5 days after treatment and *M. incognita* two days after treatment.

Chitosan @ 7% killed all *E. vigintoctopucnctata* on 10 days after treatment and *R. reniformis* 8 days after treatment.

## 46. Biology and predatory potential of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) on insect pests of cowpea.

Different biological parameters of *R. marginatus viz.* fecundity, adult longevity, duration of nymphal instars, pre and post oviposition periods, oviposition period and morphometrics have been studied on larvae of *S. litura.* Predatory potential of third instar nymph of *R. marginatus* at different prey densities was studied on fourth instar larvae of *S. litura*. Number of prey killed by the predator increased with the increase in prey density. Efficacy of the predator was studied in

cages where the predator reduced the population of *S. litura* significantly. It also reduced the aphid population when released at 20 days interval. The evaluation of *R. marginatus* in field proved that *R. marginatus* reduced the population of *A. craccivora* and *S. litura* in field without affecting the population of other predators.

## 47. Efficacy of *Neoseiulus longispinosus* (Evans) (*Mesostigmata: Phytoseiidae*) for the management of *Tetranychus urticae* Koch (*Prostigmata: Tetranychidae*) on cucumber under protected cultivation -PG

Purposive surveys, conducted in fifteen polyhouses in four districts of Kerala *viz.,* Thrissur, Palakkad, Wayanad and Thiruvananthapuram, revealed the occurrence of four species of tetranychid mites, *viz.*, *Tetranychus truncatus* Ehara, *T. urticae* Koch, *T. okinawanus* Ehara, *Eutetranychus orientalis* (Klein) and one species of tarsonemid mite, *Polyphagotarsonemus latus* (Banks) on cucumber. The occurrence of *T. truncatus* and *T. okinawanus* is a new report on cucumber in polyhouse. Hence, DNA barcoding was carried out to confirm the species identity of *T. truncatus* (TOCRF001-15) and *T. okinawanus* (TOIR001-15). Studies on the relationship of crop stage and mite incidence on cucumber revealed that the population of spider mites was significantly higher during the late fruiting stage of the crop, followed by early vegetative stage. Relatively lower population was recorded at flowering stage and early fruiting stage.

Four species of insect predators and six species of mite predators were recorded in association with spider mites on cucumber. The insect predators were *Stethorus pauperculus* (Weise), *Oligota* sp., *Scolothrips* sp. and an unidentified species of Cecidomyiidae. The predatory mite fauna included *Agistemus garrulus* Chaudhari, *Amblyseius paraaerialis* (Muma), *Cunaxa* sp., *Cheyletus* sp., *Neoseiulus longispinosus* (Evans) and *Tydeus gossabaensis* Gupta. *Neoseiulus longispinosus* was found to be the predominant species of predatory mite on spider mites infesting cucumber.

Tetranychus urticae recorded a developmental period of 6.75 days in male and 7.15 days in female. The sex ratio was female biased in T.urticae. Total developmental period of N. longispinosus was 3.91 and 4.27 days for male and female, respectively. Adult male lived for 19.66 days and the female, for 22.75 days. Parthenogenesis was not observed in N. longispinosus. The adult of N. longispinosus recorded significantly higher predation compared to the nymph. Both nymph and adult, showed preference towards egg compared to active stages of the prey. The time needed to eliminate the available prey population was found to increase with increase in prey density.

Studies conducted to identify the optimum predator : prey ratio required for field release of N. longispinosus against T. *urticae* on cucumber in the laboratory showed that, at ratios of 1:5 and 1:10, the prey population was completely eliminated by tenth day. The prey population recorded in the ratios, 1:20, 1:25 and 1:33 were on par with this. In the polyhouse, the predator: prey ratios of 1:20 and 1:25 were found to significantly reduce the population of T. *urticae* on cucumber.

# Project Coordination Group - Plant Pathogens and Beneficial Microbes(12)

**Project Coordinator - Dr. Anita Cherian K**

**Concluded Projects: 26**
**Ongoing Projects: 27**

## Concluded Projects

1. **Development and adoption of microbial Inoculant technology for cropping systems of Kerala- Lead Centre - State Plan**

   Production of microbial inoculants in KAU can be scaled up to 800 tons per year from less than 22.50 tons per year before 2012-13 with the strengthening of infra structure facilities of 12 sub centres of KAU and the Department of Agricultural Microbiology, College of Agriculture, Vellayani functioning as the lead centre in the project. Household waste management technology using composting inoculum was further refined with a new design having cement pots of 60 cm diameter & 60 cm height. Constructed a Pilot Plant for solid waste processing at College of Agriculture, Vellayani for managing waste generated in the campus particularly of Ayyankali school. The centre also provided advisory service and regular supply of microbial inoculants to the farmers.

2. **Development of microbial consortium for bioremediation of organophosphorus pesticides-RKVY**

   The inoculum dosage of microbial consortium for bioremediation of organophosphorus pesticides was standardized with three levels of inoculum *viz*., 1ml, 0.1ml and 0.01ml and 100,500 and 600 ppm each of spray fluid of chlorpyrifos. Based on the study, the dosage was standardised as 0.01 ml of consortium for 100ppm spray fluid and 0.1 ml for 500 and 600 ppm spray fluid respectively. *In vitro* study to monitor the effect of consortium on the degradation of chlorpyrifos in spray fluid revealed significant reduction in the residue of chlorpyrifos in the consortium applied treatments compared to control. A novel concept of delivery of the organisms in the spray fluid of chlorpyrifos was developed and tested in two target crops, *Amaranthus tricolor* and Bhindi.

3. **Soil based Nutrient Management plan for Agro Ecosystem of Kerala**
   **Phase II – Population dynamics of microorganisms in soil samples of Kerala**

   Enumeration of fungi, bacteria and actinomycetes were carried out in **1120** soil samples collected by Agricultural Officers of selected Krishi Bhavans in the Dept. of Agrl. Microbiology, College of Agriculture, Vellayani, eventhough the study targeted analysis of 2400 samples. The population of important microorganisms such as nitrogen fixers, *Azospirillum* and *Azotobacter*, P' solubilizers and antagonistic microorganisms like *Pseudomonas fluorescens* and *Trichoderma* were also assessed. It was found that even though the population of Nitrogen fixers such as *Azospirillum* and *Azotobacter* and antagonistic flora of *Trichoderma* and *Pseudomonas fluorescens* were less in majority soil samples, significant number of 'P' solubilizers could be recorded in many of the samples.

4. **Standardization of liquid formulation of PGPR mix–I and its evaluation for plant growth promotion in Amaranthus (*Amaranthus tricolor* L.)**

   The study aimed at standardization of liquid formulation of PGPR mix–I and evaluation of its plant growth promotion attribute in amaranthus was conducted in the Department of Agricultural Microbiology, College of Agriculture, Vellayani. The component cultures of PGPR mix-I, *Azospirillum lipoferum, Azotobacter chroococcum, Bacillus megaterium* and *Bacillus sporothermodurans* were procured from the Department of Agricultural Microbiology, College of Agriculture, Vellayani.

   Under *in vitro* conditions, the nitrogen (N) fixers, *Azospirillum lipoferum* and *Azotobacter chroococcum* produced 40.31 and 36.43 ppm of IAA whereas *Bacillus megaterium* and *Bacillus sporothermodurans* produced 1.28 ppm and 3.36 ppm of IAA respectively. Among the cultures,

the nitrogen (N) fixers, *Azospirillum lipoferum* and *Azotobacter chroococcum* yielded 21 and 14 mg N $g^{-1}$ of carbon source whereas solubilization of phosphorus (P) by *Bacillus megaterium* was 69.36 ppm, which also recorded a clearing zone of 8 mm and 12 mm diameter in NBRIP and Pikovaskaya's medium respectively. *Bacillus sporothermodurans* under *in vitro* conditions recorded K solubilization of 12.18 ppm of potassium (K) and a clearing zone of 18 mm diameter in Glucose Yeast Agar medium.

An experiment carried out to standardise the protocol for the preparation of liquid formulation of PGPR mix–I in completely randomized design with 2% Glycerol, 2% Polyvinylpyrrolidine (PVP), 15mM Trehalose, 1% Glycerol + 1% PVP, Glycerol (2%) + Trehalose (1%) + Yeast extract (1%) + PVP (1%) + Proline (1%) as treatments and control without any additives in four replications and talc based formulation as a standard revealed the formulation amended with 15mM Trehalose was the best with maximum viable count even after fourteenth month of inoculation. The efficiency of selected liquid formulation was tested as pot culture experiment in amaranthus with treatments, 100% NPK as per KAU recommendation as chemical fertilizer alone, talc based or liquid formulation of PGPR mix–I each alone and with 100% and 50% NPK, control with additives without PGPR microorganisms and absolute control in three replications. The treatments were applied @ 2 % as seedling dip at the time of transplanting and as soil drenching @ 50 ml in each pot two weeks after transplanting.

The results indicated that the treatment $T_6$- liquid formulation of PGPR mix–I+ 100% NPK recorded, maximum plant height of 37.54 cm, leaf number of 44.44 and leaf area index of 4.97 at harvest, fresh and dry weight of shoot (55.41 and 4.97 g $plant^{-1}$ respectively) and fresh and dry weight of root (6.6 and 0.56 g $plant^{-1}$ respectively). but was on par with $T_3$- talc based formulation of PGPR mix–I+ 100% NPK. But $T_6$ recorded the least oxalate content of 0.39 per cent as well. However, the treatment liquid formulation of PGPR mix–I + 50% NPK ($T_7$) was found to be statistically on par with chemical fertilizer @ 100% NPK ($T_1$) in parameters such as plant height, number of leaves, leaf area index, fresh and dry weight of shoot and root and oxalate content.

Application of treatments also had significant effect on the soil available NPK content. Analysis of rhizosphere population after application of PGPR mix-I revealed successful colonization of organisms of PGPR mix-I in the rhizosphere of amaranthus.

## 5. Isolation and characterization of Pink Pigmented Facultative Methylotrophs (PPFMs) associated with paddy

The main objectives of the study were isolation, characterization and evaluation of Pink-Pigmented Facultative Methylotrophs (PPFMs) associated with paddy for antagonistic efficiency, seed germination, seedling growth and yield of paddy.

Forty six isolates obtained from different locations were tentatively identified PPFMs based on the characteristic pink pigmented colonies on AMS agar supplemented with 0.5% methanol as sole source of carbon and energy and code numbers were allotted for each of the isolate. The product of Tamil Nadu Agricultural University was taken as the reference culture.

Different isolates of PPFM showed production of Indole Acetic Acid (IAA) and carotenoid pigment in the ranges of 9.27 to 68.65 µg $mL^{-1}$ and 0.07 to 1.74 µg $mL^{-1}$of culture filtrate, with a maximum IAA production of 68.65µg $mL^{-1}$ by PPFM35 and the highest carotenoid production was recorded in PPFM16 (1.74 µg $mL^{-1}$).

The antagonistic efficiency was tested against three major pathogens of paddy *viz. Rhizoctonia solani, Pyricularia oryzae* and one bacterial pathogen, *Xanthomonas oryzae* pv. *oryzae* by dual culture method along with the reference culture. Six out of forty seven isolates tested inhibited *Rhizoctonia solani* and the isolate PPFM 10 exhibited the maximum zone of inhibition (ZOI) of 12.72 mm. Four out of forty seven isolates tested showed antagonistic activity against *Pyricularia oryzae* with PPFM24 producing the maximum zone of inhibition of 10.00 mm. Four isolates inhibited *Xanthomonas oryzae* pv. *oryzae* and PPFM5 produced the maximum ZOI of 9.80 mm diameter.

The isolates were also tested for their efficiency to enhance seed germination and seedling growth and cent per cent germination was recorded for the isolate PPFM35.However the isolates, PPFM30 and PPFM22 recorded maximum shoot length of 26.38 cm and maximum root length of 24.20 cm respectively. Highest seedling vigour index of 4756.35 was observed with PPFM22 and maximum root shoot ratio of 0.62 was observed with PPFM26 and PPFM35.

In pot culture experiment with variety Jyothi (Ptb-39)) in completely randomized design using wetland soil, PPFM application was found to positively influence, growth, biomass production and yield of paddy. The isolate, PPFM11 recorded the highest grain yield of 46.30 g $hill^{-1}$ compared to 33.65 g $hill^{-1}$ in control and 38.40 g $hill^{-1}$ in the reference culture. Physiological characterization of plants revealed significant influence of PPFM isolates on chlorophyll content, cell membrane stability and proline content of the plant compared to untreated plants.

The isolates PPFM11, PPFM16, PPF19, PPFM22 and PPFM35 were adjudged as superior isolates based on maximum germination percentage, seedling vigour index, growth promotion efficacy and grain yield of paddy. These five isolates were identified as *Methylobacterium* spp. based on morphological, biochemical and molecular characteristics.

**6. Standardization of liquid formulation for enhancing the shelf life of *Azospirillum* and phosphate solubilizing bacteria (PSB)**

The performance of liquid formulations of *Azospirillum* sp. and PSB was assessed under field condition using amaranth as test crop.

Based on the plant height, number of leaves, number of days taken for flowering and total biomass of plant, the PSB (liquid formulation) was the most promising biofertilizer for enhancing the growth of amaranth. While comparing the performance of liquid and carrier-based formulations of *Azospirillum* sp. and PSB, the liquid formulations of the two biofertilizers performed better than carrier based formulations.

**7. Exploitation of native agriculturally important microorganisms (AIMS) for integrated nutrient management in various agro-ecosystems of Kerala**

A total of 11 bacteria, 4 *Pseudomonas* 17 actinomycetes, one PSB, 12 nitrogen fixers,4 *Rhizobium* were isolated from twelve soil samples were collected from Maradu (agro-ecological unit-Southern laterite, agro-ecological zone: Midland laterite) and Kannur (Agro-ecological unit: Kaipad, agro-ecological zone: Coastal plains, AEU-7). The isolates were tested for PGP characterization and one isolate (K2PSB) from Kaipad was positive for IAA, four isolates from Maradu (M3BBb, M4BB, M4BA1 and M4BA) for HCN, 7 isolates (five from Maradu and two from Kaipad) for siderophore and 34 (15 from Kaipad and 19 from Maradu) for ammonia production.

Nitrogen fixer from Maradu was identified by 16S rDNA sequencing as N2ANFA from Maradu as *Rhizobium* sp. Other nitrogen fixers were identified as *Microbacterium*(two isolates), one

*Sphingomonas*, one*Burkholderialatens*, one *Novosphingobium*, one Arthrobacter and one *Agrobacterium*. Nitrogen fixers and actinomycetes from Maradu region exhibited more antagonistic activity towards plant pathogens. Fifty isolates were tested for antagonistic activity against five soil borne plant pathogens: *Sclerotium rolfsii, Pythium aphanidermatum, Rhizoctonia solani, Fusarium oxysporum* and *Ralstonia solanacearum*. *Rhizobium* sp. exhibited antagonistic activity against *Rhizoctonia* (27.7% inhibition), *Sclerotium* (33.3 % inhibition) and *Fusarium* (44.4% inhibition).

**8. Inoculants Technology for cropping systems of Kerala - State Plan**

A total of 920 kg *Pseudomonas fluorescens*, 526 kg *Trichoderma viride*, 476 kg *Azotobacter*, 467 kg *Azospirillum*, 38 kg *Rhizobium* were produced and distributed to farmers after necessary quality check. Around 960 litres of composting inoculum were also produced and distributed for solid waste management. For all the products like *Bacillus subtilis*, *Pseudomonas fluorescens*, *Azotobacter*, *Azospirillum* and *Rhizobium* colony count of $>2x10^8$ c.f.u/g cells and for *Trichoderma viride* > $2x10^6$ c.f.u/g cells were maintained.

**9. Metagenomic analysis of the bacterial diversity in the rhizosphere of arecanut palms affected by yellowing in Wayanad-PG**

Soil samples were collected from the rhizospheres of healthy palms in yellowing affected plantation (apparently healthy) and completely healthy palms from unaffected plantation and analysed for their chemical and biological properties. The analysis of soil physico-chemical parameters revealed that an increased proportion of Fe and Al in the yellowing affected soils might have hindered the uptake of other nutrients like calcium and magnesium. The culturable microflora and microbial biomass carbon analysis indicated that there was a slight increase in the rhizosphere of healthy palms from unaffected plantation than that of arecanut palms from affected plantation. A significant increase in the population of *Bacillus* was observed in the completely healthy arecanut palm rhizospheres.

The predominant bacterial phyla in the arecanut rhizosphere included Proteobacteria, Actinobacteria, Acidobacteria, Bacteroidetes and Firmicutes. The phyla Proteobacteria, Acidobacteria and Verrucomicrobia were found to be dominant in the apparently healthy arecanut palm rhizospheres when compared to the yellowing affected counterpart. The class Alphaproteobacteria was found to be abundant in the apparently healthy rhizosphere with the other classes namely Beta, Gamma and Epsilon Proteobacteria showing no pattern of abundance. The abundance of genera *Bradyrhizobium, Sphingomonas* and *Burkholderia* were observed in the apparently healthy rhizosphere soil samples. An increased population of *Pseudomonas, Bacillus* and *Nitrospira* in one of the completely healthy soil sample was identified, while an increased proportion of *Massilia* in one of the yellowing affected rhizosphere was recorded. Bacterial diversity in the rhizosphere of apparently healthy palms was found to be higher than that of the yellowing affected palms as indicated by Shannon-Weaver and Simpson indices.

**10. Eco friendly management of leaf blight disease of Amaranthus.**

Objective was to formulate an integrated disease management package for leaf blight disease of Amaranthus. Spraying with Mancozeb (0.2%) in cowdung slurry at two weeks interval found to be the best treatment for managing leaf blight disease of amaranthus. Next best treatment was soil application of *Trichoderma* + spraying with *P fluorescens* at two weeks interval.

**11. Development and adoption of microbial inoculant technology for cropping systems of Kerala**

The objective of the study was for strengthening the research, production and distribution of bio-fertilizers and biocontrol agents in Kerala. Six bio-control agents *viz*., *Pseudomonas fluorescens*,

*Trichoderma viride, Metarhizium anisopliae, Lecanicillium lecanii, Paecilomyces lilacinus* and *Beauveria bassiana* were commercially produced and distributed to the local farmers.

12. **Establishment of organic input production and technology support centre in college of agriculture, Padannakkad.**

**Main biocontrol agents produced** - *Trichoderma* sp., *Pseudomonas fluorecens, Verticillium, Beauveria, Metarhizium*

**Other Products-**Azolla

**Novel products developed under the project:-**Micronutrient mixture ( AYAR), Ready To Use Neem oil Garlic Soap (RAKSHA), Panchagavya, Fish Jaggery Extract, Vermiwash**.**

13. **Biocontrol potential of plant associated bacteria from Piper spp. against *Phytophthora capsici* infecting black pepper**-PG

The objective was to study the antagonistic effect of plant associated bacteria from *Piper colubrinum* and *Piper nigrum*, and their potential for the biological control of *Phytophthora capsici* induced foliar infection in black pepper in the nursery. The study revealed that wild relative of black pepper, *P. colubrinum* is a good source for isolation of antagonistic bacteria against *P. capsici*. Bacterization with endophytes improved the plant growth characteristics and helped in better establishment of plants. Treatment with plant associated bacteria from *P. colubrinum* and *P. nigrum* suppressed the development of foliar infection of *P. capsici.* The endophytes of *P. colubrinum*, *Rhizobium* sp PCRE10 and *B. velezensis* PCSE10 were selected as best candidates when both disease suppression and plant growth promotion were considered.

14. **Evaluation and improvement of production technology of paddy straw mushroom (*Volvariella* sp.).**

The objective was to study their morphological characters, improvement of techniques for production of paddy straw mushroom and to make an evaluation of the nutritional and organoleptic qualities. As a part of the study collections were made from various locations of Thiruvananthapuram and Kollam districts and thirteen different isolates of paddy straw mushroom were obtained. Comparison on the effect of different substrates for paddy straw mushroom production showed that paddy straw along with oil palm bunch waste on equal proportion amended with 5% gram flour was the best substrate for cultivation with a biological efficiency of 16.33%.

15. **Management of collar rot of cowpea caused by *Rhizoctonia solani* Kuhn using biofumigants.**

The objective was to evaluate the biofumigant nature of plants, oil cakes and plant oils against *Rhizoctonia solani* for evolving an ecofriendly management strategy for the collar rot of cowpea. The experiments revealed the scope of biofumigation for the management of *R. solani* under *in vitro* as well as *in vivo.* The collar rot caused by soil-borne pathogen, *R. solani* could be successfully managed by incorporation of either mustard plant (50g/kg soil) or tea tree oil (5% soil drench) or mustard /groundnut oilcake (10g/kg soil) two weeks before raising cowpea.

16. **Integrated management of Cercospora leaf spot of vegetable cowpea (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt.).**

The present investigation aims to study the symptomatology and etiology of Cercospora leaf spot of cowpea and to develop an integrated management strategy. From the study, it was concluded that foliar application of difenoconazole (0.1%) at an interval of 35, 50 and 65 DAS was found to be the most effective treatment in managing Cercospora leaf spot in vegetable cowpea besides supporting proportionately attractive pod yield (2570 kg/ha) at an acceptable B:C ratio (3.04:1).

Among the organic formulations, mineral oil (0.1%) was found to be the effective treatment in controlling leaf spot with a pod yield of 1293 kg /ha. While, *P. fluorescens* recorded a pod yield of 1318 kg/ha with B: C ratio of 1.57:1.

**17. Organic strategy for the management of sheath blight disease of rice**

The objective was to develop an ecofriendly disease management package for sheath blight of rice using organic preparations, botanicals, soil amendments and non-hazardous chemicals. The pot culture study revealed that the symptoms of rice sheath blight disease developed during 45-52 DAS, which coincided during the active tillering stage of the crop. The least RLH and the maximum percentage suppression over control were observed in the plants sprayed with fermented egg-lemon juice extract (15.24% and 79.42% respectively) and garlic extract (15.29% and 79.36% respectively), which were on par with the fungicide check hexaconazole (15.29% and 79.36% respectively). As far as the yield attributes were concerned, the maximum grain yield was observed in the case of the plants sprayed with fermented weed extract (15.98 g) which was on par with fermented egg-lemon juice extract (15.33 g), garlic extract (14.66 g), lime solution (13.65 g) and potassium silicate (13.32 g).

**18. Exploration of natural products from botanicals and fungal root endophytes for the management of cowpea mosaic virus.**

Objectives are to develop serological and molecular tools for the early detection of cowpea aphid- borne mosaic virus (CABMV); and its management using natural products from botanicals and fungal root endophytes. *Phyllanthus niruri* and *Boerhavia diffusa* at 0.5 and 1%, and the fungal root endophyte Piriformospora indica could significantly reduce the incidence of the cowpea aphid- borne mosaic virus (CABMV) by >90% during pre and post -inoculation of the virus.

**19. Integrated management of viral diseases of bitter gourd (*Momordica charantia* L.)**

The proposed research programme aims to study the occurrence and distribution of viruses in bitter gourd in the cultivated areas of Thiruvananthapuram, Idukki and Palakkad, immune-molecular characterisation of viruses, screening of antiviral chemicals, products of animal, plant and microbial origin for the management of the diseases. A field trial to study the effect of treatments on natural incidence of the viruses in the susceptible variety Preethi indicated that the treatment, three sprays of ASM-50 ppm (V.I- 28.33) at ten days interval was on par with buttermilk (three times dilution of curd) (V.I-39.16). Yield was also significantly high in ASM-50 ppm (437 g plant$^{-1}$) followed by *Pseudomonas fluorescens* talc based formulation (2%) (233 g plant$^{-1}$) among the treatments.

**20. Characterization and exploitation of jelly mushrooms (*Auricularia* spp. / *Tremella* spp.)**

The project aimed at standardization of techniques for production of jelly mushrooms (*Auricularia* spp./ *Tremella* spp.) in agricultural wastes and to study their morphological, physiological and cultural characteristics as well as nutritional and organoleptic qualities. The present study revealed that *A. polytricha* can be cultivated successfully in Kerala by utilizing the locally available materials. Availability of rubber sawdust is not uncommon so it can be effectively utilized for the production of fruiting bodies along with two per cent rice bran since it grows well in tropical conditions. In order to enhance the productivity of mushroom, weather parameters like temperature, aeration, relative humidity and light have to be managed properly. The attractive colour, ear shape, taste, nutritional as well as medicinal attributes are the supplementary benefits of this mushroom. The anti-cancerous activities revealed that there is a greater scope for utilizing this particular mushroom in medical field.

## 21. Base line studies on vegetable crops under protected cultivation in Kerala as a prelude to precise disease management

Results of the experiment for management of early blight of tomato showed that, systemic fungicide, Quintal (0.1%) was most effective in reducing the disease severity closely followed by Propineb (0.2%) which were on par. Among the bioagents, PGPM was more effective than *Trichoderma viride* and the endophytic bacterium *Bacillus subtilis*. The highest yield was recorded in Quintal -0.1% (9.01 kg/plot) followed by Quintal -0.05% (6.17 kg/plot).

## 22. Cataloguing and documentation of fungal disease of Gerbera in Kerala -PG

This study "Cataloguing and documentation of fungal diseases of gerbera" was to examine the causal agents of diseases, to study their symptomatology, cultural, morphological as well as management of fungal pathogens in the commercial cut flower crop, Gerbera.

Leaf blight 1 (LB-1) pathogen was identified as *Alternaria alternata,* LB-2 as *Alternaria tenuissima,* LB-3 as *Myrothecium roridum,* powdery mildew pathogens as *Golovinomyces cichoracearum* and *Podosphaera* sp., petal blight pathogen as *Curvularia lunata,* root rot pathogen as *Phytophthora cryptogea* and wilt pathogen as *Fusarium solani. In vitro* evaluation of bioagents revealed that fungal antagonist, *Trichoderma viride* showed per cent inhibition of 48.8 to 70 per cent of all the fungal pathogens tested when compared to the bacterial antagonist, *Pseudomonas fluorescens* which showed 22.2 to 57.7 per cent only. *In vivo* evaluation of *Alternaria* leaf blight, *Phytophthora* root rot and *Fusarium* wilt were carried out using fungicides and bioagents which showed promising result under *in vitro* evaluation.

Carbendazim 12% + mancozeb 63% showed 90 per cent disease reduction against *Alternaria* leaf blight. Propineb 70WP, cymoxanil 8% + mancozeb 64% (0.2%) and copper hydroxide 77WP (0.2%) showed 40 per cent disease reduction against *Phytophthora* root rot. Cent per cent disease reduction was noticed with carbendazim 12% + mancozeb 63% (0.2%), difenoconazole 25EC (0.1%) copper hydroxide (0.2%) and *Trichoderma viride* (2%) against *Fusarium* wilt.

## 23. Variability of *Colletotrichum* isolates inciting anthracnose in mango-PG

Variations in the phenotypic characters and cultural characters of the fungal isolates were studied on Potato Dextrose Agar (PDA) and Green Bean Agar (GBA) media. Among the 30 isolates, only 11 isolates showed the development of acervulus and of which only nine isolates produced pink spore mass in the culture. On GBA medium, no variation of cultural characters was observed and the isolates did not produce fruiting body on this medium. Growth rate of each isolate on PDA and GBA media was calculated and based on which the isolates were grouped as fast growing (Group I) and slow growing (Group II). The isolates PI, BL2 and AL4 were recorded as fast growing isolates on both media.

Vegetative compatibility was studied using dual culture technique. Out of the 465 combinations, only 79 showed compatible reactions like intermingling of hyphae and the isolate BL2 recorded the highest compatible groups with other isolates. To study the variations in the pathogenic efficiency, the isolates were cross inoculated on other varieties. The isolate, CT recorded infection on all seven varieties whereas NF3 and PL1 recorded infection on six varieties, which were selected as highly virulent isolates.

Based on the phenotypic and pathogenic characters, seven virulent isolates of *Colletotrichum gloeosporioides*, one from each variety was identified and confirmed as *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. by NCFT with ID No. 8214.16-8220.16. *In vitro* evaluation of plant protection chemicals (three contact fungicides, four systemic fungicides and two insecticides) was carried out to check the sensitivity of isolates. All the four systemic fungicides showed cent per cent inhibition on the growth of 30 isolates and were found most

effective for the control of *C. gloeosporioides.* Bordeaux mixture (1 %) and copper hydroxide (0.15%) recorded cent per cent inhibition of the growth of 28 and 24 isolates respectively. The insecticides, malathion (0.1 %) and dimethoate (0.05%) also recorded inhibition of fungal growth in the range of 50.74 to 83.70 per cent.

**24. Management of downy mildew, *Pseudoperonospora cubensis* (Berk. & Curt.) Rcstow.) of cucumber under protected cultivation -PG**

Downy mildew of cucumber in polyhouse can be expected if the RH inside is ≥79%. Biological management of downy mildew is as effective as chemical control using systemic compounds. The B:C ratio is also more with bio control if premium price is ensured for the produce. Foliar spray with cymoxanil + mancozeb (T10) was the most effective treatment for the management of downy mildew in both poly house and rain shelter followed by foliar spray with mancozeb (T11) and soil solarisation + seed treatment and soil application + foliar spray with *Trichoderma viride* (T1) and these were on par.

**25. Enhancement of systemic resistance to soil-borne pathogens of ginger by enriched spent mushroom substrate of *Pleurotus sajor-caju***

Defence related enzymes and phenol in response to pathogen infection was estimated from the pot culture experiments. SMS softened with $P_1F_1$+$M_1F_2$ recorded the highest activity PPO and phenol. Whereas SMS softened with $K_1B_1$+$T_2B_1$ recorded the highest peroxidase activity. Field evaluation to evaluate the growth promotion and bio control efficiency of enriched and biosoftened SMS in ginger revealed that SMS softened with $T_1F_2$, and $P_1F_1$+$M_1F_2$ were the most effective for the management of soil borne disease of ginger, whereas, SMS softened with $P_1F_1$+$M_1F_2$ recorded the highest growth parameters. The selected fungal antagonists *viz*. $T_1F_2$, $P_1F_1$ and $M_1F_2$ were identified as *Trichoderma viride, T. koningii* and *T. harzianum* and the bacterial antagonists, $P_3B_2$, $T_2B_1$ and $K_1B_1$ were identified as *Bacillus safensis, B. methylotrophicus and Burkoholderia gladioli* respectively.

**26. Enhancing bio-efficacy of *Trichoderma* spp. for the management of soil borne Fungal Pathogens -PG**

Pot culture and field evaluations of the selected mutants (M40M3 & K80M13) and fusants (F2 & F4) of *Trichoderma* sp. with their parents were conducted. From the data it was revealed that, the mutant K80M13 recorded the maximum disease suppression of rhizome rot of ginger and the highest yield compared to the reference culture of KAU. This isolate was identified as *T. asperellum* and can be released after multi-location trials and toxicological studies.

## Ongoing Projects

**1. Development of Liquid formulations- Centre of Excellence in Microbial Technology- Plan**

**a. Nitrogen Fixers** -Developed liquid formulation of Nitrogen fixers viz., *Azospirillum lipoferum* & *Azotobacter chroococcum.* The survival of these Nitrogen fixers in the developed liquid formulation was analyzed at monthly intervals. Significant population was observed even after one year when compared with talc formulation.

**b. PGPR Mix I -**

Liquid formulation of consortium of biofertilizers- PGPR Mix- I was developed and the shelf life studies revealed significant population even after eleven months of storage. The study is in progress. Continuous advisory service was provided to the farmers visiting the centre. Regular supply of microbial inoculants was done to the farmers.

## 2. AINP on Soil Biodiversity- Biofertilizers- Integration of Biofertilizer Technology with farming practices of tribal farmers of Attappady - ICAR

A total quantity of 402 kg of PGPR Mix I was distributed to 402 tribal farmers engaged in the cultivation of vegetables, pulses, banana, sorghum, groundnut, ragi etc. One kg each of PGPR Mix I was distributed uniformly to the selected farmers. Fifty kilograms of composting inoculum for composting biowaste was distributed to 50 tribal farmers of Attappady. Three training programmes were organized at three different locations of Attappady for creating awareness on beneficial aspects of biofertilizers and method of application of biofertilizers to tribal farmers, SHG's and Extension officials. Hundred tribal farmers were selected from each location**.** In order to demonstrate the beneficial effect of the consortium of biofertilizers (PGPR Mix I) field trials were laid out at two different locations of Attappady in banana and chilli. The effect of PGPR Mix I on growth of Arecanut seedlings at Puthoor location was also evaluated.

## 3 Centre of excellence in Microbial Technology

Development, mass production and popularization of biofertilizers and biocontrol agents for different agroclimatic zones of the State, metagenomic approach for soil and plant health management, assessment of soil carbon dynamics and carbon sequestration in different agroclimatic zones as influenced by climate change, microbe-assisted biosolid waste management, impart training to farmers, students and teachers on production and use of bioagents (biofertilizers, biocontrol agents and in waste management) were the objectives of the project.

Enzyme assay was carried out in broth culture for cellulase, laccase and amylase for two bacterial and two fungal isolates. *T. viride* and *Gongoronella butleri* recorded higher amylase and laccase activity whereas *B. niabensis and B. subtilis* were found to possess higher activity of cellulase and glucnase.

Two isolates of bacteria (*B.subtils* and *B. niabensis*) and two fungal isolates (*Trichoderma viride* and *Gongoronella butleri* ) were screened for their plant growth promoting activities *in vitro* and most the isolates possessed PGPR activities like IAA, HCN and siderophore production. The fungal isolate *G. butleri* showed positive for IAA, HCN and siderophore production and exhibited phosphorus solubilization and antagonism against plant pathogens *Rhizoctonia solani* (per cent inhibition 73.33) and *Ralstonia solanacearum* (100 per cent inhibition).The bacterial isolate *B. subtilis* showed siderophore production and antagonism against plant pathogens *Sclerotium rolfsii* (per cent inhibition 14.40), *Rhizoctonia solani* (per cent inhibition 38) and *Ralstonia solanacearum* (per cent inhibition 82.22). The isolates were tested for their compatibility *in vitro* by dual culture technique and the compatible isolates were tested for their efficiency to degrade biosolid waste. Different formulations of *B. subtilis* and *Gongronella* along with cow dung as control treatments were tested for biosolid waste degradation in Thumburmuzhi aerobic composting units and the result showed that per cent reduction in volume was highest in *B.subtilis* (62.43%) and yield of compost was maximum in treatment with cow dung (64 kg). Formulations of *B. subtilis, Gongronella, Trichoderma* and their combination were also tested for the efficiency of decomposing biosolid waste in KAU Smart biobins designed for household waste management. In KAU Smart biobins, inoculation of *B. subtilis* recorded maximum yield of compost after 80 days of treatment (700 g)

A replicated trial was also laid out with three treatments (*B. subtilis, G. butleri* and cowdung) in Thumburmuzhi model aerobic composting units. *B. subtilis* and *G. butleri* recorded significantly higher values for volume reduction (62.43 and 58.47 per cent respectively). *G. butleri* recorded maximum temperature ($62.17^0$C) on second day and *B. subtilis* recorded maximum temperature ($60.83^0$C) on fourth day.

## 4 Soil Biodiversity and Biofertilizers - AINP

Efficiency of few novel nitrogen fixing bacteria obtained from the rhizosphere of black pepper from Wayanad were tested in field with *Microbacterium, Cellulosimicrobium, Paenibacillus,* and *Azospirillum lipoferum* (reference culture of KAU) as treatments and farmer's practice as control. Among the different biofertilizers, *Paenibacillus* treated pepper, ginger, cowpea and bitter gourd plants recorded increase in growth parameters and yield compared to uninoculated plots.

Eight native isolates of cowpea rhizobia from Wayanad were characterized by sequencing of *nif H and nod*C genes. Field evaluation of rhizobial isolates on cowpea revealed that RH-4 and RH-2 were efficient in improving nodule number and yield of cowpea.

Metagenomic DNA was isolated from soil samples collected from the rhizosphere of the selected areca palms with standard kit. Quality and quantity of DNA was checked on agarose gel and spectrophotometry and the samples were subjected to Next Generation Sequencing (NGS) using the Illumina platform. A combination of V3-V4 regions on the 16S rRNA gene was sequenced using Illumina, MiSeq. Sequence reads were analyzed using bioinformatics tools.

A comparison between yellowing affected and apparently healthy (AH) samples revealed an increase in the number of OTUs in the rhizosphere of AH plants. The three most abundant bacterial phyla in yellowing affected plant rhizosphere belonged to the order Bacteroidetes (*Terrimonas* (40 %), *Chitinophaga* (28 %)), Actinobacteria (*Arthrobacter* (41 %), *Thermolephilum* (10 %)), Firmicutes (*Bacillus* (59 %) and *Clostridium* (8 %)) and Proteobacteria (*Massilia* (11 %)) whereas Actinobacteria (*Arthrobacter*(45 %), Thermolephilum (7 %)), Firmicutes (*Bacillus* (58 %) and *Clostridium* (10 %)) and Bacteroidetes (*Terrimonas* (28 %), *Chitinophaga* (18 %)) dominated the rhizosphere of AH plants.

## 5. Evaluation of *Bacillus thuringiensis* isolates against *Diaphania indica* (Saund.) (Lepidoptera: Pyralidae) -PG

To develop a commercial formulation of *Bacillus thuringiensis* and evaluate its bioefficacy for the management of *Diaphania indica* (Saund.) was the objective of the project. Twenty Bt isolates were tested for morphological, biochemical and molecular characterization. Among these, seven isolates yielded *cry*1 gene amplicons. Three native isolates (KAU-11, KAU-474 and KAU-2189) were selected for laboratory bioassay against the lepidopteran pest pumpkin caterpillar (*Diaphania indica*). Bio efficacy of the liquid formulations was evaluated in green house conditions using little gourd (*Coccinia indica*) as a test crop against *D. indica*. Btk (ABTEC), a commercial formulation was also used as check. The highest per cent mortality was recorded for the formulation containing HD-1 in coconut water which was comparable to the percentage mortality obtained for KAU-2189 in coconut water. Leaf damage was minimum in HD-1 in coconut water, which was statistically on par with native isolate KAU-2189. Shelf life studies of liquid formulations indicated that both population and spore count decreased from fourth month onwards.

The study revealed that the native isolates have the potential to be developed into a biopesticide. Coconut water could be used as an ingredient for low cost liquid formulation.

## 6. Evaluation of biofilm based microbial antagonists for the management of soil borne diseases and growth promotion in cowpea (*Vigna unguiculata* L. Walp)-PG

The project was initiated with objective to increase the survivability of *Trichoderma* sp. and *Bacillus* sp. through biofilm production and to evaluate the biofilm-based biocontrol agents for

the management of soil borne diseases caused by *Phythium aphanidermatum* and *Rhizoctonia solani* and also growth promotion in cowpea. Work is in progress.

7. **Evolving strategies for integrated management of diseases of salad cucumber and vegetable cowpea under poly house cultivation in terraces**

   Objectives of the study included to develop an integrated package for the management of important diseases of salad cucumber and vegetable cowpea grown in poly house on terrace, and to validate the best treatments from the above experiments to arrive at a comprehensive integrated disease management strategy and pesticide residue analysis.

   The project was initiated during April, 2017. Eight varieties (Lola, Vellayani Jyothika, Gitika, NS 621, Vybhav, Reenu, Bably and Hari Rani) of yard long bean were screened and among them, NS 621 was identified as the high yielder as well as the most susceptible variety to powdery mildew disease, the most important foliar diseases of yard long bean in poly house cultivation. The trial for the management of powdery mildew revealed that foliar spray of fermented papaya leaf extract in cow urine (1:1:5) followed by *Pseudomonas fluorescens* KAU isolate (2%) on $30^{th}$, $45^{th}$, $60^{th}$ and $75^{th}$ DAS resulted in the highest yield and lowest incidence of powdery mildew disease.

8. **Identification of Pathotypes / races in red rot pathogen-ICAR**

   Reported no emergence of new pathotype in the zone.

9. **Evaluation of pre-zonal/IET/zonal varieties/ genotypes for resistance to red rot - ICAR**

   Out of 62 genotypes evaluated for red rot resistance, 31 entries found to be resistant/ moderately resistant.

10. **Survey of sugarcane diseases naturally occurring in the area on important sugarcane varieties.**

    The diseases observed were rust, mosaic and Pokkah Boeng and foliar disease *viz*., ring spot and sheath blight. But none of the diseases were in a severe stage to cause any drastic yield decline.

11. **Commercial micropropagation of high value crops as per national certification system for tissue culture plants- network project**

    The objectives of the study were to co-ordinate the virus indexing activities at different participating centres; to assure quality of micropropogated plants produced at various centres through clonal fidelity testing and virus indexing; and to give training on commercial micro propagation and quality assurance of micropropogated plants. Trials were undertaken.

12. **Development of technologies including alternative for banned pesticides for the management of pests and diseases of major crops in Kerala- RKVY**

    Objectives of the study are developing eco-friendly management measures for the control of amaranth leaf blight caused by *Rhizoctonia solani*, the major diseases threatening the cultivation of amaranth in the State; developing eco-friendly management measures for the control of Fusarium wilt, Rhizoctonia root rot and web blight and Pythium collar rot of vegetable cowpea, serious threats in the cultivation of cowpea in the state; developing eco-friendly management measures for the control of downy mildew and powdery mildew diseases of cucurbits (bitter gourd and snake gourd) seriously affecting the cultivation of cucurbits in the state; and

developing eco-friendly management measures for the control of Cercospora leaf spot of bhindi which is becoming a serious problem affecting the cultivation of bhindi in the state. Trials were undertaken.

13. **Establishment of an Advanced Research Centre for Plant Disease Diagnosis**
    Objectives include establishment of an Advanced Research Centre for Plant Disease Diagnosis, Consultancy / Advisory Services, Training for scientists working in this field of specialization, Maintain a type culture collection for reference during diagnosis and Maintain a cryptogrammic herbarium. Research is in progress

14. **Synergism in Defense and Growth: Exploration of a root endophytic fungus *Piriformospora indica* for the management of *Fusarium* wilt in banana with enhanced crop production.**
    Objectives include standardization of the co-cultivation of *P. indica* with major banana varieties grown in the state, determining the best stage of seedling to prime the roots with *P. indica*, evaluation of the primed seedlings (TC plants) and suckers against *F. Oxysporum* f. sp. *cubens* and *R. similis* for root and foliar infection of *Fusarium* (Panama) wilt, evaluation of the primed banana seedling against the natural incidence yellow and black sigatoka and other foliar diseases including major viral diseases, the compatibility study of *P. indica* with commonly used pesticides in banana cultivation and mass multiplication and commercial formulation of *P. indica*. Trials were undertaken

15. **Triazole, strobilurin and its combination fungicides for the management of anthracnose and fruit rot of chilli**
    Objectives include to study the host range of *Colletotrichum capsici* (Syd.) Butler and Bisby the incitant of anthracnose and fruit rot of chilli, in vegetable crops and to develop management strategy using new generation fungicides. Trials were undertaken

16. **Integrated management of Alternaria leaf spot of cabbage (*Brassica oleracea* var. *capitata* (L).**
    The objective of the experiment is to develop management strategy to control the disease using fungicides and biocontrol agents. Trials were undertaken.

17. **Evaluation of Biochemical and Anti-cancerous activities of Mushrooms**
    Objectives include to undertake cultural, spawn production and cultivation aspects of five mushrooms namely, the reishi mushroom, *Ganoderma lucidum*(Curtis) P.Karst., the white oyster mushroom, *Pleurotus florida* (Mont.).,the pink oyster mushroom, *Pleurotus djamor* (Fr.) Boedjn., the blue oyster mushroom, *Hypsizygus ulmarius* (Bull Fr.)Redhead. & the milky mushroom *Calocybe gambosa* (Fr.) Singh and to evaluate their biochemical and anti-cancerous activities. Trials were undertaken

18. **Survival and genetic diversity of gemini virus infecting okra (*Abelmoschus esculentus*.L.)Moench) and bitter gourd (*Momordica charantia* L.) -PG**
    The study aimed at identification of genetic variability in gemini virus isolates infecting okra and bitter gourd and their dissemination in the associated weeds. Trials were undertaken

19. **Ecofriendly management of anthracnose of betel vine (*Piper betle* L.) -PG**
    Objective of the experiment was to evolve an integrated management strategy involving organic preparations, biocontrol agents and new generation fungicides for anthracnose of betel vine. Trials were undertaken

**20. Etiology and management of mosaic disease in ginger (*Zingiber officinale* Roscoe) -PG**

Objectives include to identify, characterize, clone and sequence the genes of *Ginger mosaic virus* along with the management of the disease. Trials were undertaken

**21. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala – Disease management in ginger - RKVY**

Combination products of SAAF and Ekalux and SAAF and biocontrol agents was also found effective in reducing disease incidence. However, it was observed that germination was inhibited slightly when the rhizome was treated in combination with SAAF and biocontrol agents. Observations on soil microflora revealed that combination of SAAF and biocontrol agents showed a considerable increase in fungal population compared to treatment with SAAF alone. Moreover, it was observed that the residue of plant protection chemicals in soil decreased drastically within 15 days of drenching and also residue in ginger rhizome were found to be Below Detectable Levels (BDL). Hence, the recommended dose of combination fungicide, carbendazim + mancozeb @2g/l or carbendazim + mancozeb 2g/l in combination with *Trichoderma viride* / *Pseudomonas fluorescens* can be recommended for the management of rhizome rot of ginger since the former treatment in soil caused more loss of beneficial fungi and for seed/rhizome treatment combination of carbendazim + mancozeb @ 2g/l is recommended.

**22. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala– Disease management in vegetables- RKVY**

**a . Management of collar rot, web blight and *Fusarium* wilt of cow pea : -** Among the various treatments evaluated the best treatment for controlling collar rot is seed treatment + soil drenching with Saaf (carbendazim + mancozeb). The systemic fungicides left no residue in soil after 15 days of first drenching. However, after second drenching with flusilazole, the residual effect was present till 20 days after drenching. In the case of carbendazim, no residue was present on third day of first drenching but after second application residue was detected on third day. Hence carbendazim is showing less residual toxicity compared to flusilazole in soil. But, carbendazim caused more loss of beneficial fungi in soil compared to flusilazole.

**b. Management of powdery mildew disease of bitter gourd : -** The maximum reduction was observed with systemic fungicide tebuconazole followed by wettable sulpur and liquid formulation of *Trichoderma viride*. The residue of tebuconazole was not found from 3$^{rd}$ day onwards. Hence this compound may be recommended for management of powdery mildew of bitter gourd with a maximum waiting period of three days since the fruits were found to be completely free of the residue from 3$^{rd}$ day onwards.

**c. Management of downy mildew of bitter gourd : -** When fruits were treated with pyraclostobin alone, the residue persisted in fruits upto three days after spraying. In the case of fruits treated with chlorantraniliprole alone also, the residue persisted only 2 hours after spraying later these compounds were found below detectable levels (BDL). Hence, the systemic fungicide pyraclostrobin @ 0.5 g/l as well as cymoxanil + mancozeb @ 2g/l alone or in combination with the insecticide chlorantraniliprole (3 ml/10l) can be recommended for the management of downy mildew disease.

**d. Management of Cercospora leaf spot of Bhindi : -** The systemic fungicide tebuconazole @ 1.5ml/l and liquid formulation of *T. viride* @ 5ml/l were found effective for the management of *Cercospora* leaf spot in bhindi. Application of insecticide, flubendiamide (2ml/l0l) and combination of tebuconazole (1.5ml/l) with flubendiamide (2ml/10 l) were also found effective for management of shoot borer infestation. The residue of tebuconazole persisted till the seventh day only, hence the compound can be recommended for leaf spot giving a due waiting period of

10 days. Similarly, the insecticide flubendiamide can be recommended for the management of shoot and fruit borer since the residue persisted only for three days.

**23. ATMA project on Integrated management of leaf spot diseases of banana var. Nendran**

The inference of the experiment was drawn by statistically analysing the data on Per cent Disease Severity (PDS) at vegetative phase ie. six months after planting and at flowering, YLS and Disease Development Time (DDT). The results revealed that among the treatments, (tebuconazole + trifloxystrobin) was superior with lowest disease severity, followed by Tebuconazole, while unsprayed control recorded the maximum disease severity. Disease Development Time (DDT), the parameter which indicates the time or number of days taken by the leaves to produce visible symptom was maximum in the case of Hexaconazole followed by carbendazim + mancozeb. The yield component, maximum yield in terms of bunch weight was recorded in the treatment, Tebuconazole followed by carbendazim + mancozeb which was on par with Copper hydroxide, tebuconazole + trifloxystrobin and Hexaconazole. Control recorded lowest bunch weight. The residue analysis of all the chemical treatments were done by outsourcing the fruit samples to residue analysis laboratory, College of Agriculture, Vellayani and test reports revealed that the fruit samples were free of residual chemicals. Among the treatments other than chemicals, the percent disease severity PDS, YLS and DDT taken at vegetative phase and at flowering were analysed. The PDS was lowest in the case of Turmeric powder + baking soda, followed by Nanma, *P. fluorescens* + cow dung slurry and PGPR mix II respectively whereas; control recorded the maximum percent disease severity. Disease development time (DDT) was maximum in case of PGPR mix II followed by *P. fluorescens* + cow dung slurry, Turmeric powder +baking, soda Vegetable oil +baking soda and Nanma. DDT was lowest for control which was on par with cow dung enriched with *Trichoderma* + sucker treatment with *Pseudomonas fluorescens.* Maximum bunch weight was recorded in Turmeric powder oil + baking soda followed by *P. fluorescens* + cow dung slurry, PGPR mix 11and Nanma.

**24. ATMA project on Management of die back disease complex in nutmeg**

Statistical analysis of the data from field and *in vitro* evaluation of fungicides and bio agents revealed the following conclusions. The field evaluation of selected fungicides showed that, copper hydroxide (Kocide 0.2%) and Bordeaux mixture (1%) were the best fungicides for the management of various leaf spot diseases, anthracnose, leaf blight and fruit fall diseases of nutmeg. The result of the *in vitro* evaluation of the selected fungicides against the pathogens also support the observations of the field experiment. The systemic fungicide tebuconazole (0.1%) recorded cent per cent inhibition of all the pathogens under *in vitro* condition. This result is also in line with the observations from the field at Kuttikad, where, among the fungicides, tebuconazole (0.1%) showed the highest reduction (42.83%) in the incidence of anthracnose and various leaf spot diseases. Soil application of *Trichoderma viride* enriched with cow dung and neem cake along with copper hydroxide (0.2%) spraying can be recommended for the management of fruit diseases of nutmeg. The data of *in vitro* evaluation of *Trichoderma viride* also supports this observation.

**25. Network project on seed and nursery programme for planting material production**

**Sub project: Mass production of biocontrol agents**

The amount sanctioned under Farm development was utilized for renovation of existing bio control lab at roof top of Dept. of Plant Pathology. The lab was partitioned into two rooms, one for the inoculation and incubation of bio control agents for mass multiplication and other room for preparation and sterilization of media. A concrete slab with granite paving was constructed

in the existing bio control lab for keeping bottles of mother cultures of bio agents after inoculation.

**26. Molecular characterization of virus causing infectious chlorosis disease of banana-PG**

Purposive sampling surveys conducted in Thrissur district revealed highest disease incidence of 90 % on banana variety, Robusta. The symptoms of the disease were mosaic, leaf distortion and yield reduction. The transmission studies confirmed that the virus was transmitted through aphid species *viz*. *Pentalonia nigronervosa* and *Aphis craccivora* and also through the suckers of infected mother plants of banana. The morphological characteristics of the virus particles revealed the presence of spherical, isometric virus particles of size 28 nm. The molecular characterization of the coat protein gene of the virus was carried out through Reverse Transcription PCR. The Coat Protein (CP) gene was amplified using designed and reported primer pairs which yielded amplicons of approximate size of 750 bp and 700 bp respectively. The CP gene of eight isolates were sequenced and subjected to *in silico* analysis which revealed that the sequences of CMV exhibited significant nucleotide identity (99 to 96 per cent) with the sequences of CMV available in the data base of gene bank. The immunodetection techniques like Dot Immuno Binding Assay (DIBA) was standardised to detect CMV infection of leaf samples and showed positive reaction on nitrocellulose membrane. The field gene bank comprising about 175 accessions maintained at BRS, Kannara was screened to assess their disease reaction under natural conditions and the disease was recorded on 12 accessions with AA, AB, AAA, AAB and AAAB genome. Development of antibody based nano biosensor were developed by fabricating gold nanorods (GNRs) through seed mediated procedure and UV-Vis spectra of GNRs solution indicated characteristic longitudinal and transverse bands at 710 and 523 nm respectively. The image under Transmission Electron microscope revealed that the solution contained rod shaped gold nanoparticles of size 54.96 nm length and 14.75 nm diameter.

**27. Characterization of *Mycosphaerella* sp. causing sigatoka leaf spot disease complex of banana in Kerala and its management -PG**

Work initiated with field evaluation of seven chemical fungicides and nine organic/ inorganic preparations against Sigatoka leaf spot of banana. Surveys were conducted at six districts *viz.,* Thrissur, Palakkad, Malappuram, Ernakulam, Thiruvanathapuram, Wayanad and the symptoms and disease severity were documented. The DNA was isolated for the molecular characterization of the pathogen from diseased specimens. The symptoms were initially visible as small light green to yellow dashes on the underside of the leaf which changed into faint brown streaks. In the later stage, these streaks became visible as rusty brown on the adaxial side of the leaves which then developed into oval or elliptic brown spots with greyish centre surrounded by definite dark brown borders containing black pin headed like fruiting body embedded in it. Upon heavy infection, the spots coalesced resulting in complete necrosis of the leaves.

Morphological studies were carried out by KOH method followed by scrapping and preparing slides from the affected tissues. Both sexual and asexual fruiting bodies were observed on microscopic examination. Molecular characterization of the pathogen was done by isolating fungal DNA from the affected specimens followed by the amplification of ITS- rDNA region of the fungus using the primers, ITS 1 and ITS 4 which yielded an amplicon size of 600 bp. The amplicons were sequenced and blasted in NCBI which showed 100% sequence similarity to *Mycosphaerella emusae.* Hence, the pathogen inciting Sigatoka leaf spot on banana var. Nendran in Kerala was identified as *Mycosphaerella emusae.*

The host plant resistance was evaluated by screening the various accessions available in field Genebank of BRS, Kannara and five resistant and five susceptible accessions were selected for studying the anatomical and biochemical basis of resistance. The anatomical characters like epiderm thickness, cuticle thickness, no: of vascular bundles, spongy and palisade tissue thickness were found to be more in resistant variety when compared with susceptible varieties. The biochemical parameter, phenols were less in resistant varieties as the phenols were converted into defense related enzymes. The activity of defense related enzymes were more in resistant varieties compared to susceptible varieties. The studies on management of the disease using chemicals and organic/inorganic preparations revealed that among the chemical fungicides, Nativo (Trifloxystrobin + Tebuconazole) was found effective against the disease whereas; in organic/inorganic preparations, Bordeaux mixture was the most effective in managing the disease.

# Project Coordination Group - Postharvest Technology and Value Addition (13)

**Project Coordinator - Dr. Mini C**

**Concluded Projects: 8**
**Ongoing Projects: 14**

## Concluded projects

1. **Pilot Project on Demonstration and training on production and distribution of *Keraamrutham* (Neera) and *Kerachakkara* from coconut inflorescence**

   Plant was functioning mainly under Revolving Fund mode. The budget allotment was utilized for pending payments of Filtration unit, Patent application fee, repair of equipments, minor civil works for repair of the building and providing a temporary lab space in the vacant rooftop of the building.

2. **Development of *Aloe vera* gel supplemented Ready To Serve fruit beverages - PG**

   The study was carried out in the Department of Processing Technology, College of Agriculture, Vellayani during 2014-2016 with the objective to optimize the process variables for osmotic dehydration of aloe gel, supplementation of aloe gel in Ready To Serve (RTS) fruit beverages and to evaluate the quality of the product during storage. *Aloe vera* leaves were subjected to blanching treatments *viz*., steam blanch, hot water blanch and without any blanching. Aloe gel extracted by traditional hand filleting method was analyzed for biochemical, physical and sensory quality parameters. Blanching treatments did not influence TSS, pH, crude fibre and ash content of aloe gel. Aloe gel extracted by steam blanching recorded the lowest moisture content (92.58%), highest acidity (0.17%), antioxidant activity (81.30%), total phenol (40.98 µg g-1), reducing sugar (0.43%) and total sugar (0.53%). On analyzing the physical properties, highest viscosity (9.98cP at 60 rpm) and lowest optical density (0.805) were recorded for steam blanched aloe gel in addition to highest mean score for sensory attributes. Steam blanched aloe gel had a refractive index of 1.3366 and specific gravity of 1.0200 and was selected for osmo-dehydration studies. Aloe gel of $1cm^3$ size taken after steam blanching was osmosed in sugar syrup of 30, 40 and 500 B concentrations with an immersion time of four and six hour. The osmo-dehydrated aloe gel was analyzed for mass transfer, biochemical, physical and sensory qualities. Mass transfer characters *viz*., solid gain and weight loss and biochemical parameters such as total soluble solids, reducing sugar and total sugar increased with increase in osmotic concentration and immersion time and it did not influence pH, acidity and ascorbic acid of aloe gel. Osmotic treatment of aloe gel at 500B for four hour immersion time recorded 9.72% solid gain with 58.81% weight loss, 60.52% moisture, 41.03 B TSS, 7.59 µg $g^{-1}$ phenol, 75.95% antioxidant activity, 2.97% reducing sugar, 14.92% total sugar, 1.4033 refractive index, specific gravity of 1.0848, optical density of 1.442 with highest sensory score for flavour, taste and texture and hence selected to formulate aloe gel supplemented RTS fruit beverages. Osmo-dehydrated aloe gel (in 500B syrup concentration for four hour) at 5 % and 10 % level and total aloe juice (5%) were supplemented into Ready To Serve beverages of pineapple, lime and cashew apple. Formulated beverages were analyzed for biochemical and sensory properties and compared with respective fruit RTS without aloe gel supplementation. Analyses revealed that 10% supplementation resulted in RTS beverages with superior biochemical and sensory qualities Storage stability studies were done in RTS with 10% supplementation of aloe gel under room temperature for three months. The stored RTS formulations were analyzed for biochemical, sensory and microbial qualities at fortnight intervals. During storage, total soluble solids, reducing sugar, total sugar and acidity of all aloe gel supplemented RTS beverages

increased while pH, ascorbic acid, antioxidant activity and total phenol content decreased. Sensory profile of stored aloe gel supplemented RTS beverages revealed that they were acceptable during storage of three months with slight reduction in sensory scores. All RTS beverages were found microbiologically safe during storage and aloe gel supplemented lime RTS formulation recorded the highest acceptability.

**3. Standardization of minimal processing of amaranthus (*Amaranthus tricolor* L.) - PG**

The study was conducted in Department of Processing Technology, College of Agriculture, Vellayani, during 2014-16 with the objective to standardise minimal processing technology for the development of ready-to-use amaranthus with extended shelf life and nutritional quality. Amaranthus (var. Arun) harvested after 30 days of sowing were subjected to sanitisation treatments, after removing root portion and effectiveness of sanitising agents was determined for leaves and stem separately by analysing microbial, biochemical and visual parameters. The study revealed that surface decontamination with 2 ppm ozonised water had the highest percentage of microbial reduction (40.53 per cent for leaves and 39.15 per cent for stem), highest retention of ascorbic acid, anthocyanin and mean score for visual parameters. After surface sanitisation of amaranthus with 2 ppm ozonised water, effect of pre-treatments was analysed separately for leaves and stem and it was observed that pre-treatment with sodium benzoate + citric acid (0.1%) recorded the lowest physiological loss in weight, highest relative water content, membrane integrity, mean score for visual parameters, ascorbic acid, anthocyanin content, antioxidant assay and lowest microbial population for both amaranthus leaves and stem which was followed by calcium chloride (1%). Amaranthus surface sanitized with 2 ppm ozonised water and pre-treated with sodium benzoate + citric acid (0.1%) were shredded in to uniform size and subjected to pre-packaging and storage studies. Fresh cut amaranthus, packed as two different proportions of leaves and stem (1:1 and 1:2 (w/w) in different packaging materials and stored at ambient and refrigerated conditions were analysed for physical, physiological, biochemical, microbial and sensory qualities. Fresh cut amaranthus packaged in 150 gauge micro ventilated polyethylene had lowest physiological loss in weight, highest relative water content, membrane integrity, mean score for visual parameters viz. colour, texture and overall acceptability with lower score for wilting, highest retention of ascorbic acid, anthocyanin, antioxidant activity and lowest microbial load for both proportions under ambient as well as refrigerated storage. The results revealed that pre-packaging and storage of sanitized and pre-treated fresh cut amaranthus (leaves : stem as 1:1) packaged in 150 gauge micro ventilated polyethylene had shelf life up to eight days with highest retention of freshness and nutritional qualities under refrigerated storage and four days shelf life when stored at room temperature. Sensory analysis of the standardised technology revealed that there was no difference in sensory attributes of the sanitised, pre-treated, pre-packaged ready-to-use amaranthus from the freshly harvested amaranthus.

4. **Development, packaging and storage of intermediate moisture jackfruit (*Artocarpus heterophyllus* L.) - PG**

Intermediate moisture (IM) foods contain moderate levels of moisture which is less than that is normally present in fresh fruits but higher than that is left in conventionally dehydrated fruits. The texture of the product will be soft, moist and is more acceptable than conventionally dried foods. Intermediate moisture jackfruit was prepared by subjecting the bulbs of jackfruit variety '*Muttam Varikka*' to additive infusion in a solution containing 60 % sucrose, 0.2 % ascorbic acid, 0.2 % potassium metabisulphite and 2% matrix binding agent (calcium lactate/sodium alginate/corn starch/cassava starch) for 12 hours, followed by dehydration at different temperatures (40 ± 5, 50 ± 5 and 60 ± $5^0$C) for 10 to 12 hours.

Jackfruit bulbs treated with corn starch (2%), sucrose (60%), ascorbic acid (0.2 %) and potassium metabisulphite (0.2 %), followed by dehydration at 60 + 5 0C was the best treatment combination for the development of intermediate moisture jackfruit with minimum microbial load and maximum organoleptic acceptability. The product had a moisture content of 16.2 to 22.54 % and the water activity was in the range of 0.76 to 0.80. Intermediate moisture jackfruit packed in glass containers showed maximum retention of moisture (13.67%), water activity (0.74), acidity (0.34%), reducing sugars (24.91%), total sugars (61.41%) and total carotenoids (2.98mg/100 g), after six months of storage. IM jackfruit packed in LDPE (100 gauge) had the highest organoleptic score upto four months of storage, followed by the samples in glass container. After six months of storage period, samples packed in laminated aluminium foil pouches showed highest organoleptic score.

5. **Value addition of passion fruit (*Passiflora edulis* Sims) - PG**

Ten accessions of passion fruit (purple and yellow types) were characterized based on physic-morphological, nutritional and biochemical attributes. Considerable variation was observed among the accessions. Maximum fruit length (6.96 cm), fruit diameter (7.10 cm), fruit girth (22.83 cm), rind thickness (0.96cm), fruit weight (98.26 g), juice recovery (46.46%) and seed yield (18.47%) was recorded in purple type fruits whereas, rind percentage was highest (78.12%) in yellow type fruit. Brilliant yellow was the commonly observed juice colour in majority of the accessions, followed by vivid yellow and light orangish yellow. Maximum TSS (17.73 $^0$Brix), reducing sugars (8.06%), total sugar (13.04%) and vitamin C (30.50 mg/100g) was observed in purple type fruits whereas, maximum titratable acidity (4.86%), non reducing sugars (5.27%), total carotenoids (2.81 mg/100 g), total phenols (27.33 mg/100g) and total flavanoids (18.0 mg/100 g) was observed in yellow type fruits. Maximum antioxidant activity (7.36 mg/ml) was exhibited by yellow accessions.

Shrink wrap packaging of passion fruit (wrapped individually and also in areca plates) prolonged the shelf life significantly compared to control, but it did not show any significant difference with respect to film thickness. Individually shrink wrapped passion fruit with 25 µ thickness polyolefin film gave longest shelf life (26.66 days) whereas the lowest shelf life (7.0 days) was observed in control samples. Fruits wrapped in areca plates became unmarketable after two weeks of storage. Physiological loss in weight, TSS, reducing, non-reducing and total sugars increased, while, titratable acidity, vitamin C and total carotenoids decreased in all the samples. Total phenols and total flavanoids increased during first week and decreased afterwards.

Passion fruit nectar was developed from purple and yellow passion fruit separately and also by blending purple and yellow fruits in different combinations of TSS and fruit juice. Organoleptic evaluation revealed that passion fruit nectar containing 20 % juice and 20 $^{0}$ Brix was more acceptable in all the three categories. TSS, non-enzymatic browning, reducing, non-reducing and total sugars increased during storage while titratable acidity, vitamin C, total carotenoids, total flavanoids and total phenols decreased. Qualitative changes in passion fruit nectar were more conspicuous under ambient conditions than under low temperature storage.

**6. Shrink wrap packaging of selected tropical fruits - PG**

Mango cv. Prior was subjected to two forms of shrink packaging ie. individual shrink wrapping and also wrapping of 4 to 5 fruits in areca plates with polyolefin film of 15, 19 and 25 µ thickness. Maximum shelf life (18 days) was observed in individually shrink wrapped mangoes with 25 µ polyolefin film when stored at ambient temperature. Physiological loss in weight was significantly lower in shrink wrapped fruits. TSS, reducing, non-reducing, total sugars and total carotenoids increased during storage whereas, titratable acidity and vitamin C decreased. Shrink wrapped mangoes had higher organoleptic score as compared to control samples.

Banana cv. Grand Naine (hands) was shrink wrapped with polyolefin film of 15, 19 and 25 µ thickness, followed by master packing in CFB boxes. Shelf life of shrink wrapped fruits was lower than the control (unwrapped) fruits. Percentage of spoilage was higher in the shrink wrapped banana hands. The unwrapped fruits recorded a shelf life of seven days whereas, the shrink wrapped fruits master packed in CFR boxes had a shelf life of four days while it was five days in hands shrink wrapped without master packing. Retention of biochemical constituents was better in shrink wrapped samples as compared to unwrapped fruits.

Pineapple cv. Mauritius was shrink wrapped with polyolefin film of 15, 19 and 25 µ thickness, followed by master packing in CFB boxes. Individually shrink wrapped pineapple with 25 µ polyolefin film had the longest shelf life (16 days) and the same fruits master packed in CFB boxes had the shortest shelf life (9 days), when stored at ambient temperature. Physiological loss in weight increased during storage and it was significantly higher in the unwrapped fruits. TSS, reducing, non-reducing and total sugars increased during storage while titratable acidity and vitamin C decreased. After two weeks of storage, retention of biochemical constituents was better in shrink wrapped samples as compared to unwrapped fruits.

**7. Processing quality evaluation of pickling mangoes - PG**

Tender mango pickle, commonly known as *Kadumanga*, and cut mango pickles are popular in Kerala. Many of these land races are juicy types. However, studies on their suitability for preparation of different products are limited. The study was conducted in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, during 2014-2016 with the objective of assessing processing quality of pickling mango collections maintained at RARS, Pattambi and RARS, Pilicode. Twenty one accessions (8 from RARS, Pilicode and 13 from RARS, Pattambi) were selected for the study. The programme was divided into two major experiments. Fruits were collected at tender, mature and ripe mango stage. Quantitative and qualitative attributes of the selected accessions at the three stages were studied in experiment I. In experiment II fruits of these selected accessions were used for making tender mango pickle, cut mango pickle and RTS beverages. Organoleptic evaluation and microbial load of these

products was made at monthly intervals for three months.

Results of the first experiment showed that there was significant difference between the accessions in both quantitative and qualitative characters at all three stages viz. tender, mature and ripe. Biochemical parameters such as titrable acidity increased from tender to mature stage and decreased on ripening. Acidity of mangoes ranged from 1.91 to 5.01 per cent at tender stage, 2.74 to 6.71 per cent at mature stage and from 0.28 to 1.4 per cent at ripe stage. Polyphenol content was higher at tender stage, which decreased during maturation and ripening. Polyphenol content varied from 0.78 to 3.8 mg g-1in tender stage, 0.38 to 2.45 mg g-1 in mature stage and 0.39 to 1.40 mg g-1 in ripe stage. Crude fibre content varied from 0.4 to 1.58 per cent in tender mango stage, 0.61 to 3.63 per cent in mature stage and 0.7 to 3.7 per cent in ripe stage. TSS of ripe fruits varied from 12.5 to 22.2 ° brix and juice content from 20.52 to 61.63 per cent.

Organoleptic evaluation of the products was conducted based on hedonic scale. Total score for tender mango pickle increased with the increasing storage time and that of RTS beverage decreased. Accessions 15 and 17 (Chandrakaran) were the best for tender mango pickling followed by Accessions 2, 3, 6, 8, 10 and 12. Acc. 4, 8, 9 and 21 were the best for cut mango pickling. Accessions 21, 17, 1, 2, 6, 7, 8, 11, and 13 were good for RTS beverage preparation. Microbial population was negligible in tender mango pickle compared to cut mango pickle. Accession 8 was suitable for all the three products. Accessions 6, 8 15 and 17 were good for both tender mango and cut mango pickle preparation. Accessions 8 and 21 were good for cut mango pickle and RTS beverage. Accessions 16 and 21 were least acceptable for tender mango pickling; 16, 19 and 20 for cut mango pickling and 9, 10, 14, 16 for RTS beverages.

## 8. Instant juice powders of cashew apple (*Anacardium occidentale* L.) and pineapple (*Ananas comosus* (L.) Merr.) - Ph.D

The present investigation was carried out in the Department of Processing Technology, College of Agriculture, Vellayani during 2013-2016 to optimise the process parameters for micro encapsulation through spray drying of cashew apple and pineapple juices, to evaluate the effect of drying on physical, chemical and nutritional quality parameters of fruit powders, to formulate blended fruit powder and to assess organoleptic quality, storage stability, economics and consumer acceptability of the standardised formulations. Fruit juice mixed with a carrier, maltodextrin or resistant dextrin in 80: 20, 70:30, 60:40, 50:50 and 40: 60 solid ratios were fed to co-current spray drier at inlet temperatures of 150$^{o}$C, 160$^{o}$C, 170$^{o}$C, 180$^{o}$C, 190$^{o}$C and 200$^{o}$C for optimization of drying parameters of cashew apple, pineapple and their equal blend independently. Feed rate was varied to maintain the outlet temperature at 88 ± 2$^{O}$C with 4 bar atomization pressure and 2000 rpm blower capacity. Carrier resistant dextrin, juice solid to carrier ratio of 40:60 and 160$^{o}$C inlet temperature resulted in high recovery of fine, coarse and bulked fruit powders. This combination recovered 72.09, 85.62 and 74.70 per cent of total solid content from juice carrier mix of cashew apple, pineapple and their equal blend respectively of which 40.55, 47.06 and 42.02 per cent were from cyclone. Based on higher recovery percentages, five treatment combinations (150$^{o}$C to 190$^{o}$C with 40:60 ratio) from each carrier were selected and subjected to physicochemical analysis. Resistant dextrin yielded fruit powders with low moisture, dispersible solids, viscosity, angle of repose and with high per cent soluble solids, lightness and hue angle, whereas maltodextrin yielded fruit powders with high total soluble

solids. Resistant dextrin lowered chromaticity of pineapple and blended juice powder in contrast to the effect in cashew apple. Resistant dextrin produced pineapple powder with low water activity while maltodextrin improved bulk density of cashew apple and blended powder. Inlet temperature of 160$^{o}$C yielded fruit powders with higher bulk density whereas powder moisture and angle of repose were low at 190$^{o}$C. Drying at 160$^{o}$C could decrease water activity and improve total soluble solids of cashew apple powder whereas reduction in water activity and chromaticity along with improvement of hue angle were observed in blended juice powders. Powders with resistant dextrin had high glass transition temperature and low hygroscopicity. Powder particles were spherical with 3 - 30 μm size and had occasional surface dents. None of the treatment combinations influenced sinkability of powders. Maltodextrin yielded fruit powders with high sugars and resistant dextrin yielded cashew apple powder with high vitamin C. Carriers did not significantly influence the energy value of fruit powders. Inlet temperature of 160$^{o}$C yielded vitamin C rich powders from all fruits as well as β-carotene rich pineapple powder. None of the treatment combinations influenced crude fibre, pH, total ash or titrable acidity. Fruit powders with resistant dextrin dried at 160$^{o}$C had superior scores in sensory analysis. Good quality fruit powders produced at 160$^{o}$C using each carrier, when subjected to a storage study for six months in four packaging atmospheres, microbial growth was totally absent. Refrigerated storage could maintain vitamin C, β-carotene, moisture content, titrable acidity, total phenol and high sensory acceptability of fruit powders. Cost of production of fruit powders with carrier resistant dextrin was comparatively less and highest consumer preference was for pineapple powder. Instant juice powders of cashew apple, pineapple and their equal blend produced by spray drying at 160$^{o}$C with resistant dextrin as carrier in 40:60 juice solid to carrier ratio had optimum physical, chemical, nutritional and sensory qualities with six month shelf stability under refrigeration. Further studies to improve shelf life of the product in ambient temperature, exploration on nutraceutical functions and development of spray drier for small scale industries with higher efficiency will be highly beneficial for improving cost effectiveness and commercialization of the technology.

## Ongoing projects

1. **Establishment of Centre of Excellence on Post-Harvest Technology-Quality control lab - State Plan**

   The Quality Control laboratory was created with a view to provide facility for quality control aspects related to food. The Laboratory caters to the quality determination of fresh and processed food products of entrepreneurs, public and private institutions, researchers and students. Several firms, organizations and individuals have utilized the services of the Quality Control laboratory.

2. **Development of animal feed from jack fruit processing waste- State Plan**

   The developed technology was disseminated through 7 training programmes on processing industry waste utilization. The beneficiaries of the training programme were dairy farmers, entrepreneurs and women farmers.

3. **Postharvest characterisation and management of elite jackfruit types of Kerala - State Plan**

   Biochemical constituents varied significantly among accessions. Titratable acidity varied from 0.120 to 1.120 %. Highest ascorbic acid content (12.5 mg/100g) was recorded in the accession AH-4. Pectin content varied from 0.25 % in AH-29 to 8.39 % in AH-23. Reducing, non-reducing and total sugars varied significantly among the accessions. Highest reducing sugar content (17.28 %) was recorded in AH-11 while non-reducing sugars were highest (18.52 %) in AH-20 and highest total sugars (34.75 %) were observed in AH-34. Significant variation in total carotenoids was also recorded wherein highest content (3131.8µg/100g) was seen in the accession AH-2 which was on par (3121.5µg/100g) with the check variety *Muttam Varikkka*. Accessions from Thiruvalla (32.0º Brix), Kodungalloor (31.0º Brix) and Mannarkkad (30.0º Brix) topped the list for the highest total soluble solids. Accession AH-34 had the highest total soluble solids (32 º Brix).

4. **Establishment of centre for postharvest management and value addition for underexploited fruits and vegetables of southern Kerala.**

   Process protocols were developed for spray dried cashew apple juice powder, jack fruit wine, fresh-cut papaya and osmo air dehydrated carambola. Kerala's traditional fruit viz., karaka and water apple etc was utilized for product development. Possibility of waste utilization in jack fruit and ash gourd was explored. Value addition studies were conducted in underutilized fruit, velvet apple (*Diospyros discolor*). Value chain management practices to reduce post-harvest losses in papaya were standardized.

5. **Network Project on Value Addition and Post harvest Management & Establishing a Food Pro mall**

   Established a mechanized Virgin Coconut Oil Plant to serve as a model for the farmer entrepreneurs as well as aid in utilizing the available nuts at the station for value addition. At least two units had been established in the district by the former trainees.

   Established a food pro mall to provide a sales outlet for the innovative value added products and act as a demonstration center for technology and marketing of innovative products to entrepreneurs. The project could develop protocols of products from several underutilized/unutilized crops and could increase revenue.

   Standardised protocol for development of coconut chips (spicy), coconut water syrup, danthapala oil, coconut balls, coconut prawn pickle, coconut water wine, tender coconut pudding, coconut milk chocolate, coconut milk toffee, mouth wash, hair cream, Virgin Coconut Oil soap etc.

6. **Post harvest studies in Neelamari (*Indigofera tinctoria* L.) - PG**

   Three blanching methods including hot water, steam and microwave blanching were compared with unblanched control, followed by shade, cabinet and vacuum drying. The treated leaves were, analysed for indican content and found that, microwave blanching for 45 seconds followed by vacuum drying at 35±5°C had highest retention of indican (3.045%). Further *Neelibhrngadi Taila* was prepared using the decoctions of dried leaf samples, along with fresh Neelamari leaf juice considered as control treatment as per Ayurvedic Pharmacopeia of India (API). The

samples of *Neelibhrngadi Taila* prepared were subjected to quality assessment by estimating acid value, refractive index and performing Thin Layer Chromatography (TLC) with absolute control as the standard, as per the recommendation of API, which defines well the quality check of the medicated oils. Least acid value (1.460mg of KOH $g^{-1}$ of sample) was a desirable feature recorded in oil sample prepared using microwave blanched and vacuum dried leaf samples and the highest acid value recorded was in the sample prepared using hot water blanched cabinet dried leaves. There was no difference in the refractive index as coconut oil was the common base oil in all the treatments and it revealed the uniform extraction of phytochemicals in to the oil in all the 13 formulations. The results from TLC showed that all the oil samples except those obtained from treatment T10 (steam blanched and dried in vacuum drier) and T11 (Hot water blanched and dried in vacuum drier) gave standard Rf value, thus conforming to the quality prescribed by API. In HPTLC performed using absolute control as standard, all the samples recorded 13-17 peaks representing different phytochemical compounds whereas the standard oil recorded 16 peaks. Further studies are required to identify the phytochemical compounds.

## 7. Optimization of methods for juice extraction and value addition of passion fruit (*Passiflora edulis* Sims*)* - PG

Yellow and purple accessions collected from different localities were evaluated for their physico-chemical attributes along with the variety, Kaveri (purple type) released by the Central Horticultural Experiment Station (CHES), Chettali. The study revealed that the accessions differed significantly for different physical and biochemical traits analysed. Among the yellow accessions, Acc.1 collected from orange and vegetable farm, Nelliyampathi, possessed the highest mean fruit weight (98.27 g) and percentage juice recovery (35.38%), low rind content (46.05%), highest TSS ($19.43^0$ Brix), high ascorbic acid (25.94 mg $100g^{-1}$) and total carotenoid content (2.81 mg $100g^{-1}$). Among the purple accessions, Acc.7 recorded highest percentage juice recovery (36.79 %), low rind content (46.55%), high TSS ($19.20^0$ Brix), total sugar (11.56 %) and ascorbic acid content (32.51 mg $100g^{-1}$). Hence Acc.1 in yellow and Acc.7 in purple types were selected for further studies along with variety Kaveri.

Three methods of juice extraction (enzymatic, mechanical and conventional methods) were compared to identify the most efficient method. Among the different enzymatic treatments tried pectinase 5 ml per litre incubated at 50° C for 90 minutes was found ideal. This treatment yielded more quantity of juice (74.91% in Acc.1,74.20% in Acc.7 and 72.74% in Kaveri) with high TSS ($19.56^0$ Brix in Acc.1, $19.83^0$ Brix in Acc.7 and $19.7^0$ Brix in Kaveri), acidity (3.12% in Acc.1, 3.24% in Acc.7 and 3.23% in Kaveri) and total sugars (9.51% in Acc.1, 11.61% in Acc.7 and 10.95% in Kaveri). The juice yield was comparatively less in mechanical and conventional method of extraction. The result was same for all the accessions tried.

Sweetened juice, RTS beverage, carbonated drink and jam were prepared as part of product development. Sweetened juice and RTS beverage prepared by blending of passion fruit juice and cashew apple juice in 3:1 ratio was found more acceptable than that prepared with passion fruit juice or cashew apple juice alone. For preparation of carbonated drink blending of passion fruit juice and cashew apple juice in 1:1 ratio was found better in the case of Acc.1 (yellow type) whereas blending of passion fruit juice and cashew apple juice in 3:1 ratio was good for Acc.7 (purple type) and Kaveri. Blending rind pulp with cashew apple pulp in 1:3 ratio in Acc.1

(yellow type), 3:1 ratio in Acc.7 (purple type) and 1:1 ratio in Kaveri was found to produce the most acceptable jam.

The shelf life of RTS beverage and jam was studied by storing the products and taking the observations on biochemical characters, sensory attributes and microbial load at monthly intervals. In RTS beverage fungal population was present beyond acceptable limit at four months after storage. In the case of jam the sensory attributes recorded a drastic reduction at three months after storage. Further studies are required to improve the shelf life and acceptability of RTS and jam.

**8. Post harvest evaluation and management of cherry tomato (*Solanum lycopersicum L.var. cerasiforme* (Dunal) A. Gray) genotypes - PG**

Eleven genotypes of cherry tomato raised inside rain shelter and in open field were evaluated for the quality attributes.The physico-morphological characters showed significant variation among the cherry tomato accessions inside rain shelter. The desirable attributes like high fruit length, diameter, fruit girth, rind thickness, fruit weight, and juice per cent were observed for SLc.11, under both growing conditions. Performance of most of the genotypes was superior inside the rain shelter as compared to open field condition.

The highest content of TSS, reducing and total sugar, vitamin C, total carotenoids and lycopene was observed in SLc.2 grown inside rain shelter. TSS, sugars and vitamin C content was higher for most of the genotypes under open field condition. Total carotenoids and lycopene content was higher for most of the genotypes when raised inside rain shelter.

Packaging and storage studies were conducted in fruits of two genotypes, SLc.10 (small fruited type) and SLc.11 (large fruited type) by subjecting to four methods of packaging viz. packing in micro ventilated polyethylene cover (200 gauge), polystyrene tray covered with cling film, polypropylene punnets and shrink wrapping in polystyrene tray. Each package was stored in ambient (28 -36°C), refrigerated (5 ± 2°C) and cold storage (12 ± 3°C) conditions. The shelf life of cherry tomato was longer under cold storage than ambient and refrigerated condition. The shelf life of cherry tomato was extended to 87 days for IIHR- 2871 and 71 days for Pusa Cherry Tomato -1 under cold storage. Fruits packed in polypropylene punnets had longer shelf life for both varieties under refrigeration and cold storage conditions. The physiological loss in weight was significantly higher and shelf life was lower in unwrapped fruits under the three different storage conditions.

**9. Post harvest characterization and value addition of sweet lovi-lovi (*Flacourtia cataphracta* Roxv.ex. Willed.) - PG**

The sweet lovi-lovi accessions were collected from three centers located at Vellanikkara namely, college orchard of Department of Fruit Science, Central nursery and Regional station of National Bureau of Plant Genetic Resources. The physico-chemical characters showed significant variation among the sweet lovi-lovi accessions. The desirable post harvest qualities like high fruit weight, pulp percentage, less seed content along with highest total sugar (12.81 %), non reducing sugar (1.33 %), anthocyanin (0.04 mg $100g^{-1}$), carotenoid (582.55 mg $100g^{-1}$), iron (33.23 mg $100g^{-1}$), crude fibre (2.92 g $100g^{-1}$) and lowest tannin (0.21 mg $100g^{-1}$) was observed in Acc. 2 collected from college orchard. Hence ripe sweet lovi-lovi fruits from Acc. 2 were used for shelf life studies. Standardisation of packaging and storage requirements were done in Acc. 2

by subjecting fruits to five methods of packaging viz., packing in polythene cover (200 gauge) with ventilation, polythene cover (200 gauge) without ventilation, polypropylene punnets, polystyrene box covered with cling film, shrink wrapping in areca plate. Each package was stored in ambient, refrigerated (5 ± 2°C) and cold storage (12 ± 2°C) conditions. Shelf life of sweet lovi-lovi fruits was longer when stored under cold storage condition than fruits stored in ambient and refrigerated condition. Areca plates containing fruits wrapped with polyolefin film of 15µ thickness (T6) and fruits packed in polythene cover (200 gauge) without ventilation (T3) in cold storage were found to have longest shelf life (3 days). The physiological loss in weight (PLW %) was significantly highest and shelf life was shortest in unwrapped fruits under the three different storage conditions. The treatment T6 showed highest TSS (17.27 °Brix) and total sugar (12.73 %) after one day of storage at 12 ± 2°C.

To increase the utilisation of sweet lovi-lovi fruits, value added products like wine, preserve and Ready To Serve beverage were prepared and evaluated. Among the wine prepared from five accessions, the overall acceptability was maximum for Acc. 5 (7.50). All the attributes of wine showed an increasing trend on storage and the total score raised from 58.09 to 61.77 after three months. The highest mean scores for flavour (7.54), texture (7.27), odour (7.27), taste (8.00), after taste (7.54) and overall acceptability (7.86) were recorded for Acc. 2 among the preserve prepared from five accessions of sweet lovi-lovi. During storage, the total score for organoleptic attributes increased from 58.02 to 58.47 for preserve prepared from this accession. RTS beverage prepared from Acc. 3 recorded highest mean score for appearance (7.44), colour (7.12), texture (7.44), taste (7.81), and overall acceptability (7.78). All the attributes showed a declining trend and the total score decreased from 59.09 to 55.43 after three months of storage. Thus accessions 2, 3 and 5 were found to be ideal for preparation of preserve, RTS beverage and wine respectively. The microbial population was least during the initial month and increased slightly on storage but was within the permissible limit in all the products.

**10. Postharvest handling studies for extending shelf life of rambutan (*Nephelium lappaceum* L.) - PG**

The study conducted in the Department of Post Harvest Technology, College of Agriculture, Vellayani, during 2015-17 with the objective to extend the shelf life of rambutan with minimum nutritional loss through postharvest handling practices. Good quality rambutan fruits of uniform size and maturity with red skin colour, collected from the homesteads of Thiruvananthapuram and Pathanamthitta districts were used for the study. The harvested fruits dipped in 1% wax formulations *viz.* KAU wax (bee wax), palm wax (carnauba wax) and paraffin wax were air dried and stored under room temperature (30±2$^{o}$C; RH 80-85%) for standardizing the best wax formulation. Fruits coated with 1% paraffin wax had the lowest physiological loss in weight (PLW) (18.36%), retained highest total soluble solids (TSS) (18.46 $^{o}$B), acidity (0.40%), vitamin C (22.05 mg/ 100g), total sugar (16.78%), reducing sugar (5.33%) and antioxidant activity (66.60%) with lowest browning score (3.43) and superior in general appearance, taste and flavour with minimum pulp browning at the end of shelf life. Hence 1% paraffin wax was selected for further pre-treatment studies.

11. **Standardisation of packaging and storage techniques for green chillies spp. *Capsicum annuum*. - PG**

    Surface sanitization with sodium hypochlorite 100 ppm was found to be the best pre storage treatment for reducing microbial population and extending shelf life of chillies. Different packaging materials and storage temperature was found to have a significant effect on extending the shelf life and maintaining the quality of the chillies.

12. **Development of osmodehydrated bilimbi (*Averroha bilimbi* L.) and assessment of bioactive compounds. - PG**

    The present study was carried out in the Department of Post Harvest Technology, College of Agriculture, Vellayani during 2015-17 with the objective to standardize the process variables for osmodehydrated bilimbi and to assess the retention of bioactive compounds. Harvested mature bilimbi fruits of uniform size were washed, surface dried, pricked and blanched in hot water for one minute. Blanched fruits were subjected to osmotic treatment, with sucrose solution of 40, 60 and $80^0$B for 60, 120 and 180 minutes. The osmodehydrated bilimbi fruits were analyzed for mass transfer, biochemical and sensory qualities. Mass transfer characters *viz.,* solid gain, water loss, percentage weight reduction, yield and biochemical parameters such as reducing sugar and total sugar increased with increase in osmotic concentration and immersion time whereas free acids, ascorbic acid and antioxidant activity were decreased. The osmotic treatment of $80^0$B for 180 minutes recorded the highest value for solid gain (5.10 %), water loss (16.72%), weight reduction (22.57%), ratio of water loss to solid gain (3.25%) and yield (21.13%) with a free acid content of 2.32 %, 21.66 mg/100g vitamin C, 47.81% antioxidant activity, 8.24% reducing sugar and 18.53% total sugar which exhibited superior sensory scores for taste (8.43), flavor (8.27), texture (8.46) and overall acceptability (8.43).

13. **Evaluation and utilisation of edible lichen *Parmotrema tinctorum* (Nyl.) Hale. for food preservation- Ph.D**

    As a part of the antimicrobial studies, antimicrobial testing of lichen extracts (ethanol, acetone and chloroform) against the test organisms *viz. Bacillus subtilis, Staphylococcus aureus, Aspergillus niger and Saccharomyces cerevisiae* was completed.

14. ***Aloe vera* based edible film coating for shelf life extension in tomato (*Solanum lycopersicum*). - Ph.D**

    Standardized the plant leaf extract incorporated aloe gel based edible coating for two maturity stages of tomato. Based on quality evaluation studies, aloe based film coating was selected as superior compared to plant leaf extract incorporated aloe gel.

# Project Coordination Group - Food Science and Nutrition (14)

**Project Coordinator - Dr. Suma Divakar**

**Concluded Projects: 5**

## Concluded Projects

1. **Quality analysis and culinary utilization of cashew apple *(Anacardium occidentale)*-** PG

Cashew apple was pre-treated to remove the astringent content by steaming for 5 minutes under pressure ($T_1$), boiling in 2 per cent salt solution for 5 minutes ($T_2$), immersing fruit in rice gruel extract for 30 minutes ($T_3$), immersing fruit in 0.55 per cent gelatin solution for 10 minutes ($T_4$) and immersing fruit in 5 per cent salt solution for 3 days with the change of salt solution daily ($T_5$). Fresh cashew apple served as control ($T_6$).

Chemical analysis of fresh and treated Cashew apple observed a reduction in the chemical constituents in treated Cashew apples compared to $T_6$ (Fresh cashew apple). Nutrient analysis showed that the values obtained for different nutrients were lower for treated cashew apple. Cashew apples treated with 2 per cent salt solution ($T_2$) got comparatively higher values than other treatments in carbohydrate (11.30g) vitamin C (180.00mg) and potassium (75.20 mg) and was also on par with control ($T_6$) and the same treatment resulted in lower astringent principle and was found to be most suitable for culinary preparations such as sweet meat products, gravy preparations, chutneys and fresh salads.

2. **Phytochemical analysis and antioxidant potential of banana (*Musa* spp) - PG**

Quantitative estimation of phytochemicals revealed that total alkaloid content of the banana varieties was observed to range between 0.84 – 3.76 per cent. The varieties *Nendran* (3.76%) and *Padatti* (3.72 %) were found to be having maximum alkaloid content, whereas the variety *Rasakadali* exhibited highest flavonoid content (9.49 mg/100). Saponin content of banana varieties was found to be ranged between 0.22 -0.82 per cent. The saponin content was found to be maximum in the variety *Kadali* (0.82 per cent) and minimum in the variety *Padatti* (0.22 per cent). Total phenol content was found to be more in the varieties *Kadali* (11.6 mg/ 100g), *Poovan* (7.19 mg /100g), and *Rasakadali* (6.76 mg/100 g). The variety *Palayankodan* (4.28mg/100g) showed maximum tannin content and was significantly different from the other varieties.

Free radical scavenging activity of banana varieties were studied by DPPH radical assay and total antioxidant activity using different solvents such as petroleum ether, methanol and water. The results revealed that variety Robusta had the highest DPPH activity with an $IC_{50}$ value of 43.6 µg/ ml in petroleum ether solvent. With regard to total antioxidant activity, the variety *Padatti* exhibited highest activity with an $IC_{50}$ value of 41.2 µg/ ml in petroleum ether while the variety *Rasakadali* (48.4 µg/ ml) and Poovan (48.4 µg/ ml) showed maximum activity in methanol followed by the variety Red banana with an $IC_{50}$ value of 44.4 µg/ ml in methanol.

3. **Quality assessment and development of product from Annona (*Annona* spp) -** PG

Quantitative estimation of major nutrients revealed that highest content of carbohydrate, energy and fat were noticed in *Annona reticulata* (25.12 g, 108.40 kcal, 0.61 mg/100g respectively), whereas Annona *muricata* exhibited highest moisture content (82.46 %).

Protein content was found to be higher in *Annona squamosa* (2.05 mg/100g). TSS content of the selected fruits ranged from 18 – $25^0$ Brix. The fruits were rich in potassium, calcium, magnesium, phosphorus and iron. The fruits exhibited very low fat content. *Annona reticulata* was composed of 65.09µg of β carotene per 100 gram and *Annona squamosa* recorded a vitamin C content of 36.20 mg/100g. Oxalates and total phenol content was higher in *Annona muricata* (3.36 mg/100g, 21.72 mg/100g respectively). Acidity of the selected fruits ranged from 0.27 to 1.07 per cent. Acceptable fruit nectar was developed from the fruits with three weeks shelf stability at ambient temperature.

**4. Assessment of nutritional status and life style diseases among different income groups - PG**

On considering the meal patterns majority of the respondents had cereal, pulse and vegetable combination for their breakfast, lunch and dinner with the inclusion of non-vegetarian foods like egg and fish. The food consumption pattern indicates that consumption of fast food was very low. The nutrient intake study revealed that among the three groups energy, protein and calcium intake was below Recommended Dietary Allowance (RDA). The biochemical assessment conducted by a clinical expert revealed that majority of the respondents in all groups of males (7%, 13%, 10% for Low Income Group, Middle Income Group & High Income Group respectively) were having mild anaemia. Although the prevalence of lifestyle diseases among the respondents was not obvious, the chances for their occurrence is very high, because of the hidden risk factors like grade I obesity, hyperlipidimia, prehypertension, hereditary factors and stress related lifestyle problems.

**5. Value added baked products from raw jack fruit- PG**

Value added baked products *viz.* Fruit bread, Bun, Rusk and Pizza base, based on raw jackfruit bulb flour were ascertained for their physical, chemical, nutritional and shelf life qualities. The proportion of raw jackfruit flour ranged from 20-80% among the treatments. Sensory evaluation revealed that T6 (with 20 percent bulb flour) obtained the highest scores for appearance, texture, taste, after taste, flavour and over all acceptability for bread, bun, rusk and pizza base. The cost of the products were found to be less than that of proprietary products in market. When product acceptability was analyzed, pizza base obtained the highest rank followed by rusk, bun, and fruit bread. Incorporation of Raw Jackfruit Bulb Flour into baked products seem to improve quality of the product economically, nutritionally and also with respect to sensory qualities. The shelf life of the selected products were found to be 3 days for bread, bun and pizza base and 3 months for rusk at room temperature

# Project Coordination Group - Agricultural Economics, Statistics and Agri. Business Management (15)

**Project Coordinator - Dr. Regeena S**

**Concluded Projects: 23**
**Ongoing Projects: 2**

## Concluded Projects

### 1. Network Project on Market Intelligence - ICAR

The KAU Centre has prepared 12 forecasts black pepper, coconut and tapioca and disseminated it to the farmers. Out of the four forecasts prepared per year for black pepper, one is pre-harvest forecast and the other three are post-harvest forecasts. For coconut and tapioca, all the forecasts were for post-harvest decisions. The forecasts were disseminated through personal contacts, emails, websites, mobile phones, training programmes for farmers, sensitization programmes for agricultural officers and scientists, magazines and newspapers. Farmers were benefitted with regard to decisions on time of selling and period of storage, which resulted in an increased income of 20-40 per cent from black pepper. There was increase in area allocation towards black pepper as an intercrop. In the case of coconut, the impact of forecast was that the income of the farmers increased to the tune of 10 to 20 per cent.

The farmers' perception on the utility of price forecasts of black pepper revealed that the farmers' income has considerably increased because of the price forecast. They opined that the dissemination of the price forecasts and activities carried out as part of the project should be continued. On the basis of the price forecasting and dissemination work carried out as part of the project by the Market Intelligence Centre at Kerala Agricultural University, the Government of Kerala is planning to introduce price forecasting of agricultural commodities in the State.

### 2. Economic analysis of production and marketing of organic vegetables in Wayanad district.

The crops selected for the study were yard long bean and bitter gourd. Resource use efficiency was worked out using Cobb-Douglas production function. For organic yard long bean, cost A was Rs.150277/ha and cost $C_3$ was Rs. 591042/ha. For conventional yard long bean crop, cost A was Rs.146277/ha and cost $C_3$ was Rs.471498/ha. For organic bitter gourd cost A was Rs.159077/ha and cost $C_3$ was worked out to be Rs.785405/ha. For conventional bitter gourd crop, cost A was Rs.221059/ha and cost $C_3$ was worked out to be Rs.959105/ha. The B-C ratio of organic yard long bean and bitter gourd were 2.02 and 1.15. For conventional yard long bean and bitter gourd it was 1.68 and 0.95. Seventy three per cent of the consumers preferred organic vegetables due to health oriented motives. Cobb-Douglas production function was used to work out the resource use efficiency.

Six major marketing channels were identified and the Producer-Wholesaler-Consumer was identified as the most prominent one for the selling of produce which accounted for 50 per cent of the organic vegetable farmers and 55 per cent of the conventional vegetable farmers. Farmers selling organic products through Fair trade centers got premium price which accounted only 10 per cent of the farmers.

### 3. Economics of dairying in Thrissur District - PG

The analysis of the feeding practices among dairy farmers in Thrissur District revealed that concentrates and paddy straw are not given upto the recommended quantity whereas green grass is provided more than the prescribed quantity when compared to the feeding schedule specifications prescribed by the Productivity Enhancement Department of National Dairy

Development Board, Anand. Dairying is considered as a subsidiary occupation which gives them either a subsidiary income or a means for meeting their day to day livelihood expenses. The contribution of net income from dairying to total income is less than 15 per cent in the case of majority of the respondents.

The dairy farmers who undertake agriculture as the main occupation, continue in dairying mainly for meeting the fertilizer needs for their farm land which could be easily obtained from the cow dung. The main source of income for all the respondent farmers from dairying is from the sale of milk alone. Even farm - oriented dairy farmers are interested in selling milk directly rather than using it for value added products. Feed, labour and transportation costs have positive impact on the milk production. Hence the intervention of various institutional agencies in these areas will have an impact on milk production and thereby the income of the dairy farmers.

**4. Impact of prominent KAU rice varieties on the economic status of farmers in Kerala and Karnataka- PG**

The objectives of the study were to work out the costs and returns of prominent rice varieties, Jyothi and Uma, released from KAU, to find out the relationship between varietal adoption and net farm income, to identify specific reasons for adoption of KAU varieties and to analyse profitability of the KAU varieties in the states of Kerala and Karnataka by comparing with local non-KAU varieties cultivated by farmers.

The area of the study were major rice growing districts of Kerala (Palakkad and Alappuzha) and Karnataka (Mysore and Mandya) (selected based on the prominence in adoption of rice varieties released from KAU. The cost-return structure was worked out both for KAU and non KAU variety using cost concepts. The average cost of cultivation (cost $C_2$) of KAU varieties was found to be lesser in Palakkad (Rs. 73,213 per hectare) compared to Karnataka (Rs. 75,7331 per hectare) and Alappuzha (Rs. 81,915 per hectare) and in case of local non KAU varieties, the average cost of cultivation was Rs.83,981 per hectare, Rs. 83,634 per hectare and Rs. 94,526 per hectare in Karnataka, Palakkad and Alappuzha respectively. The net income obtained by cultivating KAU varieties was found to be higher in Palakkad (Rs. 48,143 per hectare), followed by Alappuzha (26,356 per hectare) and Karnataka (Rs. 11,746 per hectare). The benefit-cost ratio (BCR) at the $C_2$ and explicit cost level was found to be positive for KAU varieties in both the states. This implies that cultivation of KAU varieties was profitable for farmers in both the states.

**5. Analysis of supply chain management of horticultural nurseries - PG**

The study attempted to understand the supply chain management, income and employment potential and constraints of horticultural nursery business in the study area, Thrissur district, which is considered as the hub of nursery business in Kerala, was purposively selected as the location of study. The supply chain with own production of plants were identified slightly more efficient than the supply chain involving purchase of plants from other nurseries. Employment generation and income from the nursery business was also worked out. The nursery business in the study area was identified as a profitable business and they contribute substantially to the income and employment generation in the locality. Horticultural nurseries being the providers of seed material for long term investments in farming, supply of quality planting material is of

utmost importance. Lack of proper registration and monitoring mechanism leading to the proliferation of nurseries and unhealthy management were identified as major issues in the horticultural nursery business.

6. **Value Chain analysis (VCA) of coconut based food products- PG**

The study was conducted in Thrissur district of Kerala, and the four products selected for the study were coconut oil, Virgin Coconut Oil (VCO), desiccated coconut and coconut chips. The value chain map of each product was prepared including the product and byproduct flows. The main chain players involved were farmer/farmer cooperative, village traders, copra traders, processors, wholesalers, retailers, exporters and consumers. Coconut oil value chain involved almost all chain players. But for coconut chips large buyers like wholesalers were not present. The analysis of marketing cost showed that the costs involved were very less where the unnecessary middlemen were least involved or absent. Price spread analysis has shown that VCO has the lowest producers' share in consumers' rupee (24.04 per cent) whereas the producers' share in consumers' rupee was the highest in coconut oil (71.04 per cent). The index of Modified Marketing Efficiency (MME) was worked out which showed that coconut chips was the least efficiently marketed value added product (0.23).

Low market price, increased labour charges, increased cost of productio9n and labour shortage were the major problems faced by farming community. Ensuring continuous and large scale supply of raw nuts to the manufacturers is the primary need for the promotion of value addition in coconut.

7. **Pre-harvest forecasting models and trends in production of banana (Musa spp.) in Kerala- PG**

The influence of plant growth parameters on banana yield established by correlation analysis that there was a significant relationship between yield and biometrical parameters. Models were built in order to predict yield with the help of minimum number of variables as possible in early stages of growth. In Nendran cultivar, the best yield prediction models estimated using biometrical characters as independent variables and bunch weight as dependent variables and the best estimated model was obtained at fifth month. In the case of Njalipoovan cultivar, the partial regression coefficients corresponding to plant height and number of leaves at fourth month were statistically significant and highly contributing to total yield in consecutive growth stages from fourth month onwards. Among the different stages of crop growth, $4^{th}$ month was the best time for prediction of bunch weight. For Red banana, the results revealed that fourth month onwards the partial regression coefficients corresponding to plant height and plant girth were highly significant. Among the different stages of crop growth, fourth month was the best stage for early yield prediction. Results of prediction models for Robusta showed that, pre-harvest prediction of yield is possible in fourth month itself with help of plant height and plant girth as explanatory variables with high precision. Plant height at fourth month and plant girth of third month were chosen as best predictor variables for early prediction. Cubic model was best and for production quadratic model was best suitable model.

## 8. Strengthening Centre for Intellectual Property Protection

IPR Cell has organized 6 awareness programs in the area of Intellectual Property Protection and its management resulting in a better awareness about IPR and its impact in Agricultural sector. Farmer groups were motivated to form farmer associations to apply for GI registration. Characterization and documentation of unique products were done to facilitate their registration as Geographical Indications. Producers of registered GI were facilitated for registering as "authorized user "of each product. The registration process of Nilambur teak and Tirur vettila are in the final stages.

## 9. Institutional preference for agricultural credit in Kasaragod district of Kerala

For all the farmers - marginal, small and large - co-operative banks are the most preferred choice of institutional finance, followed by RRBs as the next best alternative. However, public sector banks have disbursed the highest amount of loans followed by private banks and RRBs. Co-operatives have mostly concentrated on small ticket loans targeted at marginal and small farmers.

The results of factor analysis showed that institutional factors explain 36 per cent of the choice of institutional source and credit related factors are responsible for 29 per cent choice of source of finance. Proximity to the lending institution, cost of credit, adequacy and timeliness do not have any influence on the institutional preference of farmers. However, factors like procedural hassles, approachability, banker's behavior and flexibility are found to affect the choice of source of finance.

As micro credit could not make any significant contribution for financing the agrarian activities in the study area, micro credit channels have to be improved for providing farmers with necessary finance, which can serve as bridge loans, i.e. as term loans till their term credit/working capital finances are sanctioned and disbursed from institutional sources.

## 10. Economic analysis of production, marketing and price behaviour of coconut

Though area, production and productivity of coconut in India showed an increasing trend, no continuously increasing trend was observed in case of area and production of coconut in Kerala, which exhibited growth rates of 0.4 per cent for area and 2.12 per cent for production. However, the productivity showed an increasing trend during the period.

The price behavior of coconut and copra in major markets of Kerala *viz*., Alappuzha and Kozhikode were analyzed by decomposing the monthly price data into four components *viz*., secular trend, seasonal variation, cyclical variation and irregular variation assuming a multiplicative model of time series. The price of coconut and copra in these markets showed an increasing trend in the long run.. Three to four cycles were seen in both the market prices but the length of cycles was observed to be varying. Co-integration analysis of coconut prices in the above two markets were carried out and it was revealed that both the markets were integrated. . In order to provide additional evidence as to whether and in which direction, price transmission was occurred Granger Causality test was carried out and the results proved the existence of unidirectional causality between Kozhikode and Alappuzha market prices in the long run.

Since coconut is a perennial crop, its yielding phase was assumed to be 50 years, with a non-bearing phase of 7 years. The cost and returns were estimated taking into account the establishment cost and the maintenance cost. The cost of cultivation per hectare was Rs. 1, 01,989 with a net return ofRs. 24,011. It was noted that human labour accounted for 50 per cent of the total cost. To evaluate resource use efficiency in coconut cultivation, Cobb-Douglas production function was fitted. Manures, fertilizers and plant protection chemicals were found to be significantly contributing towards the yield. Moreover, an increasing returns to scale in coconut production was observed in the study area which implies that there is ample scope to increase the profit of farmers by proper adoption of technology and by optimal allocation of resources.

Majority of sample farmers in the study area sold coconut in the form of copra till the last few years. But during the last 5 to 6 years, 70 per cent of the produce being marketed was in the form of raw nuts. Lack of storage facilities and fluctuating prices made the producers to sell raw nuts immediately after harvesting instead of waiting for a higher price. Majority of the wholesalers in the study area sell raw nuts in Coimbatore market, Tamil Nadu where they get a reasonable price. The most efficient marketing channel identified in the study area was channel 3 (Producer-retailer- consumers) with a high efficiency index of 5.2.

Major constraints identified in the study area were wide fluctuations in coconut prices, high labour cost, pests and diseases attack and inadequate procurement scheme. In order to tackle these problems, it is necessary to encourage coconut farmers to replant old and senile trees by providing subsidy and ensure high production by strengthening the existing procurement scheme. Strategies emphasizing implementation of comprehensive coconut rejuvenation programmes, enhancing productivity through better technology integration and value addition through product diversification to ensure better price for farmers are suggested.

## 11. Price forecast models for coconut and coconut oil

Analysis of price pattern revealed that wide fluctuation exists in the prices of coconut oil and copra at Alappuzha, Kochi and Kozhikode markets and price of coconut at Alappuzha market. For coconut oil and copra price, the coefficient of variation was around 50 per cent indicating the instability in prices and a coefficient of variation of 37 per cent for coconut price showed that variability in price is lower than that of coconut oil and copra.

Seasonal indices for the 12 months from January to December showed that December is the peak price month for coconut oil at Alappuzha and Kozhikode markets, whereas it is January at Kochi. Lowest price is observed in May at Alappuzha and Kozhikode markets, whereas, at Kochi it is in July. In all the three markets, September– February is the buoyant phase and price depression is during March - August. For copra, peak price is in December at Alappuzha and Kochi markets, whereas, it is in November at Kozhikode. Trough price for copra is in May in all the three markets. October to February is favourable for copra price in all the three markets, whereas, depressed phase is from March to September.

For coconut, peak price at Alappuzha market is in December and the buoyant phase is from November to February. April is the low price month with depressed phase from March to October. During the summer months from March to May, harvest the coconuts as tender and increase the production of neera. Also, during March- September, where the price of coconut oil

and copra is low, steps are to be taken to convert coconut into other value added products like desiccated coconut powder, virgin coconut oil, activated carbon etc. and to identify regular markets in major cities of India as also outside India.

Different forecast models viz., Auto regressive Integrated Moving Average (ARIMA), Artificial Neural Network (ANN) and exponential smoothing models (single, double, Holt-Winters' additive and multiplicative seasonal) were fitted and compared for prices of coconut, coconut oil and copra in different markets. Holt-Winters' Multiplicative Seasonal (HWMS) model is the appropriate forecast model for price of coconut oil at Alappuzha and Kochi markets. At Kozhikode market, Seasonal ARIMA$(1,1,1)(1,0,1)_{12}$ and HWMS are equally good. HWMS model is selected as the suitable forecast model for copra at all markets. ARIMA (0,1,1) model is suitable for forecasting price of coconut at Alappuzha market.

**12. Ground water irrigation: Management, adaptation and economic costs under declining resource conditions**

The study was conducted in three Block Panchayats (BPs) falling under three classes of groundwater development (over-exploited, critical and semi-critical) in Palakkad, one of the agriculturally prosperous districts of Kerala. Three BPs viz. Chittur, Malampuzha and Pattambi (falling under over-exploited, critical and semi-critical classes of groundwater development) were purposively selected for the study. Statistical tools like descriptive analysis, regression analysis and stochastic frontier analysis were employed for the analysis of the data.

In most of the GMWs in the study area, the Water Level from Ground (WLG) has been declining over the years. The trend was more predominant during early summer (Dec.–Jan.) in Chittur and Malampuzha and in late summer in Pattambi BP. Regression analysis showed that WLG was significantly influenced by one year lagged rainfall in Chittur and current year rainfall in Malampuzha and Pattambi.

The average well density was 205/km2 with highest in Pattambi. Density of defunct wells was highest (45/km2) and the average functional age of bore wells was lowest (7 years) in Chittur. The depth of well was highest in Chittur where bore well depth (136 mbgl- meters below ground level) was double than that of Pattambi. Coconut based cropping system was prevalent in most of the farms except in Malampuzha where paddy was the major crop. Flood, basin and sprinkler irrigations were found to be more common in Malampuzha and Pattambi BPs, while drip irrigation was prevalent in Chittur. Cost of irrigation in Chittur was about Rs. 29,000/ha/year which accounted for 37 per cent of cost of cultivation. Annual net return per ha. of farm was lowest (Rs. 17,640/-) in Chittur due to low cropping intensity. Stochastic Frontier Analysis indicated that mean economic efficiency was high (99.9 %) in Chittur as most of the farms were functioning along the cost frontier. The variability among the farms in Chittur was low.

The study suggests policy interventions in regulating bore well digging and revisiting the power subsidy system. In Chittur area, where the rainfall is scanty, extension of the Right Bank Canal of the Chittur River irrigation project is the most feasible solution. Taking up on-farm research trials in the area to suggest efficient farming systems and practices may also be done. Simultaneously water resource conservation strategies are to be popularized through awareness creation, capacity building programmes and subsidy support.

## 13. Market access to quality paddy seed in Kerala

Rice seed production and distribution scenario in Kerala can be broadly documented as formal rice seed supply chain and informal rice seed supply chain. Informal supply include farmer saved seed and farmer exchanged seed. Formal rice seed supply is done through different agencies such as KSSDA (Kerala State Seed Development Authority), NSC (National Seeds Corporation) and KAU (Kerala Agricultural University). The major formal rice seed supply chains are:

Chain 1: KAU Research Station – Rice farmer
Chain 2: Agriculture Research Station – Participatory rice seed production unit – Participatory rice seed grower – Participatory rice seed production unit – Rice farmer
Chain 3: Agriculture research station – State Seed Farm (SSF) – KSSDA – Registered rice seed grower – KSSDA – Rice farmer
Chain 4: Agriculture research station – NSC (National Seeds Corporation) – Registered rice seed growers – NSC (National Seeds Corporation) – Rice farmer

Economics of rice seed production in farmers' field came to Rs. 68628/ha, out of which hired human labour accounted for 51 per cent followed by material cost (25%) and machine labour (18%). Average rice seed yield at farmers' field was 5331 Kg/ha with a gross income of Rs. 152089/ha. Benefit Cost Ratio was found to be 2.22 at Cost A1 and 1.66 at Cost C2.

Major constraints faced by rice seed growers were untimely seed procurement and payment followed by climate change and high labour cost. Constraints faced by rice farmers in access to quality rice seed was lack of timely availability followed by poor seed quality and unavailability of subsidized seed in required quantity. Access to Seed Index (ASI) was also worked out in order to compare different supply chains in terms of accessibility to rice farmer. KAU rice seed supply chain (chain 1&2) was having highest ASI (0.657) followed by KSSDA rice seed supply chain (0.644) and NSC rice seed supply chain (0.433).

## 14. Economic analysis of production, marketing and price of arecanut in Kasaragod district of Kerala

The price behaviour of ripe arecanut in Nedumangad and Telicherry markets and dry arecanut in Nedumangad, Calicut and Kanhangad markets were analysed by decomposing the monthly price data into four time series components *viz.*, secular trend, seasonal variation, cyclical variation and irregular variation, assuming a multiplicative model of the time series. The price of ripe and dry arecanut in these markets showed an increasing trend in the long run. While analysing the seasonal variation, it was noticed that arecanut prices shows considerable seasonality. Three to four cycles were seen in both the markets but the length of cycle was observed to be varying. Pair-wise cointegration analysis of arecanut price in the above said markets were carried out in the following combinations; Nedumangad ripe and Telicherry ripe, Nedumangad dry and Calicut dry, Nedumangad dry and Kanhangad dry and Calicut dry and Kanhangad dry, which revealed that all the markets prices were co-integrated. This proved that there is strong co-movement of prices between the markets of arecanut within the state.

The cost of production of arecanut was worked out as Rs. 133, Rs. 166 and Rs. 137 per kg for yield increasing, yield stabilising and yield declining stages respectively. The cost of production in aggregate was estimated as Rs.150 per kg in Kasaragod district. To evaluate resource use efficiency in arecanut cultivation, Cobb-Douglas production function was fitted. Plant protection chemicals were found to be significantly contributing towards the yield per hectare while expenditure on human labour was found to be negatively contributing to yield per hectare.

About 45 per cent of the total sample farmers sell their produce in the form of dehusked dried nut to the village traders as they get immediate payment in cash, while 40 per cent of sample farmers sold through CAMPCO.

The four marketing channels identified were, (i) Producer-village trader-wholesaler-retailer-consumer, (ii) Producer-wholesaler-retailer-consumer (iii) Producer-CAMPCO-retailer-consumer and (iv) Producer- consumer., of which the first three were the important ones. The marketing cost was highest in channel I (Rs. 33.9), and lowest in channel III (Rs. 28.44). The marketing margin ranged from Rs. 25 per kg in channel I to Rs. 16.5 per kg in channel II and the share of marketing margin in consumer's prices ranged from 9.09 per cent and 6.15 per cent. Price spread was highest (Rs. 58.90) in channel I and lowest in channel III (Rs. 16.76). The producer's share in consumer's rupee was 83.02 per cent in channel III, while it was 78.54 per cent in channel I. The marketing efficiency was highest in channel III (9.42 per cent) and lowest in channel I (8.11 per cent).

Scarcity of skilled climbers for harvesting and spraying of plant protection chemicals were identified as the major constraint, followed by water scarcity. The major constraints faced by sample farmers in production were occurrence of diseases and pests, wild animal attack, high wage rate, climate change and wind and lightning. Fluctuation in prices was the foremost constraint faced by the farmers in marketing of arecanut.

Based on the above findings the following policy interventions are suggested:

1. Mechanization of operations- efficient sprayers for plant protection measures on arecanut bunches from the ground and self-operated climbing devices.
2. A workable price stabilization mechanism and regulation on the import of arecanut.
3. Farmers should be encouraged to avail the warehousing facilities to store their product and use the warehouse receipt as a negotiable instrument to avail loans.
4. Value addition and product diversification of raw arecanut to help the farmers to move up in the value chain.
5. Market intelligence and extension approaches should be strengthened to help the farmers in making decisions on timely harvesting, storage and sales.
6. Efforts must be taken to strengthen and restructure the existing water harvesting schemes initiated by NABARD and other government agencies.

## 15. Assessment and management of risk at farmer's level in rice and banana cultivation

Paddy farmers face production constraints, financial constraints, marketing constraints and institutional constraints. Production risk was captured through their responses on realized yield levels during the past 10 years. The maximum realized yield was reported to be 5718 kg/ha with high variability at 96.8 per cent. This was realized only during two years over a span of ten

years. The minimum yield was found to be 4181 kg/ha realized for three years and showed higher levels of inter-farm variability. Maximum average returns realized amounted to Rs.1.28 lakh at a unit price of Rs.22.50/kg whereas minimum return realized was Rs.41812 at Rs.10/kg.

Uncertainty in prices is one of the major factors that affect profitability in paddy cultivation. Institutional risk results from uncertainties surrounding government actions. Various institutions are functioning at national, state and local levels with various schemes to protect and preserve rice cultivation in the state. The intervention of the Kerala State Government through the paddy Procurement Scheme of SUPPLYCO is a major step for the promotion of rice farming Farmers in the survey area agreed that they have largely benefitted from the procurement of paddy by the Supplyco. The delay in effective payment after the procurement (3-4 months) and failure to procure on time cause difficulty to farmers.

To estimate the production risk associated with rice cultivation, Modified Just and Pope production function was fitted. It was found that higher levels of investment on fertilizers and plant protection chemicals increases the risk in paddy production. Higher levels of labour involvement and larger holdings are found to be less risky.

To identify the major risks faced by paddy farmers in the study area, Henry's Garrett Ranking Technique was employed. Unexpected change in weather conditions is perceived as the most important risk factor with an average score of 70.90 followed by the severity of pests and diseases with an average score value of 70.35. Agricultural insurance is considered to be an effective mechanism to tackle farm loss.

The risks in banana farming was analysed by similar methods based on a sample size of 40 banana growers. The production risk in banana was captured through the realized yield levels. The maximum realized yield was reported to be 22330 kg/ha with a variability of 107 per cent. The minimum yield was 14342 kg/ha with very high variability of 128 per cent. Returns per hectare ranged from Rs 9.30 lakhs at a unit price of Rs.50/kg to Rs..2.15 lakhs at Rs.15/kg.

92.50 per cent of farmers sourced capital from external sources. Of this, 67.56 per cent was from the scheduled commercial banks and 24.32 per cent from cooperative societies and the rest by RRBs (8.10 per cent). Farmers are getting good support from VFPCK for large scale agricultural production and better price realization resulting in increased agricultural income and reduced indebtedness.

Wide fluctuations in the market price, damage by wind, high labour cost and high cost of inputs were the major constraints to farmers. 72.5 per cent of the sample respondents had insured their crops under the State Insurance Scheme with a premium of Rs.2.50/plant. Education, years of experience and land holding size has significant influence on the banana farmers to make a choice on adoption of crop insurance as a risk management strategy.

## 16. Economic impact of microbial inoculants on vegetable production in Thiruvananthapuram District

Average size of holding of selected farmers was 46.03 cents. Analysis of the extend of use of microbial inoculants revealed that only 27 and 17 per cent of the respondents were following the recommended rates in yard long bean and amaranthus respectively whereas 53 and 70 per cent were applying MI above the recommended rate. In the case of amaranthus as well as yard long

bean, MI using farmers obtained more yield (7835kg/ha) compared to conventional farmers (7306 kg /ha) and the respective cost of production were Rs.7/kg and Rs.10/kg at cost A1. In the case of yard long bean, the B:C ratios of conventional farmers and MI using farmers were 1.46 and 1.51 and net returns were Rs. 51,072/ha and Rs.122716/ha respectively. In the case of amaranthus the B: C ratios were 1.17 and 1.19 and net returns were Rs.21, 463/ha and Rs.48662/ha respectively for conventional and MI using farmers. Present study revealed that by using MI, cost of cultivation per ha of yard long bean and amaranthus can be reduced considerably when compared to conventional cultivation. High cost of seeds, high cost of panthal material and high pest and disease incidence were identified as major constraints in vegetable production.

## 17. Exploratory analysis of Permanent Manurial Trials in rice

Exploratory Data Analysis using graphical and non-graphical methods was attempted to realize yielding behavior of treatments. Summary statistics viz., mean and median explicitly showed that treatment $T_1$- Cattle manure at 18000 kg ha $^{-1}$ was superior followed by treatment $T_5$- Cattle manure at 9000 kg ha$^{-1}$+ ammonium sulphate to supply 45 kg N ha$^{-1}$+ superphosphate to supply 45 kg $P_2O_5$ ha$^{-1}$ + 45 kg $K_2O$ ha$^{-1}$ as muriate of potash. Box plot of yield data remarked consistent yielding performance for the same treatments during both kharif and rabi seasons. Yield trend as assessed by regressing crop yield on time factor showed no significance in yield trend. Analysis of groups of experiments also superiority of treatment $T_1$ followed by $T_5$ during both seasons.

Influence of weather on grain yield was studied for three growth stages of rice viz., early tillering to panicle initiation, panicle initiation to flowering and flowering to milk stage. The results followed from correlation and regression analysis pointed to minimal role of weather in affecting grain yield. Consistency of treatments assessed through two consistency measures showed that treatments $T_1$ and $T_5$ had average consistency. Maximum Sustainability Yield Index (SYI) was recorded for treatments $T_1$ followed by $T_5$ during both seasons.

Statistically optimum fertilizer requirement was obtained by compiling the results followed from the aforementioned analyses. Treatment $T_1$ - Cattle manure at 18000 kg ha $^{-1}$ to supply 90 kg N ha$^{-1}$ was chosen as the optimal fertilizer schedule for rice.

## 18. Time series analysis and forecasting of the prices of Indian Natural Rubber

The decomposition of domestic rubber prices into time series components was carried out under the assumption of additivity. The data were decomposed into trend, seasonal and cyclic components. The trend values proved that there was quadratic trend over the years.

For evaluation of growth and instability, volatility and instability analysis were carried out for pre WTO, post WTO and overall periods in terms of rupees and dollars. Intra-annual volatility (within year dispersion) and inter annual volatility (between year dispersion) were higher in post WTO for international and domestic NR price series and crude oil prices showed higher volatility in pre-WTO period in terms of rupees as well as in dollars. GARCH (1, 1) model gave an additional evidence for persistence of volatility. It proved that the volatility persisted in the overall period in terms of rupees and dollars for domestic rubber price and for international rubber price.

Instability analysis showed that the price instability in post WTO was almost double than that of pre WTO and triple in overall period in terms of rupees and in terms of dollars, the instability in post WTO was almost triple than that of pre WTO for domestic and international NR price and crude oil prices showed double instability than pre WTO.

The relationships between domestic and international prices were analyzed through cointergration analysis and Vector Error Correction Method (VECM). Cointegration analysis showed that there was at least unidirectional relationship among the variables and Vector Error Correction Method (VECM) showed that there was long run relationship between domestic price, international price and crude oil price.

There were many factors affecting the prices of Indian NR in general like Synthetic rubber (SR) production, SR consumption, crude oil prices, International rubber prices, International demand and supply, international transactions, exchange rates, natural factors and development of automobile industries. Separate factors were sorted out affecting in pre-WTO and post-WTO using Step wise regression analysis. The analysis revealed that NR price in pre-WTO was affected by International rubber prices and in post-WTO by International rubber prices and SR consumption. Moreover, in overall period, international rubber price and high import values from other countries were the main cause for downfall of domestic rubber prices.

Domestic rubber prices were forecasted with three different models like Stepwise regression method, ARIMA and SARIMA. In stepwise regression method, annual domestic rubber price could be predicted by using annual international rubber price and annual import value of NR. Among the different forecast models tried for domestic NR price, ARIMA (4, 1, 4) and Seasonal ARIMA (4,1,4) (1,0,1)12 were selected.

**19. Economic impact of climate change and adaptation strategies in Black Pepper (*Piper nigrum* L.) cultivation in Kerala**

Average temperature during $Q_3$ (July-September) and $Q_4$ (October-December) had a negative and significant impact on the production of the pepper. Rainfall had a positive effect on production but was statistically insignificant. The various adaptation practices adopted were mulching with coir pith or dry leaves, shading of young plants, spraying 1 per cent lime solution to foliage and moisture conservation tillage. Mulching was the major adaptation practice which was followed by 68.75 per cent of the respondents. While analyzing the compensation to pepper farmers in Wayanad, it was seen that compensation for flooding due to heavy rainfall and high speed wind was more than that for drought which was Rs.32, 81,192 and Rs.48, 64,984 per annum respectively. Sulthan Bathery block in Wayanad had the maximum beneficiaries for both type of compensations viz. compensation due to drought and compensation for flooding due to heavy rainfall and high speed wind.

**20. Economic assessment of the use of microbial inoculants in Black Pepper (Piper nigrum L.) in Idukki district**

Analysis of extent of use of microbial inoculants revealed that only 33 per cent were following the recommended rate of microbial inoculants whereas 46.6 per cent of farmers used it in excess .Cost C was calculated as Rs.295050.13/ha and Rs.439399.87/ha for microbial inoculants using farmers and non microbial inoculants respectively. Major share of cost A1 was contributed by

cost of hired labour for both categories followed by cost of manures, fertilizers and soil ameliorants. B:C ratios were 1.8 and 1.23 for MI adopters and non MI farmers respectively at cost C. Difficulty in proper identification of pests and diseases in the study area, less availability of microbial inoculants other than Pseudomonas and Trichoderma, lack of knowledge about recommended method, dose and time of application of MI and climate change were the major constraints observed. The MI using pepper farmers obtained total yield of 760 kg/ha and non MI farmers obtained an yield of 795 kg/ha .The gross returns obtained from pepper using MI was Rs. 532000/ha which is less than that of non MI farmers(Rs. 540600/ha). The net return obtained by MI using pepper farmers was more than that by non MI farmers as the price was Rs.700 and Rs.680 per kg respectively.

**21. Comparison of statistical methods for control of error in long term experiments in rice (*Oryza sativa* L.)**

The study was mainly based on the data on a field experiment on rice (var. Aiswarya) viz. 'Permanent plot experiments on integrated nutrient supply system for a cereal based crop sequence' conducted at Integrated Farming System Research Station (IFSRS), Karamana. The field experiments consisted of 12 different treatments on modified fertilizer doses based on the recommended dose including a control T1 (no fertilizers and no organic manures) and T12 (farmer's practice). Randomized block design (RBD) with four replications was used for kharif and rabi seasons for all these years. The main items of observations collected were grain yield, straw yield, plant height, total number of tillers, number of productive tillers, dry matter production and harvest index. It is concluded that, the ordinary pooled analysis of data was found to be the best under the exploratory analysis. Analysis of covariance with one covariate was found to be equally good with adjusted MSE almost to that of MSE of ordinary pooled analysis.

It was found that neither the serial correlations nor partial regression coefficients were found to be significant for kharif, rabi as well as yearly data. Which means there is no any significant relationships between the season as well as yearly data.

**22. Pre-harvest forecasting models and instability in production of cassava (*Manihot esculenta* crantz.)**

In prediction models of Sree Jaya, the best linear model was obtained using inter nodal length at 3 MAP and number of primary branches plant$^{-1}$ at 4 MAP with $R^2$ of 50 per cent. The best predicted variables based on non linear models were number of functional leaves plant$^{-1}$ at 2 MAP and number of primary branches plant$^{-1}$ at 4 MAP with $R^2$ of 56 per cent.

In case of Sree Vijaya, the best linear model was obtained for the pre-harvest prediction of yield, by using inter nodal length at 2 and 5 MAP and number of functional leaves plant$^{-1}$ at 2 MAP and plant height at 5 MAP with $R^2$ of 58 per cent; based on non linear equations, the best model obtained was using inter nodal length at 2 and 3 MAP and number of functional leaves plant$^{-1}$ at 5 MAP with $R^2$ of 59 per cent.

Multiple regression models for the variety Sree Swarna showed that the best linear model obtained for prediction of yield was using inter nodal length at 2 and 3 MAP and number of functional leaves plant$^{-1}$ at 5 MAP with $R^2$ of 43 per cent; with non linear functions the best

model obtained was using inter nodal length at 2 and 3 MAP and number of functional leaves plant$^{-1}$ at 5 MAP with $R^2$ of 49 per cent.

The best linear model obtained for prediction of yield in the variety Vellayani Hraswa was using number of functional leaves plant$^{-1}$ at 2 MAP and plant height at 4 MAP with $R^2$ of 35 per cent; with non linear equations the best model obtained was using number of functional leaves plant$^{-1}$ at 2 MAP and plant height at 2 and 4 MAP with $R^2$ of 40 per cent.

### 23. Statistical models for profit maximization homesteads in Kerala

Majority of the homesteads in AEU8 (82.5%) and AEU9 (92.5%) were semi-irrigated and coconut based with an average size of 0.18 ha and 0.21 ha in AEU8 and AEU9 respectively. Perennial fruit trees like mango, jack, papaya and annual fruit trees like banana were grown in most of the homesteads. Tuber crops were a dominant category, and tapioca was found in almost 90 per cent of the homesteads in both agro ecological units. Majority of the homesteads in AEU8 (82.5%) and AEU9 (92.5%) were semi-irrigated. The commonly summer vegetables along with banana were grown mainly for household consumption. Black Pepper was trailed on trees in the homesteads. Livestock such as cow, buffalo and goat were less and poultry was more.

The estimated total net return of the existing of the average size of 45 cents HFS S1, S2 and S3 was Rs.27,596/-, Rs.55,244/- and Rs.1,72,245/- in AEU8 and Rs.23,303/-, Rs.34,272/-and Rs.1,31,516/- in AEU9 of average size 52.5cents respectively.

The optimum model developed for a homestead farmer of AEU 8 by investing an amount of Rs.28,793/- would receive a net profit of Rs. 34577/- which indicates 25.30 per cent enhancement in net profit over the existing plan. The optimum model left a total area of 439.79 m2 with an unutilized interspace area of 390.27 m2 as an indication of lapse in proper farm planning.

The optimum model AEU 9 was developed by investing an amount of Rs.23384.18/- would receive a net profit of Rs.28623.72/- indicating 22.83 per cent enhancement in net return as compared to net return from the existing plan. The model worked out for S1 in AEU 9 was found to have non binding solution for enterprises like coconut, cashew, ginger, dioscorea, pineapple and banana but binding solution for all other enterprises with B: C ratio of 2.22. The optimum model for average S1 homesteads in AEU 8, comprising of 23 enterprises including house and permanent structures.

## Ongoing Projects

### 1. Organic Farming in Kerala: Field Realities and Strategies for Future

The project was carried out to document the existing practices of organic farming in Kerala and assess the economic viability based on case studies, compare its economic and environmental viability with chemical based farming, to identify major constraints and prospects of organic farming in Kerala and to develop a guide/ road map for promotion of organic farming in Kerala.

Four existing practices, viz., Spiritual Farming/ Zero Budget Farming/ Natural Farming, Biodynamic Farming, Homeo treatment in Agriculture and Organic Farming were documented. These promote beneficial microbial growth and facilitate the availability of plant nutrients. The

system donot require farm inputs to be purchased and in zero budget farming the basic approaches include mixed crop and crop rotation, mulching, canopy level irrigation and nutrient management.

A. **Biodynamic Farming -** The idea of Bio dynamic farming was drawn from the ideas of Rudolf Steiner during 1920s in Germany. The preparations in biodynamic farming are denoted by number starting from 500 to 508. Preparations 500 and 501 are made by packing cow dung or silica, respectively, into cow horns and burying them for a number of months before use. Steiner believed that cow horns, by virtue of their shape, functioned as antennae for receiving and focusing cosmic forces, transferring them to the materials inside. After exhumation, the contents are diluted with an unspecified amount of water to create a homeopathic solution, which when applied to soil (Preparation 500) or crops (Preparation 501), was thought to influence root or leaf growth. Six other compounds (Preparations 502–507) are extracts of various plants packed into either the skulls or organs of animals (e.g., deer bladders, cow peritonea and intestines) or peat or manure, where they are aged before being diluted and applied to compost. Steiner believed that the chemical elements contained in these preparations were carriers of terrestrial and cosmic forces and would impart these forces to crops and thus to the humans that consume them.

B. **Homeo treatment in Agriculture -** By principle homeopathy is a science based on experience. In 2010, a German homeopath named Christiane Maute, first published 'Homeopathy for Plants' based on a decade of personal experience applying remedies in her own garden as well as to indoors and balcony plants. Homoeopathic medicine works by producing certain chemicals that are repellent to harmful insects or by increasing the natural immunity of the plants and trees.

C. **Organic Farming -** The agricultural production practices based on organic inputs, with minimum of synthetic inputs can be considered as organic.

   The management practices in organic farming are based on local knowledge systems or information shared among the farmers, through mass media as well as electronic media. The pest/disease incidence in organic farming is generally reported to be high, especially during early days of conversion. In paddy, the attack of rice bug is very common and the organic farmer's popular practice is to keep decayed sardine in different location of the paddy field to repel the bug. Neem oil spray is also an alternative method. The proportion of commercial farmers, who strictly adopt organic methods are rather limited. Economics of organic cultivation of different crops is being worked out.

## 2. Optimisation techniques in long term fertiliser trials: rice - rice system

Objective of the study is to study the cumulative effect of weather factors and plant nutrients on the crop productivity, dynamics of soil characters in relation to the fertiliser treatment responses and to suggest appropriate statistical optimisation techniques with respect to yield and its forecast. The data from Long Term Fertiliser Experiment (LTFE) on rice (variety: Aiswarya) with twelve treatments in four replications laid out as RCBD at RARS, Pattambi from 1997 to 2017 will be collected along with the details on weather variables.

# Project Coordination Group - Agricultural Extension and Developmental Studies (16)

## Project Coordinator - Dr. N. Kishore Kumar

**Concluded Projects: 6**

## Concluded Projects

1. **Technology utilization of banana in Thiruvanathapuram district- PG**

The objective of the study is to assess the level of adoption of selected KAU practices in banana cultivation and analyse the constraints experienced by farmers in adoption of these practices. Suggestions for refinement of practices as perceived by the farmers will also be studied. Level of adoption had positive and significant relationship with education, risk orientation, economic motivation, attitude of farmers towards scientific technologies, and extension contact. Out of five variables only education had significant at 5 per cent level.

There were 1.1 per cent innovators 13.3 per cent early adopters 35.5 per cent early majority 34.4 per cent late majority and 15.5 per cent laggards. There was slight variation from standard Roger's curve which is depicted in figure 4. More variations are found in innovators and early majority. As per standard Roger's curve, 2.5 per cent innovators and 34 per cent of early majority will be there normally. But in this study only 1.1 per cent innovators and 35.5 per cent early majority present.

From the study of adoption of KAU practices on banana cultivation it could be observed that majority of them (73.3%) had medium level of adoption. Moreover 14.4 per cent of them had low level followed by 12.2 per cent with high level of adoption. Though more than 85 percent of respondents were aware about selection of sword sucker sand paring & pralinage, they were not directly adopting it. In the case of pre-harvest bunch spray with 3 per cent $K_2SO_4$, awareness was only negligible (5.5%). Also awareness about correct spacing, fertilizer recommendation, spraying one per cent Bordeaux mixture for controlling leafspot, use of traps in rhizome weevil, chemical control of pseudostem weevil and high density planting were poor. So efforts should be taken to create awareness about these practices among banana growers.

2. **Indigenous agricultural practices in rice farming by tribal and non tribal agricultural labourers and farmers in Wayanad district: A Comparative analysis- PG**

Objective of the study is to identify and document the indigenous agricultural practices and study its scale of practice by tribal and non tribal agriculture laborers and farmers. Their work participation, social participation, media utilization, profile characteristics and constraints will also be studied.

3. **Enhancing livelihood security and local socio economic development through Mahatma Gandhi national rural employment guarantee scheme: an analysis- PG**

The study intended to find out the nature and extent of integration of MGNREGS with the agricultural development programmes implemented at the local level, the factors affecting planning, implementation and monitoring of MGNREGS as perceived by different stakeholders of the programme, demand side preference, supply side performance and assess the impact of MGNREGS on the livelihood security of beneficiaries.

The study showed that there is perceptible difference in the extent of integration of different agricultural development programmes and their components with MGNREGS, across the six

Grama Panchayats studied. Among 26 developmental programmes in the state, seven schemes are commonly integrated in all the six panchayats. While the implementing officers perceived institutional factors as most important in both planning and implementing stages, people's representatives perceived managerial factors as most important in all stages of MGNREGS. The impact of MGNREGS on the livelihood security of beneficiaries was assessed based on the indices of direct as well as indirect changes. Employment generation and income generation- which reflected direct changes in livelihood security- were found to have increased as a result of implementation of the scheme. Distribution of beneficiaries based on indirect changes measured in terms of the 'sense of empowerment' showed that majority of respondents belong to medium category. While demand side preferences varied significantly across the grama panchayats, supply side performance did not vary too much. However, supply side performance indices were found to be lower than the corresponding demand side preference. Out of the several socio economic characteristics observed, age and caste were found to be significantly correlated negatively to income generated by the household. The study shows that MGNREGS has significantly enhanced the livelihood security of rural poor. However, integration of the programme with agricultural development is grossly inadequate in Andhra Pradesh. This suggests major policy shifts in the implementation of MGNREGS to make the programme effective. Unless local self government institutions are given enough authority to plan their own programmes, the quantum of employment generated would not be adequate to meet the demand. More components of the state sponsored and centrally sponsored schemes will have to be integrated with MGNREGS. The rural population should also be oriented to the provisions of the scheme to demand and avail more employment.

4. **Transition to organic agriculture in Kasaragod District: A multi dimensional analysis- PG**

The present study attempted to characterise the process of transition to organic agriculture in Kasaragod District and find out the nature and extent of institutional support available for this transition. The study also explored the perception of major stakeholders about organic farming, impact of the ban and the functional constraints. The sample included 90 farmers drawn at the rate of 30 farmers each of three major crops viz. Coconut, Banana and Rice. Multistage random sampling method was employed to select farmers from the six panchayats which were selected from the six blocks in the district. The sample also included 40 extension personnel from the department of agriculture. Data were collected by using structured interview schedules, questionnaires and consultative discussions. A detailed analysis of the special programme on organic farming implemented by the Department of Agriculture from 2012-13 to 2016-17 indicated that the interventions to sustain the ban and promote organic agriculture had not been uniform. Moreover, majority of the farmers (67.8%) and extension personnel (75%) had unfavourable perception about the ban on chemical inputs. However, 96.7 per cent of farmers and 77.5 per cent of extension personnel were found to perceive the dimensions of sustainability of organic agriculture favourably. While the costs of production of paddy and coconut were found to increase in organic methods, no significant increase was observed in banana. However, both paddy and banana were registered reduction in yield by 21 per cent and 26.4 per cent respectively, on adopting organic agriculture. No significant difference could be obtained in the

yield of coconut after conversion. As much as 56.6 per cent of the farmers had low levels of adoption of organic practices. Mulching, incorporation of residues, application of FYM etc., were found to be adopted invariably across different crops. Institutional support was found to be inadequate as majority of the farmers (88.8%) had not availed institutional support in terms of subsidy for organic manure production. However, training programmes had been widely conducted in several places. Among the different socio economic and psychological variables, 'attitude' was found to have significant role in transforming adoption level from low to medium. 'Contact with extension agency' and 'availability of organic inputs' were found to transform adoption levels from medium to high. Poor quality of organic inputs, lack of availability of alternate plant protection materials, unavailability of organic inputs in time, high incidence of pest, disease and weeds, high cost of production and low market price were found to be the major constraints identified by farmers. For extension personnel, lack of effective alternative organic pesticide to replace inorganic pesticide, high incidence of pest, disease and weeds, unavailability of organic inputs in time, poor quality of the available organic inputs etc., were the major constraints. The constraints faced by the farming community calls for monetary compensation for the losses during the transition period, establishment of organic manure production units, adequate mechanisms for quality assurance of organic inputs, integration of various farming components, establishment of a network of markets exclusively for organic products, institution of minimum support price etc. Extensive conversion into organic farming would not be sustainable unless institutional support is strengthened.

5. **Accomplishing food security through community based initiatives in Thrissur:A participatory analysis- PG**

The study intended to appraise the nature and relative role of community-based organizations (CBO) involved in ensuring food security, explore the extent of awareness of various stakeholders in agricultural development process and factors contributing to it, identify gaps in food grain production in a selected Grama Panchayat and assess possible interventions to ensure food security through community based initiatives. Observations on the basic details of CBOs included the details of members, year of start, production and market details, subsidiary enterprises, marketing of products, relation with local bodies, skills and aspirations of CBO members and difficulties encountered. The different constraints faced by the extension agents in implementing food security programmes were also noted. The awareness level of stakeholders on the different dimensions of food security concerns of the community was assessed.

Farmers were found to have better awareness on production and nutrition dimension; CBO members had better awareness on the distribution and socio economic dimensions as well as food security as a whole. The extension agents had the least awareness on all the four dimensions. Positive correlation between farmer's awareness on food security and age was found and negative correlation was found between their awareness and sex. Negative correlation between age, farming experience and income of extension agents and awareness was observed. Significant, positive correlation between CBO member's awareness and their age was noted. Positive correlation between awareness and their farm size and negative correlation between awareness and education were also observed. It was also found that negative correlation existed

between awareness and farm size of the people's representatives. A methodology for quick assessment of food requirement of a locality was developed through participatory method in *Kuzhikany* North watershed of Kodakara Panchayath. A synthesis of wealth ranking and survey and recall method was employed. The daily requirement of food grain, vegetables, pulses and tubers for individuals of each class was found out through memory recall method. This tool can be used in any place for rapid estimation of food requirement. The requirement and production of different food items in the above panchayath was found out and considerable difference was noted. The major policy implications of the findings of the study include reorientation of agricultural development planning on the basis of location specific food requirement, intensification of household production of vegetables and tubers, formulation of exclusive programmes for food security, standardizing the procedure for leasing out land in a participatory mode, and mediating the process of leasing out private paddy lands for food production. LSGIs should facilitate gender sensitive farm mechanization for CBOs to operate effectively in food security programmes and organise focused and customized programmes for building awareness on food security for all the stake holders.

6. **Specifications of an integrated information system for micro level planning in agriculture: a user-centered analysis - Ph.D**

The study tried to characterize the legacy databases and types of information used for this purpose, with focus on availability and completeness of data. Alongside, the study attempted to evolve a typology of information and development databases required for micro level planning. Specifications regarding the content and hierarchy of an 'Integrated Information System for Micro Level Planning in Agriculture' was also formulated.

Analysis of the socio economic and psychological profile of respondents and their perception on efficacy of micro level planning was also attempted. Comparison of the perception on efficacy of micro level planning, which included four dimensions such as planning, participation, implementation and impact, showed that 'planning' was perceived as the most important dimension by Extension Personnel and 'participation' was perceived as the most important by People's Representatives. Analysis of the perception on efficacy of legacy databases which included four dimensions viz., completeness, adequacy, reliability and updatability showed that 'reliability' was perceived as the most important dimension by both Extension Personnel and People's Representatives. Perception on the proposed Integrated Information System for Micro Level Planning in Agriculture was studied under four dimensions viz., comprehensiveness, usability, updatability and spatial and temporal orientation. Both the groups perceived 'usability' as the most important dimension. Scores on the awareness of stakeholders on rural databases and information systems showed that 75 per cent of the respondents were in medium category. The information items required for micro level planning were identified and grouped into 16 categories viz. land, water, soil, climate, demographic characteristics, socio-economic characteristics, crops, technology, infrastructure, mechanization, institutions, market, government policies, government programmes for agricultural development, project monitoring and existing perspective plans. The overall information requirement of stakeholders in micro level planning showed that information on government policies was the most needed and valuable data, followed by data on government programmes and data on project monitoring. The

different stakeholder institutions involved in micro level planning mechanism were identified and the data support provided by them was explored. Soil Survey Department, Land Use Board and Village Office were found to provide pertinent data for micro level planning. With regards to constraints, Extension Personnel and People's Representatives identified lack of proper mechanisms for regular updation of data as the most severe constraint. The study also proposed a conceptual model for an Integrated Information System for Micro Level Planning in Agriculture.

# Project Coordination Group - Sugar crops and Tuber crops (17)

**Project Coordinator - Dr. Sheeba Rebecca Issac**

**Concluded Projects: 4**

**Ongoing Projects: 26**

## Concluded projects

### 1. Performance of cassava varieties in lowlands

An experiment to evaluate the performance of released and local varieties of cassava in lowlands was conducted in the Instructional farm, CoA Vellayani during 2015-16. It was laid out in RBD with eight varieties of cassava replicated thrice. The varieties differed significantly with respect to their effect on growth attributes, yield attributes and tuber yield. The highest tuber yield was recorded by the popular local variety *Kochangathalayan* (48.47 t $ha^{-1}$) which was on par with another local variety *Kantharipadarpan* (41.89 t $ha^{-1}$), Sree Vijaya (40.32 t $ha^{-1}$ ), Sree Jaya (36.38 t $ha^{-1}$ ) and Vellayani Hraswa (36.13 t $ha^{-1}$) indicating the suitability of these varieties for cultivation in the lowlands. The yield attributes and economics of cultivation also followed, a similar trend conforming the above finding.

### 2. Weed management in cassava (*Manihot esculenta* Crantz)

The study to develop an effective weed management strategy for cassava was carried out in Agronomy farm attached to the Department of Agronomy, College of Horticulture, Vellanikkara from May to October 2015. The treatments included applications of three pre emergence herbicides *viz.*, oxyfluorfen @ 0.2 kg/ha, pendimethalin @ 1.5 kg/ha and imazethapyr @ 80g/ha, directed application of glyphosate @ 0.8 kg/ha at 30 Days After Planting ($T_1$-$T_4$), all the four herbicide applications were followed by one hoeing and earthing up at 60 DAP, hoeing and earthing up twice at 30 and 60 DAP ($T_5$-$T_8$), concurrent growing of fodder cowpea ($T_9$) and *in situ* green manuring and earthing up at 60 DAP ($T_{10}$), and an unweeded control plot. The results suggest the possibility of reducing the number of earthing up in cassava by applying a pre emergence herbicide – pendimethalin. Pre emergent application of pendimethalin @ 1.5 kg/ha followed by earthing up showed highest BC ratio followed by oxyflourfen (@ 0.2 kg/ha)

### 3. Tillage and nutrition for productivity enhancement in Tannia (*Xanthomonas sagittifolious* (L). Schott)

The experiment was laid out in split plot design with 4 tillage systems as main plot and combinations of 3 soil conditioners and 2 nutrient management practices as sub plot treatments in 4 replications during 2014-15 and 2015-16. The experiment proved that deep tillage to a depth of 30 cm followed by pit system of planting under organic nutrition (FYM @ 37.5 t $ha^{-1}$ + wood ash @ 2 t $ha^{-1}$ ) could be recommended for economic production of tannia. Wherever coir pith and rice husk are available at cheaper rates, they can be applied @ 500g $plant^{-1}$ as soil conditioner.

### 4. Standardisation of agronomic techniques for minisett cultivation of elephant foot yam (*Amorphophallus paeoniifolius* Dennst. Nicolson)

The objective of the project was to standardize the spacing and nutrient management package for *Amorphophallus* raised from minisetts under pure crop and intercrop situations in homesteads and to assess the response of minisetts to organic nutrition. Adopting a wider spacing of 60 cm x 60 cm and an NPK dose of 80:40: 120 kg/ha was found to be the most ideal in terms of yield and profits for pure crop of minisett elephant foot yam. As intercrop in banana, the lower dose was found to yield highest but was on par with the organically managed crop in the lowland.

Among nutrient sources used intercropping, although 100 per cent organic nutrition recorded higher yields, it was on par with 50% and 75% RDN substitution with organic sources. Considering the economics, 50% and 75% RDN substitution with organic sources would be better option unless the organic manures are produced *insitu*.

## Ongoing projects

1. **Agronomic performance of elite sugarcane genotypes**

   In the case of early varieties, the germination percentage and tiller count were influenced significantly by the various genotypes and the highest values for the aforesaid parameters were recorded by CoC 671 followed by Co 10005. With regard to mid late varieties, both growth and yield parameters were influenced significantly by the genotypes and the highest values for cane length, cane girth, single cane weight, MCC, cane yield and sugar yield were recorded by Co10015.

2. **Impact of integrated application of organics and inorganics in improving soil health and sugarcane productivity**

   Among the various treatments, $T_8$ (FYM/compost @ 10 t/ha + biofertilizer (Azotobacter/Acetobacter+PSB) +100 RDF) recorded significantly higher values for cane length, MCC *etc* and resulted in maximum yield in plant crop as well as in ratoon.

3. **Use of plant growth regulators (PGRs) for enhanced yield and quality of sugarcane**

   The highest germination percentage, tiller population, maximum cane length, MCC and sugar yield were recorded by $T_8$ ($T_4$ +$GA_3$ spray (35ppm) at 90,120 and 150 DAP) and the lowest value for the above parameters were recorded by $T_2$ (planting of setts after overnight soaking in water).

4. **Scheduling irrigation with mulch under different sugarcane planting methods**

   The maximum cane length, cane girth, single cane weight, MCC, cane yield and sugar yield were recorded by $P_4$ (furrow planting at 120 cm spacing with alternate skip furrow irrigation after earthing up + green manure/brown mulching and was found significantly superior to other planting methods/ mulch practices. With respect to irrigation scheduling, the highest value for cane length, cane girth, MCC, cane yield and sugar yield were recorded by $I_3$ (IW/CPE ratio - 1.00)

5. **Identification of pathotypes of red rot pathogen**

   The isolates Cf 92012 (Kanjanur), CfPI 1110 (Mathakadi) and CfPI 1110 (Kothangudi) exhibited a variable and more virulent reaction than the standard isolate CF06 with respect to Co7805, CoS 767 and Co 7717 respectively during the current year.

6. **Evaluation of zonal varieties for resistance to red rot**

   Varieties which showed either Resistant (R) or Moderately Resistant (MR) reactions to red rot are

   **IVT Early:** Co13002, CoSnk13101, MS 13081, Co13003, Co13004, CoN 13072

**IVT Mid late :** Co 13005, Co 13009, Co 13011, Co 13013, PI 13132, CoSnk13104, CoM 13082, CoT 13366, Co 13008, CoN 13073, CoN 13074, Co 13014, CoSnk13105, CoSnk13106, Co 13020

**AVT Early I:** Co 11001, Co 11004, CoM 11081

**AVT Early II:** Co 11001, Co 11004, CoM 11081, Co 10004, Co 10005, Co 10006, Co 10027

**AVT Mid late I:** Co 11005, Co 11007, Co 11012, CoM 11086 and Co 11019

**AVT Mid late II:** PI 10131, CoVC10061, Co 09009, Co 10015, Co 10017, Co 10031, Co 10033, CoT 10368, CoT 10369, CoVC10061

## 7. Survey of sugarcane diseases naturally occurring in the area on important sugarcane varieties

(**1**) **Pokkah Boeng**: Common disease in most of the cultivated varieties during south west monsoon period (May – June). Stunting of plants along with twisting and yellowing symptom in younger leaves and the infected young leaves get converted to twine like structure and tied to main shoot. But all the affected plants were recovered after the monsoon showers.

**(2) Sheath blight:** Sheath blight symptoms on leaves and leaf sheath due to *Rhizoctonia solani* was observed in the entire experimental field during May – June. Sclerotia of *Rhizoctonia solani* were also produced in the field. Proper field sanitation and detrashing at regular interval for two to three times reduced the incidence of this disease.

**(3) Ring spot:** The most common and predominant foliar disease observed even from two months till harvest. Proper field sanitation and detrashing at regular interval for two to three times reduced the incidence of this disease.

**(4) Rust:** Observed during August – September. Uredospores were observed as light orange pustules on leaf lamina during the month of August. The teliospores were observed as black raised pustules during September. Severely affected leaves got dried up. But the disease subsided with the onset of North East monsoon showers.

**(5) Mosaic:** Mosaic was seen commonly in most of the crop varieties, but the disease was not in such a stage to cause any severe yield reduction.

**(6) Grassy shoot:** This disease was not observed commonly.

## 8. Initial Varietal Trial – Early

Promising genotypes were MS 13081, Co 13003, Co 13002 and CoSnk 13101

9. **Advanced Varietal Trial (Early) – I Plant**

Promising genotypes were Co 11004, Co 11001, CoM 11082 and CoM 11084

10. **Advanced Varietal Trial (Early) – II Plant and Ratoon**

**a. Advanced Varietal Trial (Early) – II Plant**

Promising genotypes were Co 10004, CoT 10367, Co 10005, CoT 10366, CoT 10367, Co 10027, Co 10006 and Co 10004

**b. Advanced Varietal Trial (Early) – Ratoon**

Promising genotypes were Co 10026, CoT 10367, Co 10005, Co 10027, Co 10006 and Co 10004

11. **Initial Varietal Trial – Midlate**

Promising genotypes were Co 13016, Co 13006, PI 13131, Co 13008, PI 13132 and CoT 13366

12. **Advanced Varietal Trial (Midlate) – I Plant**

Promising genotypes were CoM 11086, CoM 11085, Co 11012, Co 11007 and Co 11019

13. **Advanced Varietal Trial (Midlate) – II Plant and Ratoon**

**a. Advanced Varietal Trial (Midlate) – II Plant**

Promising genotypes were Co 09009, CoVC 10061, CoT 10369, Co 10015 and PI 10131

**b. Advanced Varietal Trial (Midlate) – Ratoon**

Promising genotypes were Co 10017, Co 10031, Co 09009, CoT 10369, CoVC 10061 and PI 10131

14. **Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2005 series and 2007 series**

Ratooned nine cultures from 2005 series viz., 96/05, 98/05, 113/05, 131/05, 171/05, 177/05, 182/05, 195/05 and 219/05 along with five cultures from 2007 series viz., 27/07, 79/07, 202/07, 218/07 and 294/07

15. **Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2008 series**

Ratooned 14 cultures under initial evaluation trial

16. **Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2009 series**

Ratooned 10 cultures under initial evaluation trial

17. **Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2011 series**

Ratooned 36 cultures under clonal multiplication and evaluation

18. **Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2012 series**

Ratooned 103 cultures under clonal multiplication and evaluation.

19. **Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2013 series**

    Ratooned 115 seedlings under progeny row trial.

20. **Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2014 series**

    Ratooned 2639 seedling transplanted to main field

21. **Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2015 series**

    Ratooned 6841 seedlings belong to 52 different cross combinations.

22. **Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2016 series**

    Raised 3941 seedlings

23. **Performance of improved short duration tapioca varieties under different population densities in flood prone upper Kuttanad area**

    Based on the results of farm trials, it was concluded that a spacing of 75 cm x 75 cm was most suitable for getting maximum tuber yield in short duration varieties. The local variety (*Vettikavala Local*) responded well to different spacing and it has recorded the highest tuber yield (595 t $ha^{-1}$) followed by the variety Sree Jaya (4601 t $ha^{-1}$) .The promising variety *Vettikkavala Local* is under consideration of the State Variety Release Committee for regional release with the name KAU UTHAMA.

24. **Exploitation of under-utilized root and tuber crops for food and nutritional security**

    Field trial demonstrating the influence of INM and organic nutrition in West Indian arrowroot was laid out in farmers' field at Vellayani.

25. **Weed management in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]-PG**

    The experiment was envisaged to investigate the effect of frequency of weeding through various means on growth and yield of elephant foot yam and was completed in December 2016. The data have been tabulated and statistical analysis are in progress.

26. **Agronomic package for container grown elephant foot yam -PG**

    Corms of elephant foot yam were planted in different growth media under various nutrient and irrigation schedules as per technical programme. The crop was harvested in December and chemical analysis are in progress.

# Faculty – Agricultural Engineering

# Project Coordination Group - Farm Power Machinery and Energy (FPME) (01)

## Project Coordinator - Dr. V. R. Ramachandran

**Concluded Projects: 14**

**Ongoing Projects: 3**

## Concluded Projects

1. **Development of a bio-fungicide applicator attachment for four wheeled riding type rice transplanter – AICRP on Onfarm Implements and Machinery**

   Design and fabrication of the attachment was done. It had a diaphragm pump powered by the 12V DC from the battery of the transplanter had a discharge of 2.31 l/min. LDPE tubes of 12 mm and connectors were used to connect the nozzles. The span of each nozzle was 35 cm and for covering 180 cm, five nozzles were used. Testing of the bio-fungicide applicator was conducted and obtained an application rate of 12.5 g per litre, which is satisfactory and can ensure uniform application without any additional labour cost.

2. **Prototype feasibility testing of Ridge plastering machine**

   The performance evaluation of Redlands ridge plastering machine in different soil conditions was conducted in the Kharif season of 2016 at Tavanur. It was found that the machine is useful and economical for plastering of bunds in paddy lands. But it should operate only when the moisture content of the soil was between 30-50%. Another problem was the lack of traction for the pneumatic wheels at slushy field condition.

3. **Prototype feasibility testing of Mini thresher cum winnower**

   The suitability of mini thresher cum winnower for different varieties of paddy under different moisture contents was evaluated. The thresher was conceptually suitable for small farmers. The performance with respect to labour saving is not much attractive. The cleaning efficiency was also lower compared to combine.

4. **Prototype feasibility testing of Combination implement for seeding and herbicide application for dry seeded rice**

   A refined seeder with an electrically operated herbicide spraying attachment developed at KrishiVigyan Kendra, Palakkad was tested for further refinement and popularisation. It was observed that the weed population, weeding cost, and plant population was less in combination method comparing with that of the broadcasted. The yield was higher (11%) in the plot operated with the combination implement compared to broad casted field.

5. **Prototype feasibility testing of Kerala model palm climber with safety belt**

   The safety belt to palm climber developed by the Central Plantation Research institute was tested so as to give recommendations. A full body belt with front anchor is used. The belt was attachable to the hook of a wire rope attachable to the palm trunk through the upper member of the climber. For climbing up harvesting and climbing down on a palm of about 7 m height it took less than 10 minutes. There was a slight increase in time compared to the climber without safety belt (7.5 minute), which was not insignificant when considering increased safety.

6. **Prototype feasibility testing of Tractor operated rake (windrower)**
   The tractor operated rake was assessed for its potential use in Kerala. The rake could be attached to the three point hitch of the tractor and powered from the tractor PTO (540 rpm). There were six rotating raking arms working in the clockwise direction. The machine was capable of collecting the spilled straw from 2 m width and windrows it to the left of the tractor. The side board can be adjusted so as to get the proper width of the windrow. The field capacity and field efficiency was observed as 0.833 ha per h and 83.3% respectively.

7. **Prototype feasibility testing of Pre-germinated paddy seeder attachment to Chinese 8 row rice transplanter**
   The performance evaluation of the engine powered pre-germinated seeder for rice was done at the instructional farm of KCAET, Tavanur as well as the farmers' field at Tirunavaya, Malappuram district. The attachment was driven by the transmission shaft with the help of a gearbox and chain and sprocket system. The seeds are dropped on the ridges formed by the sliding float and this improves the germination of seeds due to the easy drainage of ponded water through the small furrows created by the float. The attachment was found suitable for the farmers who prefer wet seeding. The performance with respect to labour saving was not much attractive.

8. **Assessment of ergonomic parameters of rice transplanters for women operators- PG**
   Ergonomic evaluation of existing models of three 8 row self-propelled riding type rice transplanters namely Yanmar, Redlands and Yanji was done. An anthropometric survey was conducted with 450 women agricultural workers in three zones of Kerala. The energy expenditure was minimum for Yanmar rice transplanter with a value of 9.89 kJ $min^{-1}$. The overall discomfort rate was maximum for transplanting by traditional method followed by transplanting with Yanji, Redlands and Yanmar rice transplanters.

9. **Modification and testing of tractor operated KAU banana sucker uprooting machine- PG**
   The existing hydraulically operated banana sucker uprooting machine was modified. A 55 hp tractor was used as prime mover and the field performance was assessed in two types of soil, laterite soil and clay soil. The efficiency of modified banana sucker was observed as 75% in clay soil and 80% in laterite soil. The cost of uprooting by machine was Rs. 22930 per ha. The cost and time saved over manual uprooting was about 52.22% and 93.06% respectively.

10. **Investigations on energy input-output in below sea level rice production systems in Kuttanad region of Kerala- PG**
    ANN modeling was done to find out changes occurring zone wise and farm wise. Seven hundred and thirty one farmers were selected from the different agro-ecological zones of Kuttanad. The results showed that the input and output energy in Kuttanad region were about 27305.87 and 114346.90 $MJ.ha^{-1}$ respectively. The input energy for fertilizer was higher in Kuttanad region, because of the higher application rate of fertilizers above PoP recommendation. The second higher energy input was observed for electricity which can be reduced by using more efficient pumps for water management. The introduction of drum seeder can reduce the human energy input and high cost associated with it.

11. **Design, development and testing of a tractor drawn semi-automatic rhizome planters for ginger and turmeric- PG**

A tractor operated semi-automatic horizontal disc planter was developed and field tested. The rhizome planter was designed to suit various soil types and conditions to perform several functions simultaneously by opening the furrows, application of manure, and planting of rhizomes and covering of rhizomes by soil and forming ridges in single pass. The average field capacity and efficiency was observed as 0.14 ha $hr^{-1}$ and 78.76%. The savings in cost and time for mechanical planting was about 59.52% and 96.57% respectively.

12. **Development of attachments for four wheel riding type rice transplanter- PG**

The study included the agro-economic analysis of a four wheeled rice transplanter and development of transport wheels, applicator system for spraying of liquid bio-fungicides and micronutrient mixtures for four wheeled rice transplanter. Three types of four wheel riding type transplanters *viz*. Yanmar Vp8D (TR1), Yanmar Vp6D (TR2), and Kubota NSPU68C (TR3) were selected. The agro economic assessment showed that the annual fixed and variable cost and hourly operational cost was minimum for TR1, followed by TR2 and TR3 respectively. TR1 has highest field capacity (0.4 ha $h^{-1}$). A pneumatic wheel of 680 mm diameter and width of 100 mm were selected for front wheel. Rear wheel had a diameter of 720 mm and width of 130 mm. The applicator attachment had a 12 V electrically operated diaphragm pump, LDPE pipes as conduit, five solid cone nozzles fitted on a LDPE boom. The droplet size of the nozzle at a height of 50 cm was in the range of 200-300 microns.

13. **Design and development of a lime applicator attachment to tractor operated rotavator- PG**

A rear mounted lime applicator attachment to a tractor drawn rotavator was designed and developed for basal application of lime in paddy fields. The major components of the lime applicator attachment were hopper, metering mechanism, lime discharge chute, agitator and sprockets and chain with box assembly. The trapezoidal hopper was made up of galvanized iron sheet folded in 54°having dimension of 1600 × 460 × 340 mm. Single shaft baffle type metering mechanism with drive taking from the rotavator was used to metering lime. The rate of application of lime of 335 - 360 kg $ha^{-1}$ was obtained. Fuel consumption was 3.7 $l h^{-1}$ and 26 $l ha^{-1}$. Actual field capacity, theoretical field capacity and field efficiency were calculated as0.33 $hah^{-1}$, 0.39ha $h^{-1}$ and 84 per cent respectively. Cost of operation of the proto type lime applicator as an attachment to tractor drawn rotavator was found as567.15 Rs $h^{-1}$ and 1718.63 Rs $ha^{-1}$ and manual lime application followed by tractor ploughingwas627.12 Rs $h^{-1}$and 1985.21 Rs $ha^{-1}$. A cost saving of 59.97 Rs $h^{-1}$and 266.58 Rs $ha^{-1}$ with proto type lime applicator over manual lime application followed by tractor ploughing was observed. Also, a time saving of 2 h $ha^{-1}$ over the manual lime application followed by tractor ploughing was achieved with proto type lime applicator attachment.

14. **Investigations on clamping and climbing mechanisms for the design of a semi-autonomous areca palm climber- PG**

The biometric properties of the palm viz. diameter, variation of diameter along height, height and tilt angle were identified as the critical properties which has direct influence on design and operations. The designed climber had two components viz. a gripping unit, to provide to and fro

motion to the gripping arms and so that the arms grab the tree; a climbing unit which provide up and down movement to effect climbing. During climbing, a part of the robot was fixed to the tree trunk. The robotic operation was controlled by a wired remote controller. The device was suitable for the palms having diameter of 12-30 cm. The prototype will climb 15-20 cm in each step and capable of carrying about 500 gm weight without failure. The device was tested for its performance and found safe, reliable, and efficient.

**Ongoing Research Projects**

1. Computer aided analysis of sit and stand type coconut climbers for mechanical stability
2. Design analysis of KAU pokkali paddy harvester towards the development of its scale down prototype
3. Investigations on design parameters for the development of a pineapple harvester

# Project Coordination Group –

# Soil and Water Engineering (02)

**Project Coordinator - Dr. K. P Visalakshi**

**Concluded Projects: 14**

**Ongoing Projects: 3**

## Concluded Projects

1. **Establishment of a Nodal Water Technology Centre for Development and Co-ordination of Water management Research for Better Water Productivity in Kerala- State Plan**

   A Nodal Water Technology Centre could be established in Kerala Agricultural University at its main campus, Vellanikkara to undertake research in water management and allied areas. A recharge pond of 6.5 Lakh litre capacity and a roof top rainwater harvesting unit of 20,000 litre capacity were constructed at the Centre. Ground model of a typical watershed was constructed with various types of agronomic and engineering measures of soil and water conservation. A drip automation unit was installed and a test bench for flow measuring devices such as Parshall flume, V-notch, rectangular weir, trapezoidal weir, circular orifice etc. were constructed. The research results of drip irrigation for upland rice will be useful for farmers in growing rice for own consumption in their homesteads with limited water resources. Totally 14 nos. of training programmes were conducted for 561 stake holders including farmers and students and 7 nos. of research papers were published including National and International journal papers, popular articles and booklets.

2. **Measures for natural resource management at KCAET Campus-Phase I- State Plan**

   In KCAET, all the important buildings in and around the main academic block have been provided recharge facility with percolation ponds of rectangular and circular shapes with plan areas ranging from 2 to 12 $m^2$ and depths 1.5 to 2.5 m. Recharge pits were also provided for academic buildings, labs, men's hostel, foot ball ground and for some of the residential buildings in the campus. The overall quantity of annual recharge through these measures would come to about 15000 $m^3$. Water table fluctuation was studied and it was found that corresponding to 10 cm rainfall, the rise in water level in the neighbouring open wells was more than 2.0 m. Construction of two lined ponds has been completed under the project in the P-Block of KCAET. Pond I has a dimension of 39x19x6.5m with a capacity of 4500$m^3$. Lining of the pond has been done with PVC coated nylon film of grade 630 GSM (Grams per Square Metre). Pond II has a size of 33x17x7.75 m with a capacity of 4300 $m^3$. Total capacity of pond I and II would come to 8800 $m^3$. An area of about 7-8 acres of upland crops and plant nursery can be irrigated and cleaning of dairy sheds of the KCAET instructional farm can be done by making use of gravity head. Huge quantity of groundwater withdrawal can be avoided and electrical energy can be saved through these water harvesting measures

Fig.1. Percolation pond at KCAET campus

Fig.2. Lined pond I with water

**Projects under Precision Farming Development Centre, KCAET, Tavanur, funded by NCPAH:-**

3. **Standardization of irrigation and fertigation requirement of Bitter gourd (*Preeti*) under rain shelter.**

   The experiment started in September 2015. Irrigation with 80% of the ETc and fertigation with 120% of KAU adhoc recommendation (N: P: K = 84:30:30 kg/ha) gave highest yield and best performance.

4. **Standardization of irrigation and fertigation requirement of Bottle gourd (*Arka bahar*) under rain shelter**.

   The experiment started in September 2015. Best crop performance was obtained for irrigation with 80% of the ETc and fertigation with 100% of KAU adhoc recommendation (N: P: K = 70:25:25 kg/ha).

5. **Standardization of irrigation and fertigation requirement of Chilli (*Ujwala*) under rain shelter.**

   The experiment started in June 2016. Best crop performance was obtained at irrigation with 60% of the ETc and fertigation requirement of Chilli under rain shelter could not be standardized because of pest attack on the crop.

6. **Pot culture study for analyzing quality of organic filtrates and evaluating their effects on soil properties and plant growth- AICRP on Irrigation Water Management.**

   Application of vermin compost filtrate along with 50 per cent fertilizer has recorded the highest yield and water use efficiency in Bhindi. Economic analysis of the various treatments revealed that among the two manures tried, cow dung was cheaper than Vermicompost. Even though treatments with Vermicompost and its filtrate gave more yield and gross return than cow dung treatments, less net return and B: C ratio was obtained due to the higher cost of Vermicompost. Microbial status and organic carbon content of soil after the experiment was increased or not affected by the treatments.

Fig 3. Organic fertigation unit

7. **Impact of climate change and watershed development on river basin hydrology using SWAT – a case study- PG**

   The study analyses the changes in the hydrology of Bharathapuzha river basin of Kerala. The trend analysis of historic climate data using Mann-Kendall and T-test showed that the mean, maximum and minimum temperatures during 1951-2013 showed a significant increasing trend at the rate of 0.07°C/decade, 0.14°C/decade and 0.04°C/decade respectively. Trend analysis of gridded rainfall data for the period 1971-2005 showed statistically significant decreasing trend, at the rate of 15 mm/year.GFDL-CM3 RCM model data was used and two emission scenarios RCP4.5 and RCP8.5 and two scenario periods 2041-70 and 2071-99 were selected for the study. It is predicted that there will be a decrease of 4 to 7 per cent in average annual rainfall during 2041-70 compared to the present day average values, whereas the decrease will be up to 10 to 15 per cent during 2071-99. Soil and Water Assessment Tool (SWAT) model was used to simulate surface runoff and soil erosion and the model predicts 15 to 20 per cent decrease in stream flow by the end of the century if the worst situation of climate change continues (RCP8.5). ET ranges from 15 to 22 per cent of the annual rainfall in the current scenario, while it may increase to 29 to 32 per cent in the RCP4.5 scenario and 32 to 35 per cent in RCP8.5 scenario. During 2046-2070, the annual sediment loss goes up to 7 to 9 t/ha, from the present condition of 2.5 to 4 t/ha.

8. **Design and evaluation of horizontal filter unit for groundwater recharge through abandoned tube well - PG**

   The study was conducted in the research field of Nodal Water Technology Centre, College of Horticulture, Vellanikkara to design and evaluate a filter unit for the abandoned tube well. A masonry structure with a filter unit for treating runoff was constructed. The filter unit had five compartments filled with gravel, sand, charcoal, synthetic fibre and coir fibre combinations as treatments. Three sets of media combinations and three sets of length variations in media were selected for testing the efficacy of filter. Inflow and outflow water quality was tested. The combination T1F1 (Gravel, Sand, Coir fibre and Gravel) each arranged with the same length of 80 cm was found better in pH normalizing efficiency. The Gravel (80 cm), Charcoal (100cm), Sand (60cm) and Gravel (80cm) combination was selected as the best filter media.

9. **Assessment of evapotranspiration models for the humid tropical region of Tavanur- PG**

The reference crop evapotranspiration (ETo) was estimated by using ten empirical models which are widely used in Indian conditions *viz,* Thornth waite (1948), Hargreaves *et al.*, (1985), Turc (1961), Christiansen (1968) Pan Evaporation, FAO-24 Blaney-Criddle (1977), FAO-24 Modified Penman (1977), FAO-24 Open Pan (1977), Priestly-Taylor, Makkinik and FAO-56 Penman-Monteith (1991).The accuracy of these models were evaluated by comparing with FAO-56 Penman-Monteith model using six years monthly average meteorological data for the period January 2011 to December 2016 and validated with lysimetric data. The Modified Penman model gave the best performance with $R^2$ of 0.96 with RMSE 3.95 and Rel RMSE 1.22 followed by Hargreaves model. It was concluded that Hargreaves (HAM), Open Pan (OPM) and Christiansen (CHM) models were in close agreement with lysimetric data and hence these models were suggested for use in this humid tropical region. Relationships were developed between these empirical model outputs and the lysimetric data (LYM).

10. **Assessment of the impact of sand mining on the morphology of the severely affected reach of Bharathapuzha river between Pattambi and Kuttippuram using remote sensing and GIS - PG**

The study was undertaken to assess the morphological changes as well as the spatial and temporal variations along the reach due to sand mining. DEM imageries were utilised to evaluate the effect of sand mining on the morphology of the river reach by analysing the cross-sectional details. LANDSAT imageries were used to analyse the spatial and temporal variations of channel in the reach and analysis was carried out using the ArcGIS 10.5 software. The Elevation Profile add-in toolbar was utilised to create profile graphs by taking sections across the river course in ArcGIS and the morphological changes of the river were calculated by comparing the cross-section profiles. The spatial and temporal variations in river morphology were analysed by extracting the bank lines using Normalized Difference Water Index (NDWI) and overlaying the extracted bank lines. The study revealed that the impact of sand mining was high at areas closer to Kuttippuram. Channel enlargement in the reach was found to be varying from 0.52 - 8.43 m/year. The reach experienced an average rate of change in width of 0.28 m/ year. The shift in bank lines indicated the drifting of the river direction towards the north.

11. **Development and evaluation of a Solar Powered Automated Fertigation system- PG**

The study was undertaken to develop and evaluate the performance of a timer based automated fertigation system using an FIP. Field evaluation was carried out by growing salad cucumber variety 'Saniya' in grow bags inside a poly house located at Agricultural Research Station, Anakkayam. A comparative evaluation was carried out between biometric observations and yield parameters of the two sets of crop grown inside the polyhouse, one fertigated automatically and the other one with manual fertilizer application and a third group of plants grown in the open field with manual fertilizer application. The main crop growth parameters like height of the plant, days to first flowering, days to 50 percentage flowering, days to initial budding, days to first harvest and leaf area index and yield parameters *viz*. size of the fruit, number of fruits harvested per plant and average yield were recorded during the study. Values were found to be

better for the crops grown inside the polyhouse with automated fertigation compared to the other two. The developed system operates using solar panel generating a power of 250 W on an average along with a battery, which makes the system operations possible up to 4.4 days without sunshine.

**12. Hydrologic assessment of a small watershed to combat agricultural drought- PG**

In this study, the hydrology of Valanchery watershed, a small sub watershed of Bharathapuzha, was modelled using SWAT model. The study aims to calibrate the model, simulate the hydrologic elements and stream flow and to suggest remedies to combat the water scarcity in the study area. As the watershed selected for the study was ungauged, the model was calibrated for Kunthipuzha basin which lies in the immediate neighbourhood and having similar characteristics with the study area. Using the daily observed stream flow at Pulamanthole gauging station, the model was calibrated and validated. The calibration and validation periods were respectively, 2000 to 2007 and 2007 to 2009. An NSE = 0.81 and $R^2$ = 0.82 was obtained for calibration an NSE of 0.82 and $R^2$ = 0.95 was received for validation. With these calibrated parameters, the model was set up and run for the Valanchery watershed using regionalization technique. It was found that the characteristics and hydrologic process elements such as surface runoff, lateral flow, deep percolation, base flow and ET of the various sub watersheds were varying considerably.

**13. Comparative evaluation of naturally ventilated polyhouse and rain shelter on the performance of tomato- PG**

The study was conducted in the Instructional Farm of KCAET, Tavanur, during the period December 2016 to April 2017 to compare the performance of tomato variety Akshaya grown under polyhouse and rain shelter cultivation. Drip irrigation and fertigation using venturi assembly was used. Among the different treatments, early flower initiation (45 days) was noted in the polyhouse and late flower initiation (49 days) in rain shelter. Number of fruits per plant was maximum under rain shelter than naturally ventilated polyhouse at all the growing stages of the plant growth. The total yield of tomato recorded from polyhouse and rain shelter were 1.31 kg/$m^2$ and 4.15 kg/$m^2$ respectively. Quality parameters of tomato under naturally ventilated polyhouse showed a higher shelf life (9 days) than rain shelter (7 days) and TSS content of tomato under the polyhouse was found as 4.56 $^0$B and rainshelter was found as 4.0 $^0$B. The maximum benefit cost ratio of 2.14 was noted in rain shelter. From the results of the study it was evident that growing of tomato inside the rain shelter is more profitable than inside naturally ventilated polyhouse.

**14. Development of an automatic cleaning mechanism for roof water harvesting- PG**

A study has been taken up to improve the filtration efficiency and incorporate an automated drain cum back washing mechanism for the upward flow filter system. The study also included the performance evaluation of a first flush system when attached to the inlet side of the micro mesh filter. The inflow and outflow of the rooftop water samples were analysed for pH, EC, TDS, SAL and TSS parameters. In general, the PH, electrical conductivity, and TDS of the roof water samples were within the drinking water standards and the filter system was found to reduce TDS values. In the case of TSS, mostly the impurities were organic in nature and

concentration varied between 220 to 280 mg/l, a level much higher than WHO and BIS standards. The 3 micron mesh filter was removing 100% of the organic TSS impurities. The filtration rate of this filter was about 0.37 lps at a hydraulic head of 1.5 m and hence suites to rooftop rain water harvesting. First flush system showed better cleaning efficiency when attached to the inlet side of the coarser micro mesh filters. Automatic flush developed for the removal of stagnant water with impurities were performing well by removing all the stagnant water and about 92 % of the impurities. It can be concluded that 3 micron mesh filter with automatic flush can function as a near fool proof mechanism for filtering rooftop rain water.

## Ongoing Projects

1. **Study on structural design and management of Hi-Tech Horticulture in Kerala- Dept. of Agri.**

   In this project, detailed studies are going on at hi-tech research station, IF, Vellanikkara; with various crops in different shape of greenhouse, different combination of sheet, different color of shade net, different types of structures etc. Screening/ evaluation of vegetables suited for Kerala under protected structures by noting growth and yield characteristics and economic viability are also going on. Studies are progressing in six number of hydroponics units (NFT) and two number of dutch bucket systems to select suitable crops, optimum water quality parameters to be maintained in NFT while cultivating vegetable crops and to evaluate the balanced nutrient mix developed at HTR&TU. Two more units of family Aquaponics system with NFT, DWC and media bed system was constructed. A solar system has been installed to ensure smooth operation of Aquaponics and hydroponics system. EC level required for various crops like tomato, salad cucumber, chilly, tomato, capsicum and leafy vegetables at different stages in substrate cultivation were standardized and still studies are progressing. Improvements in Multitier grow bag with composting facility has been done. A final model of polykitchen garden has been developed and improvements were introduced in this aspect. The final specification of polyhouse and polykitchen garden based on the studies conducted has been given to funding agency for popularization among the public. Recommendations to farmers based on the study conducted at the centre have also been given to funding agency on nutritional aspects, bed preparation, variety selection, soilless cultivation etc.

2. **Development and testing of Organic Fertigation unit with power operated agitator - AICRP on Irrigation Water Management**

   Organic fertigation unit with hand operated agitator was developed and tested for its performance. A power operated agitator was fabricated. Nutrient analysis of agitated manure solution, filtrate, residue etc is going on. Hand operated agitator was found effective in agitating the organic manures and the experiment is in progress.

## 3. Development of a suitable filtering technique for reusing household waste water for irrigation- AICRP on Irrigation Water Management

Waste water, both kitchen and laundry waste water were collected from in and around 20 km from the station. As a preliminary study, 30 samples of each were collected and the physico-chemical parameters like pH, EC, Chloride, Carbonates, Bicarbonates and Potassium were analysed. The laboratory analysis for other parameters such as sodium, potassium, boron, calcium, magnesium, SAR, RSC were also done. Identified different filtering media (sand, bio-char and baby metal) and these were tested for optimizing the thickness required for removing impurities from waste water. Quality parameters of filtered water were tested. Analytical results showed that laundry waste water contained chlorides and bicarbonates in high amount are making the water moderately suitable/ unsuitable. But in kitchen waste water all the parameters tested were found to be within the limits and water is moderately suitable/ suitable for irrigation.

# Project Coordination Group - Food & Agricultural Process Engineering (03)

**Project Coordinator - Dr. K. P. Sudheer.**

**Concluded Projects: 14**

**Ongoing Projects: 5**

## Concluded Projects

### 1. State Network Project- Centre of Excellence in Postharvest Technology

The center of excellence for post-harvest technology is a pioneering centre for agricultural research and development in post harvest technology. It aims in creating an effective system by enabling a start-up and growth of innovative research and for cost-attractive post-harvest technologies for agricultural commodities, particularly fruits and vegetables, spices and rice. The Center will ensure adoption of research discoveries by end users to meet their needs in diverse areas of post-harvest technologies, including quality and nutritional value, value-added processing, food safety and economic aspects. The centre of excellence has five sub centers; an 'Agri Business Incubator' at KCAET Tavanur, a 'Quality control lab facility' at College of Horticulture, Vellanikkara, 'Food Pro-mall' at RARS Pilicode, "Agri-food Entrepreneurship Development Centre" at CGSAFED, Vellanikkara, and 'Centre for Post Harvest Management and Value addition for under exploited fruits and vegetables' at COA Vellayani. The research outcomes of Centre of excellence in post - harvest technology are briefed below:

### 2. Establishment of Agri- Business Incubator Facility at KCAET Tavanur

The Agri-business Incubator (ABI) facility at KCAET Tavanur encompassing agri-market-oriented development plan that seeks to improve farmers' livelihoods through agri-business incubation. ABI provide facilities for enterprise support services component and other agribusiness information resources. The centre has provided entrepreneur support to eight processing industries (two rice mills, banana based ethnic mix, dehydrated vegetables, spice powders, thermal processed tender jack fruit, Intermediate moisture ripe banana and jack fruit, passion fruit processing. These processing industries provides a regular income to the rural youth specially women group. The ABI also conducted nearly 13 training for the potential food processing entrepreneurs.

### 3. Process protocol development for vacuum fried fruits & vegetables

The vacuum frying could be an alternative technology that involves low frying temperature and pressure, aids in reduced oil absorption in fried product and preserves the quality of frying oil. Accordingly an advanced vacuum frying system with dual chambers, oil storage and a frying chamber with de-oiling system was developed (Fig.1) to produce vacuum fried raw and ripened banana chips, and ripened jackfruit chips. The developed vacuum frying system was a batch type with product capacity of 12 kg/h and frying oil tank capacity of 30 L. The product and oil properties were evaluated and standardisation of process parameters was done with the developed vacuum frying system. The oil blend (80:20, Rice bran: Palm oil) was identified as suitable frying oil with high oxidation and thermal stability among coconut, rice bran, palm, corn and blended oils. The effective de-oiling was attained with removal of 74.1 and 71.4% oil, respectively, in VF-raw and VF-ripe at post centrifugation of 1000 rpm for 5 min. The vacuum frying with de-oiling nullified the effect of pre-treatments like blanching cum drying, freezing and gum coating for the production of VF-raw and VF-ripe. The freezing pre-treatment was found to be effective in case of ripe jackfruit chips. However the quality of untreated and pre-treated samples were on par for banana chips. The quality parameters like oil content, moisture content, energy, texture, bulk density, true density, colour values, thickness expansion and

sensory acceptability of vacuum fried jackfruit chips, raw and ripened banana chips was evaluated at different processing conditions. The vacuum fried ripened banana chips processed at 105°C for 13 min, packed in 400 gauge LDPE with nitrogen flushed packaging showed good consumer acceptability upto ninety days of storage. The production cost formulated based on fixed and variable cost for 1 kg of vacuum fried raw and ripened banana chips was Rs.342/kg and Rs.363/kg.

**Fig.1 Vacuum frying system**

4. **Development and quality evaluation of Retort pouch packed tender jackfruit (*Artocarpus heterophyllus L.)***

'Koozha' jackfruit can be better used in tender stage as the wastage of ripened 'Koozha' variety jackfruit is more compared to 'Varikka'. The significant wastage of 'Koozha' variety is because of less consumer acceptance due to its poor texture after ripening, necessitated the design of a viable processing and packaging technology to extend its shelf life. Hence the present study on "Development and quality evaluation of retort pouch packed tender jackfruit (*Artocarpus heterophyllus* L.)" was undertaken with specific objectives of standardization of blanching process, standardization of thermal process in retort pouch package, shelf life study and quality evaluation of retort pouch packed tender jackfruit. Blanching treatment was optimized as three minutes with 0.3% citric acid preservative based on the enzyme test and the results of the quality parameters like texture, colour and crude fibre content. The standardized thermal process time for pasteurization at 90°C to reach F was 24 minutes and for sterilization at 121°C for attaining F010 value one was 15 minutes. After optimal blanching, the samples were packed in retort pouches with prior addition of preservatives like brine (2%), citric acid (0.3%), KMS (0.1%) and their combination using the optimized thermal process time - temperature. Shelf life study and quality evaluation in terms of TSS, titrable acidity, pH, vitamin C, crude fibre, texture and colour were done. The experiments were statistically analyzed with one way ANOVA. The samples preserved in citric acid exhibited good quality attributes and better acceptability in sensory evaluation. Microbial analysis also showed that the product was safe upto 90 days of storage. It was concluded that 0.3% citric acid blanching and 0.3% citric acid preservative as filling solution was best in terms of quality parameters and microbial analysis for the development of

thermally processed and retort packed tender jackfruit. The cost of operation per pouch (140 g) for tender jackfruit was calculated as Rs.12/-. This study is useful for the production of good quality, safe, affordable priced tender jackfruit in ready to cook form throughout the year.

5. **Development of Tuber Fortified Cold Extruded Pasta Products**

The present study on influence of millet and yam blend on cooking qualities and storage of pasta prepared from composite flour of ragi, corn, atta, elephant yam, purple yam and drumstick in six different combinations and proportions. The quality parameters *viz*. cooking properties (cooking time, swelling power, solid loss and water absorption ratio), physical properties (expansion ratio and bulk density) and engineering properties (colour and texture) for various pasta products were determined. Incorporation of tuber and ragi flour resulted in increased cooking qualities. Developed pasta products were packed in 400 gauge LDPE and kept for six months storage studies at ambient atmospheric conditions. Results of present study reveals that, storage period had insignificant effect on cooking properties of pasta products. Sensory evaluation on a nine point hedonic scale showed that the treatment with Ragi (25%): Corn(20%): Atta (25%): Elephant yam (10%): Purple yam(15%): Drumstick (3%): and Guar gum (2%), as a best combination out of all treatment combinations under concern. Based on optimization and sensory evaluation, this treatment was selected as the best combination out of all combinations under concern with a shelf life of six months.

6. **Development and quality evaluation of millet fortified tuber based extruded RTE**

The quality parameters *viz*. physical properties (moisture content, expansion ratio, bulk density, true density, porosity and water activity), functional properties (water solubility index and water absorption index), colour and textural properties for various RTE extruded products were determined. The extruded products were stored in a 400 gauge aluminium pouches in replicated kits and the active MAP was done with nitrogen flushing. The quality parameters (moisture content, water activity, colour and textural properties) of developed RTE extruded products were analysed up to three months with an interval of one month during storage. In order to get market acceptability, a treatment combination with maximum expansion, maximum colour value and crispness, minimum moisture content, bulk density and minimum hardness was selected as ideal one. Under these criteria, the treatment combination with, Corn (60%): Elephant yam (15%): Purple yam (20%): and Drumstick (5%) was found as optimum. Based on optimization and sensory evaluation, this combination was selected as the best combination out of all combinations under concern.

7. **Development and performance evaluation of a blancher cum dryer for fruits and vegetables**

In the present study a combined blancher- cum-drier (Fig.2) was developed and its performance was evaluated for matured jackfruit drying. Drying along with steam blanching significantly retains the nutritional qualities, reduces enzymatic activity, moisture content and drying rates. The new blancher cum dryer was fabricated with a volume of 2.052 $m^3$, with twelve trays. Performance was evaluated with matured jackfruit slices at three different loading rates viz; 3.8, 4.8 and 5.8 $kg/m^2$ at various temperatures. In the developed unit about 7 min of blanching time was required to inactivate the enzymes. Sensory evaluation revealed that the sample dried with 4.8 $kg/m^2$ loading capacity at 60°C drying temperature for 450 min found to be more

economical. The newly developed blancher- cum- drier is a promising equipment to small and medium scale processing industries to reduce the space, process time, and energy.

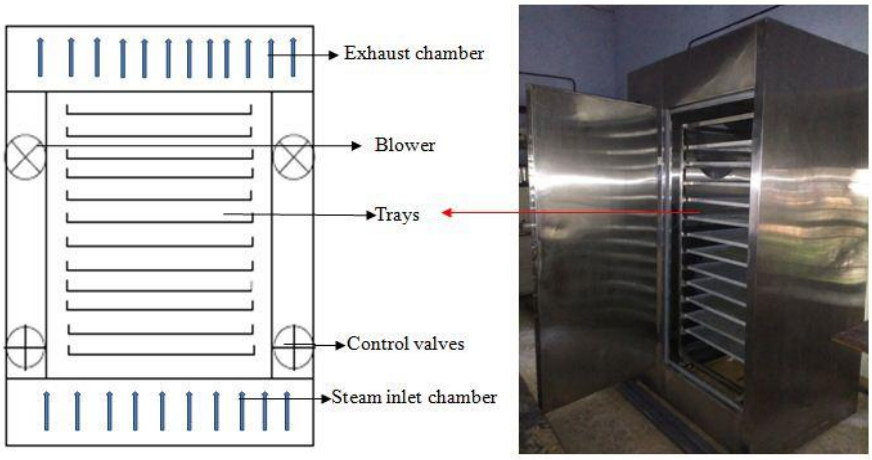


**Fig.2 Blancher cum drier**

## 8. Development and Evaluation of A Jackfruit Bulb Slicer

The traditional method of slicing of jackfruit bulb is done by using a knife, which is a time-consuming process and causes drudgery. Thus, effective mechanisation in processing is a need of the hour. The above scenario urgently demands for the development of a mechanical tool or machine for slicing jackfruit bulbs. This development will reduce the wastage of major quantity of jackfruit and also helps in preparation of primary processed products that can be used for production of other products. The developed tool can be easily operated by women and unskilled labour, so it also increases the commercial utilisation of jackfruit. The fabricated machine was evaluated for its overall capacity, slicing efficiency, percentage damage, effective capacity and thickness variance (middle and end portions). The overall capacity of jackfruit bulb slicer (Fig.3) was determined by conducting, trials with *varikka* and *koozha* varieties of jackfruit with varying weights. The average of the overall capacity was found to be 50 kg/h, average percentage damage by number is 8.4% and the average thickness was found to be 7.6mm. The developed machine helps in making the work much easier than manual method. By the principle of cutting and shearing action of blades the bulbs were sliced into uniform shapes. Hence the machine could be widely used for small and medium industrial purposes.

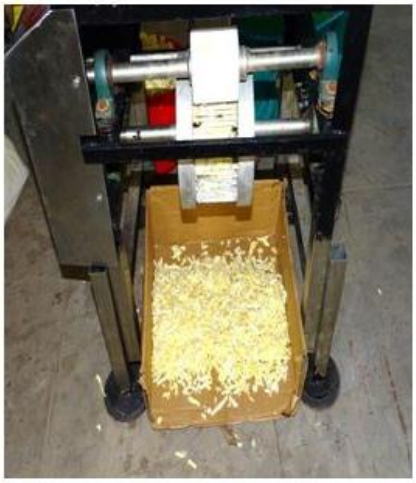

**Fig.3 Jackfruit bulb slicer**

## 9. Process control standardisation of retort pouch processed Ramasseri idli

Ramasseri is claim to fame for its simple breakfast dish called Ramasseri idli. These soft, moist, steamed cakes are made with fermented batter made from rice and urad dal. They taste salty with a hint of sourness. Various accompaniments served with it enhance its taste. Development and quality evaluation of retort pouch packaged Ramasseri idli was undertaken with specific objectives of standardization of thermal process in retort pouch package, shelf life study and quality evaluation. Retort pouch packaging system is a flexible, laminated package that can withstand thermal processing temperatures and combines the advantages of both metal cans and plastic packages. Shelf life study and quality evaluation in terms of microbial analysis (total plate count), pH, water activity, texture and colour were done during study and the analysis also showed that the product was safe up to three weeks of storage.

## 10. Development and evaluation of a jackfruit peeler cum corer AICRP on Post - Harvest Engineering & Technology

Peeling, coring and bulb separation of jackfruit are time consuming, causes drudgery and very tedium in manual operation. The present study aims at development and evaluation of a jackfruit peeler cum corer (Fig.4) machine. The principle operation of the machine is, as the jackfruit rotates peeling was done helically due to the linear motion of the blade from bottom to top. Similarly cutting-coring operation was performed by screw mechanism which pressed the core removing tool against the fruit and cut into four portion. Finally bulbs were separated manually. Performance evaluation of the machine was conducted in the laboratory to optimize the speed of fruit holder (90, 120 and 150 rpm) and corer pulley (110, 130 and 150 rpm) with three size of jackfruit, by considering the minimum processing time and bulb wastage with higher efficiency. As per the comparative study the average time taken for peeling, cutting-coring and bulb separation was more (28.8 min/fruit) during manual operation and in case of mechanical operation it was only 13.3 min/fruit. The maximum throughput of machine was 37.5 kg/h, whereas in manual operation 17.36 kg/h. The cost of the machine has been estimated as Rs. 46950/-. The operational cost of the machine was Rs.52.97/h whereas in manual operation, the operational cost was Rs. 47.5/h.

**Fig.4 Jackfruit peeler cum corer**

## 11. Development and evaluation of a continuous cocoa pod breaker

The continuous cocoa pod breaker consists of hopper, metal rollers, chute, rotating cylindrical strainers, frame, prime mover and pulleys. Cocoa fruit was fed manually in to breaker unit through hopper. Gap between the rollers was set so as the cocoa kernels were not damage during the pod breaking process. Tangential force of the roller pushed the cocoa pod towards the gap resulted in breakage. Cocoa pod, kernels and placenta then discharged to strainer through chute. Rotation of strainer separated the cocoa kernels from cocoa pod and placenta, and passed through the pores of the strainer. It was then collected and could be directly send for fermentation process. The broken pods were remained above the strainer and got separated. Performance of the machine was evaluated in terms of capacity, energy requirement, percent bean damage, per cent bean recovery, shelling efficiency and machine efficiency. The average capacity and breaking efficiency of cocoa pod breaker was 550 kg/h and 95-98%, respectively. Bean damage percentage was 0.5%. The shelling efficiency and beans separation efficiency of the strainer at inclination, 45° was 96.42 and 86.5%, respectively. The performance of the developed cocoa pod breaker was compared with traditional method of pod breaking, the total time required to break 100 kg cocoa pods and collect the beans for mechanical and manual method was 10.44 and 50.17 minute, respectively.

The fermentation studies were conducted in artificial fermentation chamber, polyhouse and ambient condition and it was compared with three different environmental conditions (ambient, polyhouse and artificial fermentation chamber). The effects of treatments on dependent variables like temperature, pH, moisture content and microorganisms during fermentation process were studied. In this study, fermentation of cocoa beans in artificial fermentation chamber found the best among the other treatments for the production of good quality cocoa. The cost of operation of cocoa pod breaker having 550 kg/h capacity was estimated as Rs.74.42 /-

## 12. Optimisation of process parameters for preparation of flavoured instant green tea-PG/Ph.D

In this research optimisation of process parameters for preparation of flavoured instant green tea were carried out. Production of flavoured instant green tea mainly includes three steps, extraction, flavour addition and drying. Extraction was performed and optimised conditions were 1:47 leaf-water ratio, 30 min extraction time and 52°C extraction temperature. Extract obtained

with optimised condition was subjected to spray drying and optimised condition were 174°C inlet temperature, 2.7% MD and 671 ml.h-1 feed rate to produce instant green tea. Further flavouring was carried out with two spices (ginger and cardamom) and one herb (tulsi) of different concentration and spray dried at optimised spray drying condition. The best combination selected after sensory evaluation are G2 (4% ginger extract), C6 (3 g of cardamom with 30 min of soaking) and H3 (3:10 tulsi to green tea ratio, 30 min extraction time). The best samples were packed in PET, ALF and LDPE and kept for storage studies at room temperature. Predicted shelf-life period of instant flavoured green tea powder packaged in ALF, PET and LDPE based on moisture gain was found to be 210, 152 and 92 days, respectively. Among the six tested sorption models, the GAB model described the best fit to the experimental data with higher $R^2$ value and lowest SSE and RMSE. The HPLC analysis for catechin fraction of instant flavoured green tea indicates that, flavour addition will not affect the green tea catechins. The heat utilization efficiency of spray dryer for spray drying of green tea extract under non adiabatic condition was 18.18% and under adiabatic condition was 89.4%. The total cost of production for 1 kg of instant green tea was Rs. 3590/-, ginger flavoured instant green tea was Rs. 3683/-, cardamom flavoured instant green tea was 4025/- and tulsi flavoured instant green tea was Rs. 3631/- and benefit cost ratio was 1.40:1, 1.63:1, 1.49:1 and 1.65:1, respectively.

## 13. Design and development of a Solar Refrigeration System – PG/Ph.D

In this study 40 L capacity three fluid vapour absorption refrigeration system (VARS) was designed and a commercially available three fluid absorption refrigerator working on electricity was procured and modified for using heat energy. The experiments with low temperatures could not produce any cooling whereas steam at116°C and 121°C and electric heater at 150°C produced refrigeration effect. The temperature obtained in the cabin of the refrigerator was 10.9°C and 8.1°C which was ideal for keeping fruits vegetables and other perishable items. For effective working of this system using only on solar energy, instead of flat plate collector, a solar steam generator that could produce steam can be used.

## 14. Development and performance evaluation of a solar dryer for copra– PG/Ph.D

An advanced forced convection solar dryer was designed and fabricated. Evacuated tube collector was used to generate hot air and it was used to dry coconuts. In the drying chamber, the basic function of solar dryer is to heat air to a constant temperature which facilitates extraction of moisture from copra kept inside an insulated drying chamber. The coconut meat is not directly exposed to the sunlight which will retain the nutritive values. The performance evaluation of the developed solar dryer was tested at KCAET, Tavanur. The average energy produced by the solar evacuated tube collector in dry day was 63668.80 kJ. Evacuated tube collector consisted of 30 borosilicate glass tubes of 1500 mm length and the outer and inner diameters were 47 and 37 mm. The length of manifold is 2.5 m and its inner and outer diameters of cylinder are 12.5 cm and 40 cm, respectively. A 24 gauge galvanized steel sheet was used to fabricate the chamber of 75 x 75 x 50 cm. The thickness of the galvanized iron sheets was 2 mm and it was completely insulated using glass wool of thickness 12.5 mm. The solar drying was performed at full load condition using heated air at 50-60℃, 61-70℃ and 71-80℃ and by using different blower velocities of $0.2 m.s^{-1}$, $0.5 m.s^{-1}$ and $0.8\ m.s^{-1}$ with and without glass wool insulation. The

temperature was controlled by providing required shade to the evacuated tubes and the blower was controlled by using a regulator for getting various air velocities. The optimized operating conditions of temperature, blower velocity and insulation were found to be of 71-80℃, 0.8 $m.s^{-1}$ and insulation with critical thickness of 12.5 mm. Microbiological analysis was conducted for dried copra and it was found that the tested samples were microbiologically safe for human consumption.

## Ongoing Projects

1. Development and optimization of microwave assisted process for extraction of nutmeg mace essential oil
2. Studies on microwave steam distillation process for extraction of lemongrass essential oil
3. Development and quality evaluation of spray dried probiotic flavoured yoghurt containing Lactobacillus bulgaricus.
4. Development of a Multi - fruit slicer- cum- dicer
5. Development and quality evaluation of hot extruded RTE product from speciality rice

# Faculty –Forestry

# Project Coordination Group - Natural Forests and Biodiversity (NFB) -(01)

**Project Coordinator - Dr. A. V. Santhoshkumar**

**Concluded Projects: 11**
**Ongoing Projects: 9**

## Concluded Projects

### 1. Explorative study and capacity development on human-wildlife conflict management in selected forest tracts of Kerala

This project conducted a two day consulatative workshop involving all stakeholders and developed a set of recommendations which was submitted to the government, other policy making bodies and planners for their active consideration. Later through explorative studies the wildlife involved in the conflicts as well as the preferred mitigation options against such conflicts could be identified for each conflict locations in the six districts. The project's findings identifies a felt need for the forest department and other agencies to meaningfully intervene and raise the awareness levels about wildlife conservation and associated aspects through various outreach programmes. All the respondents, barring those from Kozhikode and Wayanad district were having significantly different views about human-wildlife interactions. As human-wildlife interactions are location specific as well as animal specific, this call for a continuous monitoring of the nature, frequency and intensity of conflicts in these areas which will help in designing appropriate micro-site specific mitigation measures.

As a pilot attempt, College of Forestry, Kerala Agricultural University, Govt. Model Engineering College, Kochi and Integrated Rural Technology Centre (IRTC), Palakkad had jointly developed an elephant intrusion detection and early warning system (beta version) as a part of this project.

### 2. Cause- consequence analysis of human – wildlife conflicts in Nemmara Forest Division, Kerala

Independent of all socio-economic variables the respondents at each range under Nemmara Division namely Alathur, Kollengode and Nelliyampathy responded in a uniform manner and there was no significant variation in their responses despite various classification in the socio-economic strata. At the same time, all the respondents from the three different ranges showed significant difference in their responses which confirms the significant differences in the human-wildlife scenarios in the Nemmara forest division. This location specific nature was not only found in the type of conflicts but also in the respondents. The respondents at different ranges had location specific responses. At Alathur range, crop raiding with isolated cases of livestock depredation is the major issue. The main problematic animal was sambar deer since the dominant cultivation at Alathur is rubber. In Kollengode range, the main conflict was crop raiding involving wild boars, since the major cultivation was paddy and vegetables. The main problematic animal at Nelliyampathy was found to be bonnet macaques. There has been a significant change in the cropping pattern at the Nemmara forest division over the past 30 years. Particularly speaking in Alathur and Nelliyampathy ranges the change is cropping pattern was mainly from food crops such as tapioca, paddy, vegetables, pineapple etc. to plantation crops/ cash crops such as nutmeg, arecanut, mainly rubber. In the study areas at Alathur and Nelliyampathy most of the respondents were settlers who came there for job purposes and their main occupation was found to be waged labour which included rubber tapping and other such works. The major crops cultivated at Kollengode were found to be ground nut and rice. Later during the past 10 to 20 years a few areas started cultivation of plantation crops mainly mango in areas such as Muthalamada which is presently known as mango city. People also started cultivating coconut arecanut etc. in small patches. But still rice and groundnut remained. During the past 10 years groundnut cultivation has entirely changed to vegetable cultivation due to various reasons such as a landslide in 1970s, loss in price of groundnut, increased loss due to crop raiding of ground nut since it is a tuber crop. When the entire area was identified suitable for vegetable cultivation, people switched to vegetable and rice cultivation. In all the three ranges of the forest division, the respondents identified Forest department as the best responsible agency

for taking the responsibility for reducing human-wildlife conflict. the respondents had a positive regard to conservation of wildlife and nature this is justified by their opinion regarding why wildlife should be conserved in all the three ranges "For future generations" were selected as the best option and the second-best opinion was that "They (animals) have as much as right to live" as we do. The people at Alathur chose electric fencing around farmer's field, electric fencing around the park, wire fencing, trenches around the park and trenches around the farmer's field. At Kollengode the top five options were electric fencing around the park, electric fencing around the fields, trenches around the park, trenches around the fields and habitat improvement. In Nelliyampathy range, people chose electric fencing around the parks, electric fencing around the fields, trenches around the fields, trenches around the parks and wire fencing.

### 3. Functional diversity of an evergreen forest ecosystem in Vazhachal Forest Division, Kerala

At the tropical wet west coast evergreen forest of Vazhachal forest division, this study could record 175life forms. This list includeswhich 57 tree recruits, 29 shrubs, 28 herbs, 19 climbers, 14 pteridophytes, 13 polypores, 7 epiphytes, 4 orchids and 4 bryophytes. A total of 84 tree species (> 10 cm GBH) was recorded from the entire 0.5 ha area. *Aglaia barberi, Cullenia exarillata, Mesua ferrea, Palaquium ellipticum* and *Dipterocarpus indicus* are the dominant tree species in Vazhachal forest division. The density of tropical west coast wet evergreen was1093 individuals per hectare with a basal area of 85.43m2. The diameter frequency as well as height frequency distribution of evergreen forests showed the reverse J shaped curve which reflects a good regeneration status. *Euphorbiaceae*, *Dipterocarpaceae* and *Meliaceae* are the tree dominant families. Chandanthodu reported highest Margalef richness index and Shannon-Wieners index. Anamadankuthu plot has the highest Simpson index and Pielou`s index. Species richness is not distinguishable between Chandanthodu, Nellikunnu and Anamadankuthu. However it was observed to be riles richer in Thottathura and Sorrikal- 46. Among plant functional traits of the tree species, evergreen plant type dominated (70.2%). Simple type of leaves was the most dominant leaf type (72.6%). Glabrous textured leaves dominated (78.57%) the ecosystem. Mesophyll type of leaves was exhibited by 64.2% of the 84 trees. Trees with smooth bark texture accounted for 47.2% while 53.5% had medium bark thickness. Capsule fruit type was the dominant (32.1%) fruit type with zoochory (55.95%) was the dominant dispersal type. The highest functional richness (FRic) and Functional dispersion (FDis) was observed in Chandanthodu followed by Nellikunnu. The maximum value of functional evenness (FEve) and functional divergence (FDiv) was observed in Thottathura followed by Sorrikal- 46. No significant difference with regards to bulk density (1.18-1.30 gcm-3), moisture content (28.33-29.97%) and organic carbon (3.97-4.33%) was observed between the sample plots. The soil temperature (at 15 cm depth) ranges from 18.22- 22.36˚C. The soil acidity (pH) of evergreen forests ranges from 4.55 - 6.48 and highest pH in Thottathura. The soil electrical conductivity (Ec) of evergreen forests ranges from 0.054 mSm-1to 0.096 mSm-1. The soil in the tropical evergreen forests of Vazhachal was sandy loam in texture. The highest fraction of Sand was observed in Thottathura (79.50%), Silt in Anamadankuthu (15.1%) and clay in Chandanthodu (7.13%). A total of 28 different order of soil invertebrates was recorded with 860 individuals. *Isoptera* (30%) dominated followed by *Hymenoptera* and *Coleoptera*. Shannon Wiener Index and Pielou`s Evenness of soil invertebrates was highest in Anamadankuthu. Simpson`s diversity of soil invertebrates was highest in Sorrikal- 46. Bacteria colonies were the most populous soil microorganisms. The population range observed at Vazhachal is as follows: Bacteria (37-50 x 106cfu per gram of soil), Fungi (22.5-31.5 x 103 cfu per gram of soil), Fluorescent pseudomonads (16- 19.5 x104cfu per gram of soil),N2 fixers (12-17.5 x 104cfu per gram of soil), Actinomycetes (14.5 -18 x 104cfu per gram of soil) and Phosphate solubilizers (16-23.5 x 103 cfu per gram of soil.

4. **Taxonomic inventory and ecology of the bats of Silent Valley National Park, Kerala**

Bats of eight species belong to five genera and three families were recorded from Silent Valley National Park.In these eight species three species such as *Latidens salimalii*, *Myotis montivagus* and *Cynopterus sphinx* are new reports from Silent Valley.The Salimalii's fruit bat (*Latidens salimalii*) is the first report from Kerala.Four frugivorous bats from the family Pteropodidae were recorded which includes *Latidens salimalii*, *Cynopterus sphinx*, *C. brachyotis* and *Rousettus leschenaulti*. Two species from family Rhinolophidae were recorded and it includes *Rhinolopus lepidus* and *Rhinolophus rouxi rouxi*. Two species from family Vespertilionidae were also recorded and it includes *Myotis montivagus* and *Myotis horsfieldii peshwa*.

5. **Status, distribution and habitat preferences of small carnivores in Silent Valley National Park, Kerala**

- A total of seven species of small carnivores in four families were recorded from the SVNP during the present study. This comprise of two species each of herpestids, viverrids, mustelids, and one species from felidae. All of these species were camera trapped from the Silent Valley National Park
- The civets reported from SVNP are Small Indian Civet *Viverricula indica* and Brown Palm Civet *Paradoxurus jerdoni*. Thus, out of the three species of civets in Western Ghats two have been recorded from the NP
- The mongooses reported from SVNP are Stripe-necked Mongoose Herpestes vitticollis, and Brown Mongoose Herpestes fuscus. Thus 50% of mongoose species from Kerala have been reported from SVNP
- The mustelids reported from SVNP are Asian Small Clawed Otter Aonyx cinereus and Nilgiri Marten Martes gwatkinsii. Thus, out of the four species of mustelids known from the Western Ghats two have been reported from SVNP
- The only lesser cat reported from SVNP is Leopard Cat Prionailurus bengalensis. Thus, one out of the three lesser cats known from Western Ghats has reported from SVNP
- The most common species recorded was Small Indian Civet Viverricula indica (45.57%) followed by Brown Palm Civet Paradoxurus jerdoni (20.89%), Stripe-necked Mongoose Herpestes vitticollis (17.09%), Brown Mongoose Herpestes fuscus(6.33%), Leopard Cat Prionailurus bengalensis (6.33%) and Asian Small Clawed Otter Aonyx cinereus (3.16%) . The Nilgiri Marten Martes gwatkinsii was captured only once (5.5%) in the camera traps during the study period
- The camera traps also documented the presence of 14 other mammals such as Tiger Panthera tigris, Leopard *Panthera pardus*, Wild Dog *Cuon alpines*, Sambar Deer *Rusa unicolor*, Barking Deer *Muntiacus muntjak*, Indian Chevrotain *Moschiola indica*, Gaur *Bos gaurus*, Wild Boar *Sus scrofa*, Indian Crested Porcupine *Hystrix indica*, Lion-tailed Macaque *Macaca silenus*, Nilgiri Langur *Semnopithecus johnii*, Jungle Striped Squirrel *Funambulus tristriatus* and an unidentified rodent species from the Silent Valley National Park.
- These species have accounted for the 73.26% of the camera trap pictures in the National Park
- The overall small carnivore success rate has been generally high at SVNP (10.90%) when compared to other locations in Western Ghats.
- Out of the 158 camera trap images obtained during the study period 105 (66.46%) were of viverrids. Small Indian Civet was the commonest small carnivore in Silent Valley NP accounting for 45.57% of the camera trap images, followed by Brown Palm Civet (20.89%) and Stripe-necked Mongoose (17.09%)

- The analysis of activity pattern of small carnivores of SVNP showed a significant difference in activity distribution of sympatric species. The Stripe-necked Mongoose have diurnal activity pattern where Brown Mongoose have a nocturnal activity pattern. Even though two species of viverrids, Small Indian Civet and Brown palm civet are nocturnal they have varying peak activity periods
- Logistic regression analysis was done for predicting the presence of Brown Mongoose, Stripe-necked Mongoose, Brown Palm Civet, Small Indian Civet, and Leopard Cat.

## 6. Efficacy of arbuscular mycorrhizal fungi for drought tolerance in *Swietenia macrophylla* King. seedlings

Drought stress was found to affect thegrowth and physiology of mahogany seedlings significantly. The daily irrigated (control) seedlings recorded higher shoot height, collar girth, leaf area, fresh weight of shoot, fresh weight of leaves, total fresh weight, dry weight of leaves, dry weight of shoot, dry weight of root, total dry weight, shoot- root length ratio, shoot- root biomass ratio, vigour index I and vigour index II. Physiological attributes such as Leaf Area Ratio (LAR), Specific Leaf Area (SLA), Absolute Growth Rate (AGR), chlorophyll content, Relative Water Content (RWC) and water potential were also found to be higher in the irrigation control treatment while, lower values were observed for Specific Leaf Weight (SLW). The irrigation control seedlings also had higher seedling quality index and biovolume index. However, higher values for taproot length, number of leaves, number of lateral roots, fresh weight of roots and lower leaf temperature were observed for both the irrigation control and treatment IW/ET=1. The treatment IW/ET=1 showed higher rate of photosynthesis, stomatal conductance, root colonization percentage and total spore count. However, higher transpiration rates was observed for the seedlings of treatment IW/ET=0.8 too. Highest Mycorrhizal Use Efficiency (MUE) was recorded for the treatment IW/ET=0.8. The treatment IW/ET=0.8 and IW/ET=0.6 both had higher Relative Growth Rate (RGR) while, the treatment IW/ET=0.6 recorded higher Net Assimilation Rate (NAR). Performance of the seedlings were poorest in the treatment IW/ET=0.4. It had lowest shoot height, taproot length, collar girths, leaf area, number of leaves, lateral roots, fresh weight of roots, dry weight of leaves, dry weight of shoot, dry weight of roots total dry weight, shoot- root length ratio, shoot- root biomass, vigour index I, vigour index II, LAR, leaf weight ratio (LWR) ,SLA, AGR, RGR, NAR, rate of photosynthesis, stomatal conductance, transpiration rate, chlorophyll content, RWC, water potential, seedling quality index, biovolume index and MUE, colonization percentage and total spore count; and higher leaf temperature and SLW.

Colonization with AMF, especially with G. etunicatum significantly improved the
biometric as well as the physiological attributes of the seedlings. These seedlings recorded higher shoot height, taproot length, collar girth, leaf area, fresh weight of shoot, fresh weight of root, total dry weight, vigour index I, vigour index II, seedling quality index, biovolume index, MUE, root colonization percentage and total spore count. Seedlings inoculated with G. etunicatum also had lower leaf temperature and higher values of AGR, rate of photosynthesis, stomatal conductance, transpiration rate, RWC and water potential. The seedlings inoculated with R. intraradices and G. etunicatum both showed an increased number of leaves, lateral roots, fresh weight of leaves, dry weight of leaves, dry weight of shoot, dry weight of roots, shoot- root length ratio, shoot- root biomass ratio, LAR, LWR, SLW, RGR, NAR, chlorophyll content and lower SLA values. Inoculated seedlings were found to perform better compared to non-inoculated seedlings under higher levels of water stress. Among the various species of AMF used, F. mosseae was found to have the lower suitability with the host plants. The non-inoculated seedlings and the seedlings inoculated with F. mosseae both recorded lower leaf area and LAR. The non- inoculated seedlings not only demonstrated lower fresh weight of leaves,

fresh weight of roots, fresh weight of shoot, total fresh weight, vigour index I, vigour index II; but also, higher shoot- root length ratio and shoot- root biomass ratio. This treatment also had lower values for physiological parameters like rate of photosynthesis, stomatal conductance, transpiration rate, chlorophyll content, RWC, water potential LWR, SLW, AGR, RGR, NAR, and higher values for SLA. Seedling quality index, biovolume index and MUE were also found to be lower in the non- inoculated seedlings. These seedlings also recorded lower root colonization percentage and total spore count in the rhizosphere soils. From the experiment, it was apparent that the performance of inoculated seedlings was better than the non-inoculated ones. The application of AMF was found to influence the production of quality planting stock of mahogany positively. Inoculation with AMF was also observed to impart drought tolerance to the seedlings. Among the three different AMF species used, G. etunicatum was found to be the most beneficial and suitable one for the mahogany seedlings.

**7. Feasibility of forest certification in Marayoor Sandal Division, Kerala**

The present study has acknowledged the feasibility of forest certification in Marayoor Sandal Division, by assessing the socio-economic characters such as age, education, annual income, source of income and occupational status of the stakeholders. The study also enquired the feasibility of Marayoor Sandal Division to the P&C of FSC. The socio-economic parameters such as education, monthly income and source of income were the important factors which greatly influenced the participation of respondents, because the sandal division directly and indirectly enhanced the socio-economic variables of the stakeholders, especially Forest Dwellers, Local Community, Casual Labourers and Forest Officials. Similarly, the sandal division comply with most of the FSC principles, which means that the division had the potential of implementing forest certification.

**8. Species diversity and community structure of reptiles of selected agroecosystems in Thrissur, Kerala**

Total of 594 individuals of reptiles, belonging to 18 species were observed during the study. This includes six species from Family Gekkonidae, four species from Family Scincidae, one species from Family Agamidae, one species from Family Elapidae, five species from Family Colubridae and one species from Family Natricidae. The species richness was the highest in the two habitats such as Coconut plantation and Cashew plantation, with each supporting 11 species each, while the species richness was the lowest in the Wetland habitat, with just two species. The abundance of the reptiles was greatest in the Botanical Garden (159 individuals) and lowest in the Wetland habitat with five individuals. *Eutropis macularia* (Bronze Grass Skink) was the most abundant species of reptilewith 220 individuals observed across the whole ecosystems followed by *Hemidactylusbrookii* (Spotted House Gecko) with 87 individuals. More reptiles were recorded during the night hours. 391 out of 594 individuals of reptiles were recorded during the night hours. All the seven species of snakes recorded were observed during night hours. The reptilian community of the Home garden and Wetland habitats were found to be quite distinct from that of other agroecosystems studied. It is also evident that the agroecosystems such as Coconut Plantation, Cashew Plantation, Rubber Plantation and Botanical Garden have many common species among them.

Habitats variables were found to be influencing only certain species. Occurrence of Russell's Kukri Snake *Oligodon taeniolatus* was found to be influenced by variables such as litter cover, litter depth, canopy height, canopy cover, shrub cover and herb cover. Occurrence of Oriental Garden Lizard *Calotes versicolor*, Beddome's Cat Snake *Boiga beddomei*, Termite Hill Gecko *Hemidactylus triedrus*, Spotted House Gecko *Hemidactylus brookii*, Common Wolf Snake

*Lycodon aulicus*, Common TrinketSnake *Coelognathus 102esche* and Checkered Keelback *Xenochrophis piscator* was found to be influenced by relative humidity. Occurrence of Common Krait *Bungarus caeruleus*, Dussumier's Litter Skink *Sphenomorphus dussumieri* and Bark Gecko *Hemidactylus 102eschenaultia* was found tobe influenced by maximum temperature. reptiles reported from Kerala Agricultural University Main campus.

**9. Status, distribution and habitat preference of small carnivores in Wayanad Wildlife Sanctuary, Kerala**

Nine species of small carnivores were recorded from the Wayanad WLS. This comprise three species from both Family Viverridae and Family Herpestidae, two species from Family Felidae and one species from Family Mustelidae. All members available in the Western Ghats of Family Viverridae were recorded from Wayanad WLS. That includes Small Indian Civet, Brown Palm Civet and Common Palm Civet.

Three members of Family Herpestidae reported from Wayanad WLS, includes Indian Grey Mongoose, Ruddy Mongoose and Stripe-necked Mongoose. Jungle Cat and Leopard Cat were recorded from Wayanad WLS, and species comes under Family Felidae. Only one member from Family Mustelidae, Asian Small-clawed Otter, was photo captured from the Wayanad WLS.

Small Indian Civet Viverricula indica found as most common species followed by Stripe-necked Mongoose Herpestes vitticollis, Common Palm Civet Paradoxurus hermaphroditus, Brown Palm Civet Paradoxurus jerdoni, Ruddy Mongoose Herpestes smithii, Indian Grey Mongoose Herpestes edwardsi, Leopard Cat Prionailurus bengalensis, Asian Small-clawed Otter Aonyx cinereus and Jungle Cat Felis chaus. Other mammals also photographed in the camera trap study. These includes Asian Elephant Elephas maximus, Barking Deer Muntiacus muntjak, Black-naped Hare Lepus nigricollis, Bonnet Macaque Macaca radiata, Indian Crested Porcupine Hystrix indica, Leopard Panthera pardus, Indian Chevrotain Moschiola indica, Sambar Deer Rusa unicolor, Sloth Bear Melursus ursinus, Spotted Deer Axis axis, Three-striped Palm Squirrel Funambulus palmarum, Tiger Panthera tigris, Tufted Gray Langur Semnopithecus priam, Wild Boar Sus scrofa, Wild Dog Cuon alpinus and Wild Gaur Bos gaurus. These mammals represented in 44.6% of photographs recorded.

The success rate of camera trapping of small carnivores in Wayanad WLS is 6.89%. The time activity pattern study reveals the activity of some small carnivores in the study area. Small Indian Civet and Common Palm Civet are nocturnal in nature and Stripe-necked Mongoose more active during early morning and evening. Logistic regression analysis was done for predicting the presence of Small Indian Civet, Common Palm Civet and Stripe-necked Mongoose. All micro habitat parameters have significant influence in the presence all three species.

**10. Species diversity and community structure of amphibians of selected agro ecosystems in Thrissur, Kerala**

A total of 14 anurans were recorded from the selected agroecosystems such as Botanical Garden, Cashew Plantation, Coconut Plantation, Homegarden, Rubber Plantation and Wetlands of Thrissur dt., Kerala. Besides 14 species, one additional species was also recorded from the Kerala Agricultural University campus. Amphibian species richness was found to be higher in Rubber Plantation with eight species followed by Botanical Garden with five species. The amphibian abundance was higher in the Wetlands followed by Rubber Plantation.

Most common of amphibian species was *Pseudophilautus wynaadensis*. *Pseudophilautus wynaadensis* was found to be cosmopolitan in the present study withits detection from all the five habitats. Amphibian diversity was found to be significantly different between Homegarden and Botanical Garden, Homegarden and Coconut Plantation, Homegarden and Rubber Plantation, Homegarden and Wetlands, Wetlands and Rubber Plantation and Wetlands and

Botanical Garden at 1% significance and between Cashew Plantation and Botanical Garden, Rubber Plantation and Botanical Garden and Wetland and Coconut Planation at 5% significance. Among the various methods used, we found that visual encounter survey and the opportunistic sampling, were found to be efficient. The micro-habitat variables that influenced the presence or absence of *Pseudophilautus wynaadensis* were soil moisture, soil pH, litter depth, maximum airtemperature, minimum air temperature, shrub density, soil temperature at 5 cm depth and evaporation.

### 11. Geographical Indications status for Nilambur Teak (*Tectona grandis* L.f.)

In the present study it was found that Nilambur teak has a long history that helped it to secure a place in the international timber market. Unique characteristics of Nilambur teak includes its colour (Golden brown colour), higher heartwood – sapwood ratio, moderate values for density and higher values for dynamic MOE. The climate and soil also act as contributing factors that influence the uniqueness of Nilambur teak. The presence of site quality I and II in the area contribute to the superior quality of Nilambur teak. The study also found that Nilambur teak has a good reputation among the timber merchants. The factors like historical importance, reputation in the timber market and its unique characteristics as a result of genotype, climate and soil make Nilambur teak a potential candidate for obtaining GI status.

## Ongoing Project

### 1. Harvesting, processing and value addition of natural dammars of Kerala

During 2017-2018, we have done value addition of black dammar and developed Incense sticks which are having mosquito repellant properties. Training was imparted to tribes on sustainable harvesting and value addition of black dammar at various forest divisions of Kerala.

### 2. Establishment of A GIS – RS Unit At The College of Forestry, KAU – To Serve as Central Facility for the University for Spatial Databases and Cartography

Distribution map of Cashew for Dr. Smitha M.S, Assistant Professor (Entomology) Cashew Research Station, Madakkathara. Distribution map of Cocoa plantation for Dr.B.Suma, Professor and head, Cocoa Research centre, Vellanikkara. Created study area map for post graduate students. Analyzed the change detection of Kadalundi-Vallikkunnu Community Reserve (KVCR) for PhD Scholars. Created the map of "Area of production of Marayoor jaggery" for Dr.C.R.Elsy, Professor, ARS, Mannuthy. Assisted to cater mapping, cartographic and RS-GIS needs of the entire teaching, research community of KAU, including scientists and students. The facility functioned as a training centre for BSc and M Sc students of all the Colleges in the University in various aspects of RS, GIS and GPS applications.

### 3. Development of KAU Botanical Garden (Itty Achuthan Memorial Botanical Garden) into Learning Resource Centre and Biodiversity Conservation respository

A Master Plan of the Botanic Garden has been prepared. The whole area of Botanical garden is surveyed using Total Station (Leica Geosystems). Using data logger, the survey data has been processed digitally to generate contour lines in the format of AUTOCAD Version 13.0. For planning the different themes according to the elevation, a 3D model of the contour data is developed using Arc GIS 10.1. The location of different thematic areas, the local movement plan and locations of different structure are also planned based on the 3D DEM. Water harvesting ponds have been constructed. The trees in the Botanic Garden have been labeled. Two hundred

plus wildlings have been planted in the Botanic Garden during last monsoon season and all the plants have been protected using tree guard and the success have been 100%.

4. **Study on Human-Wildlife Conflict in Kerala**

This study is intended to suggest possible solutions for making the mitigation measures more effective and thereby reducing the conflicts between humans and wildlife. An understanding about the spread and intensity of human-wildlife conflict over space and time will also help in managing the conflict situations effectively. Data on human wildlife conflict for the last ten years (2006 to 2016) was collected from Forest Division Offices of Kerala Forest Departement. Location details of each conflict incident was also collected.

5. **Cause-consequence analysis of human-wildlife conflict in Wayanad district, Kerala - PG**

The study noticed a definite shift in the farming practices in Wayanad. The respondents here informed that they had long shifted to cash crops and had abandoned traditional crops that they had long practiced. Paddy and tuber crops cultivation was abandoned by many and had switched to other crops to avoid instances of crop raiding by wild animals. The respondents have reported the continuous threat from wild animals as a definite cause to shift /decrease cultivation. Some people even abandoned the cultivation of coffee, pepper, ginger and plantain because of increased crop raiding. Several respondents had opined that the attack increased mainly because of the fragmentations of the forest and disturbances to the movement corridors. Being an agricultural community, the people in Wayanad were engaged in all types of farming activities including livestock rearing. Common domestic animals such as cow, buffalo, goat, and poultry were reared by the majority of the respondents. The response in the study areas to details of participation in forestry extension programmes organized by the forest department was a mixed one. While a few of the respondents showed interest in attending, some said that they were unaware of any such programs. A few reported that the forest department did not organise any such training programs at all.

6. **Impact of invasive alien plants on understorey vegetation in Wayanad Wildlife Sanctuary-PG**

The main objective of the study is to evaluate the distribution characteristics of selected invasive alienspecies viz. *Lantana camara* L., *Senna spectabilis* (DC.) H.S. Irwin and R.C. Barneby and *Chromolaena odorata* (L.)R.M. King & H. Rob.Inthe selected ecosystems inside the Wayanad Wildlife Sanctuary. The study also aims to understand theimpact of these invasive alien species on theregeneration of other plant communities.

7. **Impact of Participatory Forest Management on the livelihood of indigenous communities in Central Forest Circle, Kerala-PG**

The main objective of the study is to understand the impact of PFM activities on the livelihood of indigenous people of the Central Forest Circle, Thrissur. This study will also attempt a perception analysis to know the pre and post PFM changes in livelihood due to PFM as perceived by the community.

8. **Diversity, distributional status and ecology of polypores in forest ecosystems of Kerala -PG**

   The objective of the study is to find out the diversity and distribution of polypore fungi in different forest ecosystems of Kerala and also to study their relationship with substrate type, diameter, and decay stage.

9. **Spatio-temporal patterns in human-wildlife conflict in Kerala-PG**

   The major objective of the study is to assess the spatial and temporal pattern of occurrence of human-wildlife conflict in Kerala. The evaluation of the present preventive measures adopted against human-wildlife conflict will be done at Mannarkkad Forest Division and Thrissur Forest Division (FD). It is also proposed to study of the attitude, expectations and perceptions of the affected individuals/community towards human-wildlife conflict, in Mannarkkad and Thrissur FD. The study aims to suggest suitable location specific measures to reduce the incidence of human-wildlife conflict in Mannarkkad and Thrissur FD.

# Project Coordination Group - Planted Frosts and Utilization (02)

**Project Coordinator - Dr. E. V. Anoop**

**Concluded Projects: 17**
**Ongoing Projects: 12**

## Concluded Projects

1. **Multitier silvopastoral systems suitable for tropical homegardens- AICRP**

   This experiment was initiated during 2012 to address the fodder scarcity and associated decline in dairy farming in Kerala. The primary objective of the trial is to secure fodder self sufficiency by developing a multi-tier fodder production system involving fodder trees, fodder legumes and fodder grasses arranged in definite design within the homestead. Management techniques will be also be standardized for maximizing fodder yield from fodder trees. This trial was initiated under AICRP but later on received additional funding from KSCSTE. The trial involves two parts.
   Part I: Development of silvopastural system for integrating with homegardens
   Part II. To optimize hedge row fodder tree management practices

2. **Performance of calliandra *(Calliandra calothyrsus* Meissn.) under diverse management regimes in a coconut based hedge row fodder production system -PG**

   The best management strategy to optimize forage yield and nutritive value of hedge row grown calliandra underneath coconut plantation at cheapest level is to adopt a stand density of 27,777 plants ha-1, maintain pruning heights of 1m and scheduling harvest at interval of 12 weeks.

3. **Comparative performance of mulberry (*Morus alba* Linn) and subabul (*Leucanea leucocephala* Lam) under diverse management regimes in a coconut based fodder production system -PG**
4. **Autoallelopathy of selected multipurpose tree species and the effect of their leachates on agricultural test crop-PG**
   - pH of all the five species via., *A. auriculiformis, A. mangium, A. triphysa, G. robusta* and *S. macrophylla* showed a decreasing trend with increasing soaking time of all the three tree parts such as leaf, bark and root.
   - An increasing concentration of total solid content is noticed with increasing soaking time in all the tree parts studied of all the five species.
   - The electrical conductivity of leaf, bark and root leachate of all the five species showed an increase in electrical conductivity with increase in soaking time.
   - Total phenol content and total carbohydrate content also showed an increasing trend with increasing soaking time.
   - The autoallelopathic effect of leachates from tree species on its own germination noted the lowest germination for seeds irrigated with leaf leachate of all the five selected tree species and maximum for the seeds irrigated with tap water.
   - The allelopathic effect of leachates from tree species on germination of agricultural test crop showed a decrease in germination percent with the seeds irrigated with leaf leachate of *A. auriculiformis, A. mangium, A. triphysa* and *G. robusta* against cent percent germination for control.
   - The germination percent of *S. macrophylla* seeds irrigated with leaf leachate showed cent percent germination showing least inhibition of germination by the biochemical present in leaf leachate.
   - The seedlings *of A. auriculiformis, A. mangium, A. triphysa* and *G. robusta* irrigated with leaf and root leachate perished by the end of the study period ie., 120 DAS.
   - The shoot length and root length of the tree seedlings in general were highest for the seedlings irrigated with tap water.

- The seedlings of the agricultural test crop irrigated with tap water as control showed increased shoot length, root length and higher dry matter production compared to the seedlings irrigated with different tree part leachate.

5. **Harnessing Arbuscular Mycorrhiza (AM) for quality seedling stock production of *Tectona grandis* Linn. and *Swietenia macrophylla* King-PG**

The study assessed the impact of inoculation of selected AMF on growth and quality of seedlings. The native AMF species (*Funelliformis mosseae, Glomus intradices, Glomus proliferum*) at different levels (10, 20 and 50 g inoculum per seedling) were applied on the seedlings raised in polythene bags. The experiment was laid out in a factorial RBD with control.

Seedlings raised in the presence of AMF showed a significant difference in plant growth and quality over those grown in the absence of AMF. The extent of growth and quality enhancement differed among AMF species and levels of inoculation. In general, mycorrhizal symbiosis significantly improved plant growth performance, such as plant height, stem diameter, shoot, root or total dry weight. Mycorrhizal colonization of seedlings ranged from 17.3 per cent to 56.3 per cent in *S. macrophylla* and 15.0 per cent to 36.0 per cent in *T. grandis*.

The growth observations like LAR, LWR, LAD, SLA, SLW, AGR, RGR and NAR showed a significant difference among the treatments in *S. macrophylla* and *T. grandis* seedlings. With a few exceptions, seedling growth observations and physiological parameters improved with AMF inoculation. Mycorrhizal inoculations significantly influenced chlorophyll content, photosynthetic rate, transpiration rate, plant water potential, stomatal conductance, relative water content and leaf temperature in *S. macrophylla* seedlings. In case of *T. grandis* seedlings, chlorophyll content, leaf temperature and relative water content were influenced by AMF inoculation. While photosynthetic rate, transpiration rate, stomatal conductance and plant water potential were not influenced by AMF. The Mycorrhizal Efficiency Index (MEI) in *S. macrophylla* was 66.43 per cent for *F. mosseae* at higher level (50 g inoculum), while in *T. grandis* MUE was 89.23 per cent on *G. proliferum* at higher level (50 g inoculum). Root colonization per cent at lower level (10 g inoculum) was found to range from 15.00 to 24.33 per cent in case of *S. macrophylla*, while it ranged from 34.33 to 55.67 per cent at higher level (50 g inoculums) of inoculation. In *T. grandis,* at lower level (10 g inoculum) root colonization was found to range from 17.33 to 33.33 per cent, while it ranged from 22.67 to 56.33 per cent at higher level (50 g inoculum) of inoculation.

By looking at overall parameters studied, it can be concluded that *F. mosseae* at 50 g of inoculum at the time of transplanting @ 10 spores /g confers maximum growth and seedling quality benefits in nursery as compared to all other fungi used in for *S. macrophylla*. Seedlings of *T. grandis* with *G. proliferum* at 50 g inoculums performed better in nursery. This technology has the potential to reduce the nursery period and increase in quality of seedlings produced resulting in considerable economic gains.

6. **Genetic diversity and population structure of two distinct natural populations of *Syzygium travancoricum* Gamble -PG**
7. **Morpho-physiological diversity assessment of Garcinia gummiguta (L.) Robs. germplasm collection -PG**
8. **Screening of *Ailanthus triphysa* (Dennst.) Alston.for preferred match wood qualities-PG**

Ailanthus triphysa, a member of the family Simarubaceae is an important tree with regard to match manufacture. Twenty Candidate plus trees (CPTs) were selected from 10 panchayats across two districts (Thrissur and Palakkad) in Kerala to study the variation in wood properties and the growth parameters of their half-sib progenies during 2013-2017. Core samples were

collected to analyse the anatomical properties and fibre indices between the CPTs, which was later found to vary significantly at one percent level. Morphological and growth parameters were observed in the half-sib progenies of the selected trees both in nursery and field condition for 150 days each. The morphological parameters like height, collar diameter, root length, leaf area, number of leaves etc. were found to vary significantly at nursery but not throughout the study period. Relative Growth Rate, Absolute Growth Rate and Net Assimilation Rate did not show significant variation among the seed sources. Field performance of the progenies was evaluated at Aaramkal, Vellanikkara, Thrissur, Kerala in RBD. Height and collar diameter varied significantly initially but the differences were not significant for collar diameter from 90 days after planting. However, survival percentage did not show any significant difference between the progenies. FCV AT 1 showed the maximum height growth at 150 days after planting. A questionnaire survey was conducted to access farmers' perception towards growing raw materials for match manufacture. The respondents had an overall positive approach toward tree farming. The majority of the respondents were confident that scientific guidance will help them in increasing the yield.

## 9. Diversity, structure and standing stock of timber in the homegardens of Thrissur district, Kerala-PG

There was a great variability in diversity, abundance and standing stock of different tree species belongs to different use categories among three homegarden size classes and across different eco regions. There were 163 total species present in the entire Thrissur district that included 122 trees species and 41 agricultural crop species. Contrary to earlier studies, consistent decline in diversity was observed with decrease in homegarden size. Highest number of taxa was observed from large homegardens (102 species) which was followed by medium (95 species) and small (85 species). Population pressure and skewed land availability may have negatively affected the species diversity in homegardens. Most abundant functional group of trees found in surveyed homegardens were medicinal trees (62 species) followed by timber species (53 species). Economically important functional groups such as timber, fodder, fuel, green manure and other MPTs were abundant in large homesteads. Eco-region wise comparison of tree diversity suggested high diversity in the midland and highland regions while lower in coastal land and peri-urban areas. *Mangifera indica* was the predominant timber tree species in terms of abundance and standing stock in Thrissur district with a total stand number and standing stock projected to the Thrissur district as 15,98,849 and 18,84,356.3 m3 respectively. Other dominant timber trees in terms of standing stock were *Artocarpus heterophyllus, Tectona grandis, Swietenia macrophylla*, etc. Standing stock per hectare of total timber species identified in Thrissur district was 55.12 m3 ha-1 and projected standing stock of all timber species in the district was 81,38,931.6 m3 . Vertical diversity of the studied homegardens suggested high species richness associated with middle storey. Also all three strata of large homegardens were more diverse than medium and small homegardens irrespective of eco-region. In total there were 41 species of agricultural crops and medicinal plants identified from selected homegardens. Musa sps., Areca catechu and Cocos nucifera were the predominant species of all size holds. Simpson Index and Shannon Diversity Indices of agricultural crops of all size holds showed no large difference.

The most frequent constraints of homegardens included high wage of the labourers involved in homegarden maintenance, less labour availability, large expense/less profit, pest and disease, etc. Wood quality assessment of *Tectona grandis, Artocarpus heterophyllus* and *Swietenia macrophylla* using NDT showed that oven dry specific gravity (SPGo.d) has no influence on eco-regions and tree size classes. The dynamic modulus of elasticity (MOEdyn) showed

significant differences for *Artocarpus heterophyllus* and *Swietenia macrophylla* across eco-regions. However, this was not prominent for *Tectona grandis.*

**10. Standardization of methodologies for improving the wood quality of coconut timber in Kerala-PG**

Wood anatomical, physical and mechanical properties of samples collected from 51 coconut palms belonging to three age groups viz., 15-25 years (young), 35-45 years (mature) and 55-65 years (over mature), grown in three agro-climatic zones (Malayoram, Central midland and Coastal sandy) of Thrissur district, Kerala were profiled in this study.

Dermal, sub-dermal and core wood from each sample were used for assessing physical and anatomical properties and samples of density above 650 kg m-3 were selected for profiling mechanical properties. Nested analysis of variance was carried out to analyse the variation in coconut palm wood properties due to location, age and radial position.

Most of the physical, anatomical and mechanical properties did not vary significantly across agro-climatic zones and age groups. However, across age groups, basic density, vascular bundle percentage, fibre lumen diameter, fibre wall thickness and compression parallel to grain (maximum load and compressive stress at maximum load) were found to vary significantly.

Along the radial positions there was significant difference in physical and anatomical properties. Basic density, being highly positively correlated with mechanical and anatomical properties, estimation of density can be used as a key to determine end use under field conditions for potential utilization at the industrial level.

**11. Forage yield, soil fertility and carbon dynamics of calliandra (*Calliandra calothyrsus Meiss*n.) in coconut plantation-PG**

Three-year old calliandra fodder banks with tree density of 27,777 plants ha-1 and harvested at 12 weeks interval yielded the maximum forage and sequestered 90 Mg ha-1 additional carbon than coconut monoculture systems.

**12. Characterisation of phytopathogenic fungi in nursery seedlings of *Tectona grandis* L.f, *Swietenia macrophylla* King and *Cassia fistula* L. in central Kerala-PG**

Thirteen isolates of fungal pathogens were obtained from 18 nurseries surveyed in Thrissur and Palakkad district (Teak-8; Mahogany-2; Indian laburnum- 3). These includes TLB (*Curvularia lunata*), TLS-1 (*Alternaria alternata),* TLS-2 (*Macrophomina phaseolina*), TLS-3 (*Botryodiplodia theobromae),* TLS-4 (*Colletotrichum gloeosporioides),* Teak collar rot (*Alternaria alternata)* Teak root rot-1 (*Fusarium solani),* Teak root rot-2 (*Fusarium oxysporum),* MLB-1(*Curvularia lunata*),MLB-2 (*Alternaria alternata*), ILB-1(*Alternaria alternata), ILS-1*(*Colletotrichum gloeosporioides*) andILS-2(*Phoma cassiocarpa*)

Molecular characterization of TLB (*Curvularia lunata*), Teak root rot-1 (*Fusarium solani),* MLB-1(*Curvularia lunata*) and ILS-1(*Colletotrichum gloeosporioides*) were done. *In vitro* evaluation of fungicides and biocontrol agents shows that foliar diseases of teak (TLB, TLS-1, TLS-2, TLS-3 and TLS-4) can be effectively controlled by Carbendazim 12% + mancozeb 63%, Difenoconazole 25EC and Carbendazim 50WP. Collar and root diseases of teak (collar rot, root rot-1 and root rot-2) can be effectively controlled by Carbendazim 12% + mancozeb 63%, Carbendazim 50WP and Hexaconazole 5EC. Foliar diseases of mahogany (MLB-1 and MLB-2) can be effectively controlled by Carbendazim 12% + mancozeb 63%, Hexaconazole 5EC, Cymoxanil 8% + mancozeb 64%, Propineb 70WP and Carbendazim 50WP. Foliar diseases of

Indian laburnum (ILB-1, ILS-1 and ILS-2) can be effectively controlled by Hexaconazole 5EC, Difenoconazole 25EC, Carbendazim 50WP and Carbendazim 12% + mancozeb 63%.

**13. Standardisation of preservation techniques of Coconut (*Cocos nucifera* L.) palm wood-PG**

Coconut (*Cocos nucifera* L.) palm wood belongs to the class of perishable timbers which can be used as an alternative wood source with effective preservation. Preservative treatment of coconut wood can enhance the service life of coconut wood. The objective of this study was to develop appropriate preservative methods to treat sawn coconut wood under the prevailing eco-climatic conditions in Kerala and to evaluate the effect of different factors on the treatability of coconut wood. Wood samples were treated with inorganic (Copper Chromium Boron - CCB and Borax Boric Acid - BBA) and organic preservatives (Cashew Nut Shell (CNS) oil, neem oil and turpentine). Diffusion and pressure treatment were deployed for inorganic preservation and organic preservatives were investigated only through diffusion treatment. A total of 354 samples belonging to high and medium density wood were preservative treated. Diffusion treatment of inorganic preservatives in high and medium density wood showed no significant difference in retention where as significant difference was observed for penetration percentage. For pressure treatment, retention and penetration were significant in high density wood whereas medium density wood showed only significant retention. A proportionate relation existed between the solution concentrations and the two observations such as overall retention and penetration percentage. Relation of diffusion period and retention in high density wood showed no uniform pattern while, an increasing trend was seen in medium density wood. Penetration depth followed an increasing pattern under increasing treatment duration in the two density classes. Among the two treatment methods, pressure treatment performed better than diffusion treatment. Absorption percentage of organic preservatives was non-significant among treatment factors (chemical concentration and duration) and their interaction in the two density classes.

The study found that sawn coconut wood samples could be effectively treated with preservatives complying with the prescribed retention and penetration percentages as per the different standards and therefore, can be used as a potential substitute for conventional timbers.

**14. Selection and evaluation of superior planting materials of *Ailanthus triphysa* (Dennst.) inThrissur-PG**

The selected candidate plus trees showed significant difference in the germination parameters studied. The selections of CPT-11, CPT10, and CPT-9 showed the highest germination percentage and other parameters like mean daily germination; germination value and peak value of germination and the CPT-1 exhibited the lowest performances in almost all the germination parameters studied. The nursery performance of the selections also showed significant differences in seedling height, collar diameter, number of leaves, number of leaflets, taproot length, number of secondary roots, number of tertiary roots, fresh and dry weight of shoot and root and root - shoot length ratio .The variation in root - shoot biomass ratio of selected CPTs were significant from 30 DAP to 60 DAP, FROM 90 DAP to 150 DAP the result was not significant. The selections of CPT-11, CPT10, and CPT-9 shown superiority for most of the characters examined and the CPT-1 was the inferior in the nursery evaluation also.

Initial growth performance in the field also showed significant difference in plant height, collar diameter, number of leaves and number of leaflets. The selections with superior growth performance in the nursery continuedtheir superior performance(CPT-11, CPT10, and CPT-9) in the field also. The CPT-5 performed better at the field even with a lower performance at the

nursery. The improvement of the tree can be achieved through systematic and careful selection of the mother plant and its propagation.

From the present investigation, it can be concluded that there existed wide variation among the selected CPTs of *Ailanthus triphysa* with respect to their initial growth performance. The CPT-11, CPT-10 and CPT-9 emerged to be the best on the basis of both the nursery and field evaluation. It implies strongly that these CPTs could be recommended and used for tapping the immediate gain by large scale planting and afforestation programmes and also for further breeding programmes for the genetic improvement of the widely accepted and cultivated tree species of *Ailanthus triphysa.*

15. **Long term effect of thinning on productivity and wood properties for 20- year-old *Acacia mangium* Willd. Stands-PG**

The major objective of the study is to assess the long term effect of thinning on growth, biomass production, carbon storage potential and soil properties in 20-year-old *Acacia mangium.* The study also attempts to understand the effect of stand thinning on wood properties of 20-year-old *Acacia mangium.*

16. **Variation in wood physical and anatomical properties of anjily (*Artocarpus hirsutus* Lam.) grown in different agro climatic zones of Thrissur district, Kerala-PG**

*Artocarpus hirsutus* is one of the endemic timber species of the southern Western Ghats. From the study, its observed that the sapwood was white in colour and distinct from heartwood. Heartwood was golden yellow colour with indistinct growth ring. Different analysis revealed that basic density and moisture content didn't show any significant variation across three agroclimatic zones as well as between girth classes. Vessel frequency, vessel area, vessel diameter, ray width, fibre wall thickness and fibre lumen diameter didn't show significant difference across three agro-climatic zones.Analysis revealed that there was significant difference of vessel frequency, vessel length, vessel diameter, ray width, fibre length, fibre lumen diameter, moisture content and basic density between homesteads and plantations. Correlation analysis also showed basic density was positively correlated with moistur content, ray height, fibre length, fibre wall thickness; The wood properties of *Artocarpus hirsutus* are also comparable to teak wood in various aspects.

Ecoanatomical characters like vulnerability index and vessel mesomorphy were also analysed and vulnerability index was found to be highest in central midland. The result of the present study can be used as a baseline data for future tree improvement programme of this species for different end uses. As information on wood properties of *Artocarpus hirsutus* is very scarce, this study can provide more details regarding wood properties of this species.

17. **Eco-anatomical characterization and development of anatomical key of selected mangrove species of West Coast of India-PG**

The present investigation focused on the ecoanatomical characterisation of the wood of 17 selected true mangroves collected from 10 locations in the Western Coast of India. A total of 221 characters listed in the IAWA (International Association of Wood Anatomists) list of card key features were studied for each species as there is a felt need for creating databases of mangrove wood anatomy which allows to quantify the relative amount of intra- and interspecific variation, as well as variation within and between the mangrove genera. Mangrove wood from West Coast of India is characterised by diffuse-porosity, scalariform to opposite vessel wall pitting,

scalariform perforations with few bars or large number of bars. Most mangrove family members were found to have simple perforations, septate or non septate fibres with distinctly to minutely bordered pits, bordered, half bordered to simple pits, paratracheal parenchyma, apotracheal and banded parenchyma. Heterocellular to homocellular rays with mostly procumbant cells with one or several marginal row of square/upright cells was also observed in these mangrove genera. Short numerous vessels with small dimension and vessel grouping were also common. The most advanced characters like vestured pit, helical thickening, crystals and vessel occlusions were present in majority of the samples. A perforated card key based on the IAWA list of microscopic card features for mangrove identification was also prepared. The development of an IAWA based anatomical key will be helpful for the identification of mangrove species based on wood anatomy.

The ecoanatomical characters such as vessel diameter, vessel frequency, vessel grouping, type of vessel plate, lateral wall pitting, type of pits of true mangrove species were studied and compared with data from their nearest upland relative. The ecoanatomical features of wood of mangrove species are correlated with xeromorphic nature of their upland relatives. Because of the highly variable and stressful environmental condition, the mangroves developed certain strategies and adaptations during their evolution. These special morphological and physiological adaptations made it for the mangrove species to survive in these conditions in contrast to their upland relatives. A safe hydraulic architecture is only one of the alternative ways for a plant to be able to survive in water stress situations. The modification of xylem hydrological structure of mangrove wood helps to balance safety versus efficiency of water transport system. These modifications of wood structure due to ecological conditions are the driving force to evolution of wood anatomy. Thus the evolution of mangrove genera has been shown to be likely driven by environmental condition and not by phylogeny.

The general pattern of wood anatomy of mangrove genera of different families indicates convergent evolution. These trends of wood anatomy in mangrove species provide new examples of phenotypic plasticity in angiosperms. To ensure safety, certain primitive structures such as bordered pits, scalariform vessel plate, scalariform, transitional, opposite lateral wall pitting and vessel bars still persist in the true mangrove genera of the present investigation. Thus the development of wood anatomical characters in mangrove genera were an example of heterobatmy. The presence of mostly primitive wood character states suggest an unbroken occupancy of stressful habitat by its ancestral genera. Mangrove occurs in different families in which the gamut of wood specialization ranges from advanced to highly advanced features. Rhizophoraceae members were found to be the most primitive ones with less specialization whereas the other mangrove species were found to have highly advanced wood anatomical characters.

## Ongoing Projects

1. **Short and long term strategies for income generation from the teak, matti and silver oak plantation areas at Panchavadi hills in KAU main campus-PG**

   The procurement of approved equipment and other infrastructure has been completed under the project. As part of the project, *Ailanthus triphysa* was established in 1.5 acre of the land at Panchavadi hills. This involves a tree improvement trial on *A. triphysa*. Promising ten phenotypically superior collections of *A. triphysa* were collected and planted in compact family blocks during June 2016.

The proposal to dispose off the old *Ailanthus triphysa* (matti) and *Grevillea robusta* (silver oak) woodlots at Panchavadi hills was forwarded to the Assistant Conservator, Social Forestry during August 2016. However there was considerable administrative delay in sanctioning the disposal of the old trees. The Social Forestry Wing finally completed the tree evaluation during May 2018 and the tree auction was held recently (26/7/2018). The trees will be removed within a period of two months. The committed restocking this area with valuable tree species *like Gmelina arborea (Kumizhu)*, Matti Mahogany will be done immediately after the existing old trees are removed. Proposal of thinning of one ha of stagnated teak stand at Panchavadi hills and management of promising trees for higher volume production is also pending in the KFD for want of sanction.

2. **Establishing bamboosetum for Kerala Agricultural University-PG**

The bamboosetum was established in August 2017 at the 3.0 acre area allotted to College of Forestry in the KAU Instructional Farm, Vellanikkara. The bamboo plants were collected from the KFRI, Peechi and from IWST, Bangalore during July 2017. All the plants are growing satisfactorily. Table shows that except for *Guodua angustifolia* and *Dendrocalamus asper* all the other bamboos were showing better growth in height and collar diameter. This could be primarily due to the smaller size of the seedlings during the planting time. Better comparison of growth shall be made during the ensuing observations.

3. **Training and Technology Demonstration Project for Making Value Added Products from Coconut Wood -PG**

Training programme on "Processing, Value Addition and Product Manufacture from Coconut Wood" was organized at College of Forestry, Vellanikkara. As part of Training Furnitures were manufactured by the trainees with the help of the master carpenter. With the assisstance of the CDB Master Trainer, final year BSc Forestry students who were doing their Experiential Learning module in the dept. of Forest products & Utilization manufactured furnitures using coconut wood. The table in the auditorium and lab stools of College of Forestry were made as part of this venture.

4. **Standardisation of propagation through branch cuttings in selected bamboo species of Kerala-PG**

Rooting trial of *B. balcooa* branch cuttings in response to season, rooting media and growth regulator and its concentrations indicated that root induction was not possible in this species with the present frame work of study. The sprouting percentage was good in this species and it ranged from 1.67 to 48.33% and sprouting attributes varied due to treatment combinations. In further trials with higher concentrations (0, 1000, 2000 and 3000 mg l-1) of growth regulators (NAA and IBA) by soaking and quick dip method of IBA and NAA treatments at concentrations used were 0, 1000, 1500 and 2500 mg l-1 also failed to initiate rooting. Studies on adventitious root induction in *Dendrocalamus giganteus* branch cuttings in response to season, rooting media and growth regulator and its concentrations also indicated that rooting was absent in this species with the treatments given. Sprouting in the branch cuttings in different treatments ranged from 5.00 to 43.3%. The experiment to initiate rooting in *Thyrsostachys oliveri* cuttings in different seasons, rooting media and growth regulator concentrations also was a failure. The maximum sprouting was observed in cuttings treated with IBA 100 mg l-1 third season(41.67%) kept in the sand and the least was in those treated with NAA 250 mg l-1 (0.00%). From the study it can be concluded that the present set of treatments are not effective in initiating the rooting in branch cuttings of the three bamboo species studied.

5. **Wood quality of plantation grown teak (*Tectona grandis* Linn.f.) grown under different site conditions within and outside India-PG**

   The objective is to analyse the variation in the physical and anatomical properties of plantation teak wood grown in different sites with special reference to the samples collected from important teak growing regions within and outside India. It is also intended to assess the extent and nature of juvenile wood in these plantation grown sources through the analysis of wood properties.

6. **Productivity, carbon and nutrient stocks in mulberry (*Morus indica* L.) and subabul (*Leucaen leucocephala*Lam.) based high density fodder production system in coconut-PG**

   The objective of the study is to evaluate the effect of tree density and harvest interval on forage yield and carbon storage potential of three-year old mulberry and subabul fodder banks underneath coconut garden. To study the variation in coconut productivity and soil fertility changes associated with intercropping these fodder trees with coconut.

7. **Field evaluation of stump and root trainer grown teak (*Tectona grandis* L.f.) plantations**

   The primary objective of the study is to evaluate and compare the field growth performance of teak plantations established by stump and root trainer technique. The study also attempts to examine the differences in root distribution patterns of teak as a function of planting technique. Further, the study compares the effect of variable spacing on the performance of root trainer grown teak plantations.

8. **Understorey productivity of selected fodder grasses in mature coconut and rubber plantations**

   The proposed study was conducted at College of Forestry,Vellanikkara.The grass slips were planted on raised beds of size 5m x 1m. Guinea and Congo signalgrass were planted at the rate of 2 slips per hill and hybrid Napier using stem cuttings. The planting was done during the pre-monsoon showers in May – June.Standard spacing and cultural practises for grasses were followed as per the KAU Package of Practices recommendations. Plants were harvested when it reaches the harvestable maturity.

9. **Screening of superior genotypes of *Ailanthus triphysa* (Dennst.) Alston, for matchwood quality**

   The objective of the study is to assess the variation in growth and wood traits of *Ailanthus triphysa* grown in the main campus of Kerala Agriculture University, Vellanikkara under a tree improvement trial. It is also aimed at screening the superior genotypes of this species through an assessment of the genetic worth of their parents.

10. **Standardisation of gum-oleoresin extraction technique in Matti (*Ailanthus triphysa* (Dennst.)Alston)**

    The main objective is to develop an appropriate technique For extraction of gum-oleoresin and also to study the Correlation between tree dimension and anatomical features With gum-oleoresin production in Matti (*Ailanthus triphysa*(Dennst.)Alston.).

11. **Optimization of fertilizer regimes and under storey**

    The applied fertilizer had profound influence on all the growth attributes of 4-year-old mahogany. There existed a direct relationship in tree growth with increase in fertilizer doze. The

range in diameter and height growth increased substantially with increase in fertilized dosage. The tree growth in general showed complementary interaction with intercrop for all growth attributes. The increase in basal area in the heavily fertilize plot compare to unfertilized control where 75.92% at the end of 24 months after the fertilizer application. Considering the growth patterns, the best fertilizer regime for optimal basal area production is F3. The total tree volume of mahogany varied from 0.028 to 0.066 m3 after 24 months of fertilizer application which is more than 130% as compared to unfertilized control. Both the mean tree biomass and stand level biomass increased with increase in fertilizer dosage (60 per cent increase). Among the components stemwood represented almost 50% of the total biomass production for all fertilizer regimes followed by roots which accounted almost 18% of total biomass production. Biomass accrual by the various components in the decreasing order was: stemwood> roots> branchwood >leaves>twigs. Mean tree and stand level carbon sequestration showed positive response to fertilizer application for 6-year old mahogany. The total mean tree carbon stocks ranged from 29.1 to 46.66 kg per tree while the corresponding value at stand level was 46.56 to 74.66 Mg ha-1. Among the various biomass components, stemwood accounted bulk of the biomass carbon which was roughly 50% followed by roots (17%). Higher carbon storage in the stemwood and roots give positive indication of possible long-term storage of carbon in biomass especially for mahogany which is used for structural timber purpose. High carbon in the roots adds to better carbon turnover in the soil carbon pools. Nutrient partitioning mahogany suggests that in general, nitrogen and potassium concentrations decreased in the order leaves > stem > branch > roots > twigs. However, tissue phosphorus concentration followed the order branches > leaves > roots > twigs > stem. Root distribution studies using logarithmic spiral trench technique suggested increase in rooting intensity with fertilizer application for total roots and root class <2.5 mm. Hence the increase in fine root count in high fertilized plots suggest higher nutrient uptake and there by higher tree growth for mahogany. The maximum foraging zone for 6-year-old mahogany has been observed to be at 2.17m lateral distance and 40 cm soil depth. At the present stocking this leads to considerable overlapping of the rhizosphere of mahogany and intercrops and thereby limits the prospects of intercropping. Hence the possible optimal spacing for 6-year-old mahogany would be 5.5m x 5.5m for effective intercropping. Performance of all the three intercrops showed better growth in fertilized plots as compared to unfertilized control. Ginger, wild turmeric and turmeric showed increase in all biometric variables and rhizome yield in the treeless open control plots as compared to mahogany intercropped plots. However the growth differences compared to open control were lower in the heavily fertilized plots.

## 12. Genetic variability and plus tree selection in natural populations of *malaveppu* (*Melia dubia* Cav.)

The study will assess the genetic diversity in *Melia dubia* and select plus trees in natural populations of this species. This study will also analyze the clonal and seed progeny of plus trees for early growth and vigor. Further, commercially viable clonal propagation protocol for the species will also be attempted.