Kerala Agricultural University

RESEARCH REPORT 2016

Edited by
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Vellanikkara, Thrissur, Kerala

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FOREWORD

Kerala Agricultural University was established with a mission of meeting the challenges in agriculture sector by providing human resources, skills and technology for the sustainable development of state's agriculture. The University has set up its policy with the major goals of academic excellence, location specific and problem oriented research and revitalization of extension activities in agriculture and allied sectors. The technologies are generated in agriculture and allied areas by conducting basic, applied and adaptive research with special reference to socio-economic conditions of the farmers. The climatological and policy challenges in agriculture sector are more pronounced in the state of Kerala due to its location and cropping pattern. The research programmes are designed in addressing these challenges. The long term objectives aim to develop technologies that help to adapt as well as mitigate climate change impacts.

With great pleasure, KAU is presenting the major research findings in the report which is a systematic compilation of the results of the several research programmes during 2015-16. I take this opportunity to congratulate all the scientists for their committed efforts. The hard work by the team at Directorate of Research is also acknowledged for bringing out this compilation.

Dr.R.Chandra Babu
Vice Chancellor

PREFACE

Kerala Agricultural University is the premier academic, research and development institution in Kerala for agricultural development. The University has an approved research policy for addressing the problems of farmers based on the interface discussions at various levels, with all stakeholders in the sector viz., farmers and officers of the line departments.

KAU at present have a network of six Colleges, six Regional Agricultural Research Stations, and seventeen Research Stations and two Instructional Farms spread throughout the length and breadth of the state. The research programmes are implemented by scientists as well as students as part of their masters and doctoral programme. Research programmes are supported by agencies like Indian Council of Agricultural Research, 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.

It is worth mentioning that KAU has released 25 new varieties in different crops during 2015-16, which include 5 varieties in rice, 9 in vegetables, 1 in jackfruit, 2 in sugarcane, 7 in spices and plantation crops and 1 in mushroom.

The efforts taken by scientists and PG students who have contributed significantly to bring out the research accomplishments are well appreciated and acknowledged. Significant role played by various research coordination groups in coordinating the research activities deserve high appreciation. Directorate of Research is happy and proud to publish this compilation which can be a reference material for future researchers, a basis for decision making for policy makers and a guide for extension persons.

I, on behalf of Directorate of Research, congratulate all the scientists and student researchers for all their efforts and wish them all success.

Dr.P.Indira Devi
Director of Research

Faculty - Agriculture

Name of the Project Coordination Group (01)

Rice and Rice Based Cropping System

Project Coordinator: Dr. Leenakumary.S

Concluded Projects: 10 Nos
Ongoing Projects: 69 Nos

Concluded PG Projects: 2 Nos
Ongoing PG Projects: 1 No

Concluded Projects:

1. **Breeding for high yielding rice varieties having short duration, seed dormancy and resistance to biotic and abiotic stresses suitable for kuttanad**

This is a research project conducted at Rice Research Station, Moncompu with the objective of evolving high yielding rice varieties with duration of about 100 days and below, varieties with seed dormancy, varieties with tolerance/ resistance to flood, salinity and other biotic and abiotic stresses.

Work done during the period under report

a. Collection and screening of rice germplasm

The Rice Research Station, Moncompu has a good germplasm collection consisting of about 500 rice varieties including land races, improved land races and high yielding varieties developed with in the state and outside the state and also exotic varieties. The varieties are grown in the field every season and necessary data on biometric characters as well as information on resistance to biotic and abiotic stress are collected.

b. Identification of Donors for hybridization programme

Based on the data collected from the rice germplasm collection at Rice Research Station, Moncompu, the following rice varieties were identified as donors for various characters for inclusion in the hybridzation programme.

Hybridization was done between high yielding varieties and donors for different attributes viz., earliness, seed dormancy, biotic and abiotic stress resistance etc. 36 Crosses were made during the period. The F1 generation of the crosses were raised in field and many of the crosses exhibited panicle sterility and seed material were collected from 18 crosses. The seeds collected from the F1 generation were raised in the subsequent season as F2 generation.

Single plant selections were made from the F2 & F3 generation and will be continued till F6 generation after which the selected cultures will be yield tested as per standard protocol. Selections were made from F6 generation during 2012-13. From F6 generation 37 cultures were selected for IET during 2012-13. Initial evaluation trial was conducted with 37 cultures along with check varieties during Punja 2012-13. Cul.M 185-2-1-1-1-1 recorded the highest grain yield of 6539 kg/ha.followed by Cul. M 184-1-2-1-1-1 (5796 kg/ha.). IET was repeated with the same cultures during the additional crop 2013.

Cul.KAU M184-1-2-1-1-1 recorded the highest grain yield of 9934 kg/ha followed by M184-3-1-2-1-1 (9025 kg/ha.). Dormancy of the cultures was in the range of 2-3 weeks. Top ranking 20 cultures were selected for conducting PYT.

KAU M 184-1-2-1-1-1 from the cross Bhadra/Gouri recorded the highest grain yield of 6442 kg/ha followed by KAU M 200-2-2-3-2-1 (Bhadra/ Uma) with a per ha yield of 6033 kg. During Puncha 2014-15 PYT was repeated with the same 20 cultures. From the pooled analysis of PYT, 8 cultures were selected for comparative yield trial. CYT was conducted with the selected 8 cultures during the additional crop 2015.

During the additional crop the highest grain yield was recorded by Cul.KAU M 192-1-1-1-2-1(8260 kg/ha) followed by Cul.KAU M 185-2-1-1-1-1(7306kg/ha.) and Cul. M 184-1-2-1-1-1. All these cultures recorded an yield on par with the check variety Uma. During Puncha 2015-16 yield in general was poor.

2. Advanced Rice breeding cum seed production centre.

The long run objective of the project is to strengthen research and development activities of rice crop of North Kerala, where at present there is no research station solely devoted to this purpose unlike other regions of Kerala. The present programme could attain the following achievements.

a) Rice research was strengthened in North Kerala where there is no research centre solely devoted to this purpose.
b) The production capacity of 'Kaipad'- naturally organic sea coastal saline prone tract of north Kerala -could be enhanced to 60-70% by popularizing the use of high yielding varieties namely, 'Ezhome-1','Ezhome-2,' 'Ezhome-3' and 'Ezhome-4' developed by Kerala Agricultural University for Kaipad tract.
c) Collected and conserved 45 traditional rice genotypes from North Kerala.
d) Established a rice germplasm conservation unit including small scale cold storage facility.
e) Established a rice breeding cum seed production centre.
f) Established a plant molecular breeding laboratory.
g) Identified organic varietal traits in rice namely, number of tillers plant^{-1} at harvest, number of productive tillers plant^{-1}, number of grains panicle^{-1} and straw yield plant^{-1}.
h) Out of 65 rice genotypes evaluated under organic management during rabi season in organic rice farmers' field, 'Jaiva', the first organic rice variety released by Kerala Agricultural University for non saline wetlands ranked first in grain yield and other organic varietal traits followed by photo-insensitive pre release culture MK 115.
i) The conventional varieties which can be considered for organic farming for short and medium term periods are, photo sensitive long duration varieties 'Anashwara' and 'Dhanu', and photo insensitive medium duration variety 'Aishwarya'.
j) Parents for different organic varietal traits were identified.
k) The genotypes, culture JO560-2-1, culture MK 139-1-1, culture JO 274, culture MK 21-2, and Mullan Puncha(traditional genotype) showed tolerance to flash flooded condition with 50% survival as well as good yield performance.
l) The varieties ' Ezhome-1' and ' Ezhome-4' were found to be suitable for non-saline flooded tracts with an average yield potential of 3.5 -3.8 t/ha under organic management.
m) The varieties 'Ezhome-3' and 'Ezhome-2' were found to be suitable for upland cultivation with an average production of 3.1t/ha and 2.4 t/ha respectively under organic management.
n) 'Hands on training on organic rice farming from nursery to harvest in farmers' field' was conducted at six stages of the crop in two Panchayaths of Kasaragode district.

o) Meet of organic rice farmers of North Kerala was conducted on the bank of a reputed organic rice farming Padasekharam of Kannur district.
p) Conducted a one day 'state level workshop on sea coastal ecosystem' involving Kaipad farmers of North Kerala and Pokkali farmers of South Kerala on the bank of Kaipad tract in Ezhome Panchayath of Kannur district.
q) Carried out large scale demonstration trialsof organic rice farming using the organic rice variety 'Jaiva' in various Panchayaths of Kannur and Kasaragode districts.
r) Demonstration trials of newly released saline tolerant Kaipad rice varieties namely, 'Ezhome-1', 'Ezhome-2' ,'Ezhome-3' & 'Ezhome -4'were done in various Kaipad fields of Kannur and Kasaragode districts in fallow lands and thus rejuvenated the naturally organic Kaipad trct. Also trials conducted in Pokkali tracts of South Kerala.
s) Produced and distributed 4774 Kg Truthfully labelled seeds of rice varieties developed from North Kerala.

3. Screening and phenotyping of traditional rice genotypes of North Kerala along with high yielding rice genotypes in farmers' field under organic management

Organic farming is at its development stage and more and more farmers are in the process of conversion from conventional farming to organic farming. However, varieties developed for organic farming are meager. The experiment was conducted to select best ones among conventional rice varieties (varieties developed for responding well to chemical fertilizers) suitable for organic farming for short and medium term period, and to identify parents having organic varietal traits for development of organic varieties through hybridization.

Sixty five genotypes of rice which include traditional genotypes, improved varieties developed for conventional rice farming, and rice varieties/ cultures developed by Kerala Agricultural University adopting organic plant breeding strategies were evaluated in a randomized block design with two replications in organic farmers' field. All cultural operations were carried out as per the organic cultural management practices followed by the farming group for the last five years.

Out of eighteen growth and yield parameters studied under organic management, four parameters namely, number of tillers plant^{-1} at harvest, number of productive tillers plant^{-1}, number of grains panicle^{-1} and straw yield plant^{-1} showed both positive significant correlation and direct effect with grain yield plant^{-1}. Hence these four characters can be considered as organic varietal yield component traits.

Out of 65 rice genotypes evaluated under organic management during rabi season in organic rice farmers' field, considering grain yield and other organic varietal traits photo insensitive variety 'Jaiva', the first organic rice variety released by Kerala Agricultural University for non saline wetlands, developed based on the concepts and strategies of organic plant breeding ranked first followed by the organic photo-insensitive pre release culture MK 115.

Out of 99 varieties of Kerala Agricultural University developed for conventional farming in ordinary wetland using chemical fertilizers, 32 varieties were evaluated under organic management. The conventional varieties which can be considered for organic farming for short and medium term periods are, photo sensitive long duration varieties 'Anashwara' and 'Dhanu', and photo insensitive medium duration variety 'Aishwarya'.

Parents for different organic varietal traits are varieties 'Kanakom', 'Dhanu', 'Anashwara', 'Jaiva', Culture MK-115, 'Makam', 'Remanika' and 'Vytilla-4' for straw yield plant^{-1}, Badhra', 'Dhanu', 'Anashwara', ' Makam' and 'Jaiva' for number of productive tillers plant^{-1}, 'Dhanu', 'Anashwara' and 'Badhra' for number of tillers plant^{-1} at harvest, 'Mahsuri' for number of grains panicle^{-1}, the genotypes 'CO-47', a Coimbatore variety, 'Jaiva' - the organic variety of Kerala Agricultural University, 'Valankunhivithu' a traditional land race of Kerala and Culture MK-115 for volume expansion ratio, and 'Pusa Basmathi' an aromatic rice variety, followed by 'Ezhome-3', 'Culture MK115', 'Dhanu', 'Jaiva', 'Gandakasala', 'Mahsuri', 'Asha', 'Haryana Basmathi', 'Swarnaprabha', and 'Aishwarya' for good cooking qualities. The genotypes that can be selected as parents for tolerance to major pests are, 'Anashwara', 'Athira', 'Mahsuri', 'Dhanu', 'Culture Mk115', 'Remya', and 'Culture JK15'. The parents that can be selected for tolerance to major diseases are 'Jaiva', 'Kasthuri', 'Pusa Basmathi', 'Anashwara', 'Ayirankana', 'CO-47' 'Kuthiru' and 'Karishma'. Validation through artificial screening is necessary.

4. **Screening of traditional rice genotypes of North Kerala along with high yielding rice genotypes for Flood:**

Two hundred and three rice genotypes were raised in flooded rice tract of farmers field in Ezhome Grama Panchayath of Kannur district during June to identify genotypes tolerant to flash flood. Out of 203 genotypes, 13 genotypes showed 50% or > 50% survival both at vegetative and harvest stages in flooded condition. At harvest stage, 15 genotypes showed good yield performance of 40g -89g plant $^{-1}$. Four genotypes namely, JO560-2-1, MK 139-1-1, JO 274, MK 21-2(cultures), and Mullan Puncha(traditional genotype) showed 50% survival as well as good yield performance under flooded condition.

- **Hands on training on organic rice framing in farmers' field**:

In order to teach the rice farmers the organic farming techniques, a new venture of 'Hands on training on organic rice farming from nursery to harvest in farmers' field' was started first in Mangad Padasekharam of Udma Panchayath of the Kasaragode district during the Kharif and Rabi season. The entire training programme was scheduled for six different stages of crop period starting from nursery to harvest. The six levels of training are first level - organic mode seed treatment, mat nursery preparation ,and land preparation, second level- preparation of different types of compost and nutrient solutions, third level - scientific method of transplanting and use of bio-fertilizers, fourth level - Identification of pests and diseases, fifth level - Preparation and use of organic pesticides and fungicides , and sixth level training on scientific method of seed procurement, processing, and storage; healthy use of rice and after care of rice field for maintaining the organic ecosystem. As per the direction of IFOAM (International Federation on Organic Agriculture Movement) organic farmers should use organic seeds of organic varieties. In this programme an organic seed of an organic rice culture named MK 157 was used. The farmers witnessed the yield potential as well as the healthy way of ecosystem management in organic farming practices. The organic farming was done by a woman group named 'Salabam Sanga Krishi' comprising 7 members.

- **Organic rice farmers' meet of Kozhikode, Kannur and Kasaragode district:**
  In-order to seek the problems of organic rice farmers as organic farming is at its inception stage and also to share the experience of organic rice farmers, a meet of organic rice farmers of Kasaragode, Kannur and Kozhikode districts was conducted on the bank of Arayidam Padasekharam of Mayyil Panchayth of Kannur district who has been doing organic farming for the last few years.
- Conducted a **one day state level workshop on sea coastal ecosystem** involving Kaipad farmers of North Kerala and Pokkali farmers of South Kerala on the bank of Kaipad tract in Ezhome Panchayath of Kannur district. In the inaugural session of workshop, 'Ezhome-3' – a saline tolerant rice variety developed for Kaipad tract and approved by state release committee was commercially released to farmers. The official announcement function of entry of 'Kaipad rice' in Geographical Indication registry by handing over the GI certificate to Malabar Kaipad Farmers Society was done by the honourable Minister of Agriculture.
- **Large scale demonstration trials of organic rice farming** using the organic rice culture MK 157 (released by KAU in 2015 in the name 'Jaiva'): Demonstration trials of organic rice farming using the organic rice culture MK 157 were conducted in various Panchayaths of Kannur and Kasaragode districts. Depending upon the farm ecosystem the production ranged from 5.1 tones to 5.5 tones/ha.
- **Large scale demonstration trialsof newly released saline tolerant Kaipad rice varieties** & rejuvenation of Kaipad rice tract: Demonstration trials of newly released saline tolerant Kaipad rice varieties namely, 'Ezhome-1', 'Ezhome-2' &'Ezhome-3'were done in various Kaipad fields of Kannur and Kasaragode districts in fallow lands and thus rejuvenated the naturally organic Kaipad trct. Further trials were done in Pokkali tracts in Ernakulam district.
- **Testing suitability of *Kaipad* varieties/ cultures in non-saline flooded tracts** : In North Kerala, vast area of wetland is kept uncultivated during first crop season due to flooded/ submerged condition. During the Kharif season long duration *Kaipad* varieties/ cultures namely 'Ezhome -1' and Culture JO 532-1(Ezhome-4) were raised in non-saline flooded tract of Pallikkara Panchayath of Kasaragode district along with Jaya variety which the farmers use to cultivate there but destroys when there is severe flood.

  There was water stagnation about three weeks, five days after sowing. When the water drained away all the three entries seen destroyed, but later, the variety ' Ezhome-1' and 'Culture JO 532-1 ' (Ezhome-4') rejuvenated and recorded a grain yield of 3.5 and 3.8 tons/ha respectively. Jaya variety didn't rejuvenate.

5. Testing the suitability of rice varieties and cultures developed from North Kerala for upland cultivation:

The varieties and cultures developed from north Kerala were evaluated under various situations, soil types and different mode of raising, namely (i) Open rainfed upland with laterite soil – broad casted- Oraganic management, (ii) Rain fed Coconut garden, broad casted, sandy soil- organic management and (iii) Open rainfed upland with laterite soil – transplanted by giving spacing – POP local variety management Out of the varieties used except Vaishak all are non-lodging type.

Under open rainfed upland with laterite soil, broad casted and organically managed upland variety Vaishak gave good grain yield and straw yield. Among non-lodging varieties / cultures developed from North Kerala, for saline Kaipad soil, 'Ezhome-3' gives maximum grain yield followed by 'Ezhome-2' under open rainfed upland with laterite soil, broad casted and under organic management.

Under open rainfed upland with laterite soil, transplanted by giving spacing, and adopting POP for local variety management, Culture MK 157(Jaiva) and Vaishak gave maximum grain yield followed by 'Ezhome-3'. But maximum straw yield was exhibited by Culture JO 583. Under rainfed Coconut garden, broad casted, sandy soil, and under organic management 'Ezhome -3' performed well followed by 'Ezhome-2' for grain and straw yield.

6. **Large scale seed production of farmer participatory mode of high yielding rice varieties released from North Kerala:**

4774Kg of Truthfully Labelled Seeds of saline tolerant Ezhome rice varieties ('Ezhome-1', 'Ezhome-2','Ezhome-3' & 'Ezhome-4') were produced and distributed to farmers. The production capacity of 'Kaipad'- naturally organic sea coastal saline prone tract of north Kerala -could be enhanced to 60-70% by popularizing the use of high yielding varieties namely, 'Ezhome-1','Ezhome-2,' 'Ezhome-3' and 'Ezhome-4' developed by Kerala Agricultural University. Forty five traditional rice genotypes of North Kerala were collected and conserved. According to IFOAM, organic variety is an important link for success of organic farming along with suitable ecosystem. In the current study, for organic farming in ordinary non-saline wetlands, in addition to the organic rice variety-'Jaiva', the conventional rice varieties developed by Kerala Agricultural University, namely, 'Anashwara' and 'Dhanu', two photo sensitive long duration varieties and 'Aishwarya', a photo insensitive medium duration variety can be used for organic farming for short and medium term periods till enough organic varieties are developed and released. Identified organic varietal traits in rice namely, number of tillers plant^{-1} at harvest, number of productive tillers plant^{-1}, number of grains panicle^{-1} and straw yield plant^{-1}. Also identified parents for different organic varietal traits and flood tolerance, which will help in future breeding programmes for the development of organic varieties as well as flood tolerant varieties. Out of already released varieties from North Kerala, ' Ezhome-1' and ' Ezhome-4' were found to be suitable for non-saline flooded tracts , and 'Ezhome-3' and 'Ezhome-2' were found to be suitable for upland cultivation under organic management. A very good awareness was given to rice farmers about the newly developed organic rice varieties from North Kerala institutes of Kerala Agricultural University namely 'Ezhome-1', 'Ezhome-2' ,'Ezhome-3','Ezhome -4' and 'Jaiva' by conducting their demonstration trials in various Panchayaths of Kannur and Kasaragode districts.

7. Breeding tall high yielding rice varieties resistant / tolerant to salinity and flood for Oorumundakan tract

The study was undertaken at O.R.A.R.S, Kayamkulam to evolve a high yielding tall rice variety suited to the ill drained saline Oorumundakan tract to replace the traditional Oorumundakan local variety through intervarietal hybridization and mutation breeding.

Oorumundakan tract, the coastal saline belt of Onattukara which spreads in the two Taluks viz.Karthikappally of Alappuzha and Karungappally of Kollam Districts have an area of approximately 2000 ha of cultivated paddy land. Here salinity and waterlogging are the main problems. Salinity comes up to 5 ds m^{-1} during November-December and there will be waterlogging during North East Monsoon period. Salinity had a negative impact on a number of yield components including crop establishment, tillering and panicle emergence, formation of spikelets floret sterility, individual grain size etc. One improved variety, Sagara was released for cultivation for this tract during 1992 from Rice Research Station, Kayamkulam, which is a pureline selection from Oorumundakan local.

To develop a high yielding variety for this tract, the present project was started during 1992.Several crosses were made using OM-1 (Sagara) as the female parent and IR-42, Jaganath, Pankaj, IR-36, and H4 as the male parent. Mutation studies were also carried out by irradiating the seeds of OM-1 at different doses of gamma rays. Selections were made on the basis of duration, plant height, tolerance to salinity and flood and other yield attributing characters. The cultures 92-5-7 (OM-2), 91-44-1-3 (OM-3) and 91-4-5 (OM -4) were selected and compared in the Initial Evaluation Trial during 1997-98 with OM-1 (Sagara) as the check variety. OM-2 is a hybrid derivative of OM-1 x Pankaj, OM-2 is a mutant of Sagara and OM-3 is a hybrid derivative of OM-1 and H_4.

The results revealed that Culture 92-5-7 (OM-2) is a high yielding tall photosensitive variety with tolerance to salinity, waterlogging, major pests and diseases. The culture was released in State Variety Release Seed Sub Committee meeting held on 26-4-2015 as “Amritha”. Amritha is a hybrid derivative of Sagara and Pankaj.

Panicle of OM-2

Grains of OM-2

8. Pest and disease surveillance and Management in Kole lands

The study was undertaken at ARS, Mannuthy with the objectives of to establish monitoring, survelliance and rapid action service units for pest and disease outbreaks in the kole lands, to develop a pests and disease warnig service to avoid/reduce pest and disease outbreaks based on the constant monitoring of the biotic and abiotic factors through the fixed plot observation as well as the rapid roving surveys at periodic inervala in the different regions of the kole lands, to identify the hot spots of the endemic ,epidemic and sporadic pest species and disease pathogens and map them based on the geographical information system to enable the prediction and forewarning of the incidence, and monitoring of soil,plant,atmosphere and biotic changes with respect to climate and season of cropping in kole lands.

Regular interval analysis of soil were 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 activites and system of cultivation followed were also studied. Similarly pest and diease and physiological disorders were recorded and correction measures were adopted.Effectiveness of these corrective measures with respect to climate change were also evaluated. At the end of the project report, spatial changes in the soil, plant ,water and biota with respect to climate changes and system of cultivation will be recorded and documented.This help to develop a forewarning system for pest and diseases.CSIW officers can able to have a continous monitoring and recording of the productivity system and pest and diseases surveillance in kole lands and farmers reduce unscrupulous use of pesticides and fungicides and nonjudicial use of chemical fertilizers due to their intervention in kole lands. This enabled for the grass root level understanding of the constrains in kole land cultivation and to come out with management and technical outputs to overcome these situations. Observation on pest and disease build up with respect to varying practices of nutrition, water management, weather relation and land ecosystem were recorded. A monitoring, survelliance and rapid action service units for pests and disease outbreaks in the kole land was set up. Forewarnig system for pests and disease outbreaks in the kole lands based on data on crop parameters and weather data was developed.

9. Evolution of rice varieties having high grain and straw yield from interracial crosses of diverse origin

Seven superior cross combinations along with two local checks were evaluated at Agricultural Research Station, Mannuthy. Based on the grain and straw yield, the cultures C 26T (b), C 80 and C 28 were advanced to farm trials in kole areas of Thrissur. Farm trial was conducted in four kole padavus in Thrissur district and all the cultures performed better than the local check Jyothy with respect to grain and straw yield. The incidence of pests and diseases were also less in all the locations where the cultures were evaluated. C 80 was released as Manupriya and C 26T (b) was recommended for salinity tolerance test in kole areas in the ZREAC Workshop. Farm trial with C 26T (b) was conducted again at three locations susceptible to saline water intrusion. Performance of the culture was better than Jyothi in these areas. The culture was evaluated in Kaipad area and was found to be saline tolerant and gave grain yield of 3.5 t/ha in medium saline Kaipad area (2-4dS/cm). Due to short stature, it is not suitable for flooded Kaipad areas.

10. Standardization of media for tray nursery technique in rice

The study was undertaken at ARS, Mannuthy with the objective ofstandardization of media for tray nursery technique in rice and to evaluate its efficiency under field condition.

Experiment I: Standardization of media for tray nursery technique in rice

The media comprised of 80% RHC (Rice Husk Charcoal) +20% VC (Vermiculite), 60% RHC+20% soil+20% VC and 60% RHC+30% soil +10% VC were supierior with respect to growth characteristics of seedling viz. seedling height, biomass production, root length at the time of transplanting and number of normal seedlings. With respect to mat characteristics the mats with low weight were produced by the media of 80% RHC + 20% CC followed by 80% RHC + 20% VC. The mat strength was higher in the media of 80% RHC + 20% CC, 60% RHC+30% soil + 10% VC and 60% RHC + 30% soil +10% CC. The water holding capacity was found to be higher with the growing media of higher proportion of rice husk charcoal whereas these media recorded a lower bulk density compared to other media. The N and K content of the seedlings were higher in the media of 80% RHC+10% soil+10% VC where as the soil media recorded the higher P, Ca, Cu, and Zn contents of seedlings. The Mg, S and Fe contents were maximum in the media of 60% RHC + 20% soil + 20% VC. The media of 20% RHC + 70% soil + 10% VC recorded the highiest B content where as the Si content of seedling was maximum in the media od 80% RHC+20% soil. N,P, K, Mg, and S up take by the seedlings were maximum in the media 80% RHC+20% VC where as the soil media had higher P and Ca uptake by the seedlings. The media with 60% RHC + 20% soil + 20% VC recorded maximum S, Fe and B uptake where as the Mn uptake was highest in the medium of 80% RHC+20% CC. The soil media recorded maximum Cu and Zn uptake by the seedlings. The highest Si uptake was recorded in the media of 80% RHC + 20% soil. Even though the cost of nursery did not show significant variation due to different growing media, it was lower for 80% RHC+20% VC, 60% RHC + 30% soil +10% VC, 80% RHC+20% CC and 60% RHC + 30% soil + 10% CC compared to other media.

Experiment II: Field evaluation of best performing media from Experiment I

The number of hills planted per metre run was comparable in the entire nursery media studied. The number of seedling per hill varied from 3- 4 in the media of 80% RHC+20% VC, 60% RHC + 30% soil +10% VC and 80% RHC+20% CC. The number of missing hills per m^2 was lower in the nursery media of 80% RHC+20% VC, 60% RHC + 30% soil + 10% VC, 80% RHC+20% CC and 60% RHC + 30% soil + 10% CC . The plant population at planting was comparable in all the nursery media except the media of 60% RHC + 20% soil + 20% VC. The number of tillers per m^2 at 30 DAT was comparable in all the nursery media except 60% RHC + 20% soil + 20% VC . The number of tillers per m^2 at 60 DAT and at harvest were comparable in all the nursery media. The number of panicles per m^2, number of spikelets per panicle, number of filled grains per panicle, thousand grain weights and the spikelet sterility were remained unaltered due to different nursery media under field evaluation. The grain and staw yield and harvest index were not influenced by the different nuesery media evaluated. The content and uptake of nutrients *viz.* N, P and K by the crop also remained unaffected by different nursery media. The cost of cultivation was comparable in all the nursery media.

Concluded PG Projects

1. Performance of upland rice (*Oryza sativa* L.) as influenced by NK levels and FYM substitution

The Objective of the study is to find out the influence of different levels of N and K on growth and yield of upland rice, assessing the possibility of substitution of inorganic N by FYM. The treatment comprises different levels of N and K with and without substitution by FYM. Analysis of soil for NPK levels was done before the experiment to assess fertility status of soil.

The treatments had a significant influence on plant height at 60 DAS and at harvest stage. Among the treatments, T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) produced the tallest plants at 60 DAS and at harvest. The Highest tiller production was noticed when N applied at 120 kg ha^{-1}. At 60 DAS, the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) recorded the highest tiller number while, at harvest the treatment T_7 (120 kg N applied as 100% CF and 60 kg K_2O) produced highest tiller number. The LAI was significantly influenced by the treatments and application of 120 kg ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1}(T_9) gave the highest LAI. The highest Dry Matter Production (DMP) was recorded by the treatment T_9. Application of 120 kg N ha^{-1} with 50 per cent substituted by FYM and 60 kg K_2O ha^{-1} (T_9) registered highest number of productive tillers m^{-2}, panicle weight, panicle length, total spikelets $panicle^{-1}$, filled grains $panicle^{-1}$ and 1000 grain weight. The highest grain and straw yields were obtained with the application of 120 kg N ha^{-1} with 50 per cent substituted by FYM and 60 kg K_2O ha^{-1} (T_9) and was on par with 120 kg N ha^{-1} with 25 per cent substituted as FYM and 60 kg K_2O ha^{-1} (T_8). The treatment T_8 registered the highest harvest index. The highest net return and benefit cost ratio was registered with application of 120 kg N ha^{-1} with 25 per cent substituted by FYM and 60 kg K_2O ha^{-1}(T_8). It was concluded that the application of 120 kg N ha^{-1} with 25 per cent substituted as FYM and 60 kg K_2O ha^{-1} is recommended for farmers to get highest profit in upland rice.

2. Gene pyramiding for bacterial blight resistance in rice variety Uma

Ninety five BC_1F_1's formed the basis of present study. DNA of good quality and quantity was extracted from the 95 BC_1F_1's and their parents.STS marker RG 556 and functional marker xa5 SR were used to confirm the presence of the resistant allele of *xa5* gene in each of the backcross individuals. The amplified product of RG 556 when resolved on 1.5 per cent agarose gel did not produce any polymorphism between the parents and the backcross populations screened. The PCR products were therefore digested with restriction enzyme Dra1 and examined for specific amplicon polymorphism (SAP). Restriction digestion produced six fragments of size 128 bp, 514 bp, 587 bp, 624 bp, 650 bp and 836 bp associated with the resistant allele in the homozygous state in both the parents as well as all the BC_1F_1 plants analysed.

Similarly, foreground selection for the resistance gene *xa5* using the functional marker xa5SR, produced a 186 bp amplicon in both the parents as well as the BC_1F_1 plants analysed.

Foreground selection for the resistance gene xa13 was analysed using the STS marker RG 136 and functional marker xa13 pro. Similar to STS marker RG 556 linked to *xa5* gene, RG 136 linked to *xa13* did not produce any polymorphism among the population studied. Hence, restriction digestion of the PCR amplified product using enzyme Hinf1 was resorted to. Restriction digestion of the PCR product generated polymorphism between the parents, and the BC_1F_1s studied. Three amplicons of size 625 bp, 388 bp and 206 bp were detected in the resistant donor parent ISM, while, in the recurrent parent, three bands of size 868 bp, 388 bp and 206 bp were observed. Of the 95 BC_1F_1s studied, 92 BC_1F_1s carried the three alleles as observed in the recurrent parent Uma. Only three BC_1F_1individuals (Lane 17, 18 and 19, *i.e*., BC_1F_1 plant no. 8.3.2, plant no.8.3.3 and plant no. 8.3.9 respectively) carried the same allele as that of the donor parent.

Screening the BC_1F_1s with xa13 pro revealed the presence of 560 bp alleles in donor parent ISM while in the recurrent parent Uma an amplicon of size 328 bp was detected. Among the BC_1F_1s, in 92 plants xa13 pro amplified a 328 bp fragment similar to that found in the recurrent parent while in the plants in lane 17, 18 and 19, *i.e*., BC_1F_1 plant no. 8.3.2, plant no. 8.3.3 and plant no. 8.3.9 an amplified fragments of size 560 bp as in the donor parent was observed.

Ninety five BC_1F_1plants along with the parents were analysed for the presence of *Xa21* gene using the STS marker pTA 248. Three BC_1F_1individuals (lane 17, 18 and 19, *i.e*., BC_1F_1plant no. 8.3.2, plant no. 8.3.3 and plant no. 8.3.9 respectively) exhibited amplicons of size 855 bp as in the donor parent ISM.

The background profiling of the three R gene introgressed BC_1F_1 plants was done along with the donor parent ISM and the recurrent parent Uma using 22 rice microsatellite markers that were reported to exhibit polymorphism between the two parents Uma and ISM. All the three BC_1F_1s when analysed with the RM markers were found to exhibit the allele in the homozygous state as found in the donor parent ISM. Results indicated that the alleles of the donor parent were present in the three R-genes pyramided BC_1F_1s in the homozygous state for the all other 21 markers analysed.

However background profiling of the BC_1F_1 plant no. 8.3.2 with marker RM 307, revealed the presence of alleles from both the parents, ISM and Uma. This pointed out that plant no. 8.3.2 was heterozygous at RM 307 locus unlike the two R-gene pyramided BC_1F_1s (plants no. 8.3.3 and plant no. 8.3.9). Hence, the BC_1F_1 plant no. 8.3.2 could be expected to segregate for the allele in subsequent generation

The recovery of the recurrent parent genome in each of the three, R-genes introgressed BC_1F_1s (plant no 8.3.2, plant no. 8.3.3 and plant no. 8.3.9) was estimated from the results of the background profiling of theseplants using 22 markers used. The per cent recovery of recurrent parent was assessed through graphical genotyping software GGT version 2.0.

The results indicated that the percent recovery of recurrent parent genome varied among the three R-genes pyramided lines. The magnitude of recovery of recurrent parent genome was found to be higher in plant no 8.3.2 (23.90 %) while it was 21.80 per cent each, in plant no. 8.3.3 and plant no. 8.3.9.

Morphological characterization of each backcross individuals (BC_1F_1s**)** and the parents (donor parent ISM and recurrent parent Uma) was done to assess the variability existing in the population.Results indicated the presence of wide variability for the morphological characters across the BC_1F_1 population. The agronomic evaluation of the BC_1F_1 population for plant height, days to 50% flowering, leaf width, leaf blade length, number of productive tillers, panicle length, number of spikelets and grains per panicle, 1000 grain weight, grain length and width, decorticated grain length and width, grain and straw yield indicated the occurrence of segregants that were better than the parental genotypes while in a few genotypes the magnitude for the traits studied was found to be lower than that of the parental genotypes. For the traits like days to 50 per cent flowering, leaf blade length, grain and decorticated grain length, higher frequency of BC_1F_1 individuals resembling the donor parent ISM was observed while for most of the traits the population tended towards the recurrent parent.

The three R-genes pyramided BC_1F_1s was found to be intermediate between the two parents for characters like plant height, leaf blade length, panicle length, spikelets/panicle, grains/panicle and 1000 grain weight. However, all the three pyramided individuals were late in flowering compared to the recurrent parent Uma. Two of these genotypes *i.e.*, 8.3.2 (234days) and 8.3.3 (228 days) flowered later than the donor parent. The length of the leaf blade in these two genotypes was also found to be greater than that of the donor parent. However all the three introgressed individuals produced longer panicles than both the parents. Spikelets/ panicle and grains/panicle were very less for the three individuals. However, 1000 grain weight, grain length and width and decorticated grain length and width were almost similar to that of the recurrent parent Uma. The shape of the grain and kernel of the R-gene pyramids as per IRRI (1996) and DUS respectively was also medium as in Uma These plants also possessed red kernels unlike the white kernels of donor parent ISM. Hence it can be concluded that the three R-genes introgressed BC_1F_1s resembled the recurrent parent Uma with respect to grain and kernel characteristics.

Use of molecular markers closely linked to BB resistance along with phenotype based-selection in the present study has resulted in identification of three 3-R gene pyramided BC_1F_1s (plant no. 8.3.2, plant no. 8.3.3 and plant no. 8.3.9) from among a population of 95 BC_1F_1s.The three R-genes introgressed BC_1F_1s plants of variety Uma are expected to show resistance to the *Xoo* pathotypes prevalent in Kerala. Further backcrossing and selfing of the identified backcrossed individuals in combination with marker assisted evaluation of these lines for BB resistance will result in the production of advanced lines of Uma. Moreover, this will enable pathogen inoculation and disease scoring studies to ensure the presence of the three R-genes and also to assess the extent of resistance offered by the pyramided BC_1F_1plants to various strains of *Xoo* pathogen.

Ongoing Projects

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

   Collected, characterised and conserved improved high yielding rice varieties *viz*., Varadhan, DRR Dhan, and Dhanarasi and three local rice varieties from Wayanad.Molecular characterisation of nineteen germplasm accessions for BLB resistance was performed using STS Marker - RG 136, specific for *xa13* gene.The selected line of local aromatic landrace, Biriyani cheera (BC) exhibited 20 days earliness and other superior traits, compared to the check variety Gandhakasala (GS).

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

   Comparative yield trials of promising cultures were continued in Rabi 2015-16 in RBD with checks Jyothi, Swetha and Karuna. Out of the 18 cultures tested, 14 cultures were found to out yield Swetha and Karuna, the checks for medium and long duration respectively. Among these, 10 cultures were non lodging and high yielding. The cultures which showed consistent superior performance in last three years include Cultures 5(0614-1-6-21), 6 (0614-7-8-24), 9(0615-15-16-8), 10(0615-19-19-6-1), 13(0615-01-23-21), 14(0615-01-25-17), 15(0615-01-25-11) and 17(0615-20-24-2). These cultures are medium duration, non lodging, high yielding genotypes with high biomass, belonging to the crosses Pranava x Chettadi and Pranava x Vellari. Culture 7 (0614-10-14-7) could not be tested due to low seed quantity and hence the pure seed multiplication is carried out for testing the same during 2016-17. The cultures 5,7,9,10 and 17 will also be tested in AICRIP national testing.

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

   Exotic and indigenous rice varieties and cultures were collected from various sources and maintained.3 entries were added to the 647entries already maintained during the period making a total of 650 entries

4. **Evolution of semitall or dwarf types of tall Indica rice varieties.** Evaluation of progenies in M5 generation was under taken during Rabi 2015-16 with 9 mutant lines selected from M4 generation, comprising of 7 mutant strains of PTB 18 and 2 of PTB 21. Single plant selection was continued in segregating progeny blocks and 13 single plants were selected for further evaluation. Three mutant lines of PTB 18 (M2011-45-1-3-1, M2011-46-1-1-1 and M2011-46-1-1-2) were found to be uniform, semi tall and non lodging and hence were selected for preliminary yield trials during Rabi 2016-17.

5. **Breeding lodging resistant rice varieties for dry sowing conditions during virippu season**

   During 2015, F_3 generation of 28 crosses and F_2 generation of six crosses were evaluated and superior lines were selected from each cross.Identified superior lines will be advanced to subsequent generations and evaluated during next year.

6. Initial Variety Trials-ICAR

This experiment is conducted at RRS, Moncompu as part of the All India Co- Ordinated Rice Improvement Project where in the 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 2015-16 from the trials are furnished below.

6.1. Initial Variety Trial - Early (IVT-E-TP) Transplanted - ICAR

The trial was laid out in RBD with 64 entries and 2 replications. 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 IET No.25602(CR 2906-253-8) (4682kg/ha) followed by entry no IET No.25560 (UBKVR-66) (4571kg/ha.), IET No. 25584(RP 5940-96-7-2-1-1) (4453 kg/ha.), IET No. 25604(CR 3848-2-1-3-1-4) (4350kg/ha) and local check Prathyasa (3552kg/ha) respectively.

6.2. Initial Variety Trial-Biofortification

Observations were recorded on various characters like days to 50% flowering, plant height, plot yield, disease/pest attack etc. Among the entries, IET No. 25460 (CR 2915-1-1-3-1-B-6-2 B-1) recorded the highest grain yield of 6835 kg/ha followed by Gontra Bidan 3 (Check) with a per hectare yield of 6492 kg/ha. During the season the pest / disease incidence was low.

7. 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.

7.1. Advanced Variety Trials

The trial was laid out in RBD with 10 entries under report and 4 replications. Observation recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack etc.The highest grain yield was recorded by IET No.25672 (CR 3925-22-1) (7644Kg/ha) recorded the highest grain yield, followed by IET No. IR 81896-B-B-195 (DP) (7500kg).

7.2. Advanced Variety Trial-1-Early

The trial was laid out in RBD with 26 entries and 3 replications. 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 IET No. 24798 (HRI-184(Hybrid)) (5119Kg/ha) followed by US 314 (HC) (5038kg/ha.).

7.3. Advanced Variety Trial 2-Early

The highest grain yield was recorded by IET No.24075 (VNR-212 (Hybrid)) (5777kg/ha) followed by IET No 24082 (HRI-183 (Hybrid)) (4485kg/ha), PA 6129 (HC) (4400kg/ha) respectively.

7.4. Advanced Variety Trial- 2- Irrigated Mid Early

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

7.5. Advanced Variety Trial-1 Biofortification

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 entry no.3319 with an yield of 6925Kg/ha.

7.6. Advanced Variety Trial-2 Biofortification (AVT -2 Biofort)

The trial was laid out in RBD with 10 entries under report and 4 replications. Observation recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack etc.The highest grain yield was recorded by BPT 5204 (Check) (3935Kg/ha) recorded the highest grain yield, followed by local check Uma (3659kg).

8. 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.

8. 1. Initial Variety Trial(IVT - E - TP)

IVT - ETP is the first year testing trial for early group of rice entries under transplanted condition. During Kharif 2015, check varieties used were Gontra Bidhan (NC), PR 124 (HC), Anjali (RC) and Kanchana (LC). Among the 64 entries evaluated, national check variety Gontra Bidhan (7.7 t/ha) was the best yielding one. Other promising entries with > 6 t/ha yield were DRR Dhan 43, PR 124, IET Nos. 25557 (1012), 25601 (1060), 25591 (1049), 25574 (1030), 25585 (1042), 25568 (1024), 25569 (1025), 25560 (1015), 25554 (1009), 25552 (1007), 25604 (1063), 25548 (1003), 25551 (1006), 25573 (1029), 25592 (1050), 25602 (1061), and 25597 (1055).

8.2. Initial Variety Trial – Biofortification

IVT - Biofortification is the first year testing trial for rice entries biofortified with Iron and Zinc. During kharif 2015, check varieties used were BPT 5204 and DRRH-3 for yield whereas Kalanamak and Chittimuthyalu for micronutrient content. Among the 45 entries evaluated, IET nos. 25451(3411), 25443(3403) and 25452(3412) had >6 ton/ha grain yield, along with high content of both Zinc and Iron. Other promising entries with 5-5.6 t/ha yield and high micronutrient content were 25458 (3418), 25474 (3439), 25450 (3410), 25446 (3406), and 25467 (3430).

9. Advanced Variety Trials

As in the case of RRS, Moncompu, RARS, Pattambi also conducts Advanced Variety Trials 1 and 2 of different duration groups. 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.

9.1. Advanced Variety Trial 1 ((AVT-1 E TP)

AVT-1 E TP is the second year testing trial for early group of rice entries under transplanted condition. During Kharif 2015, check varieties used were Gontra Bidhan 3 (NC), Anjali (NC), DRR Dhan 43 (RC), US 314 (HC), and Kanchana (LC). Twenty seven entries were evaluated and the top yielding entries were 922 – IET 24053 (7.8 t/ha), 908 – IET 24746 (6.4 t/ha), 901 – IET 24058 (5.9 t/ha), 917 – IET 24741 (5.9 t/ha) and 914 – IET 24729 (5.8 t/ha). Local check Kanchana (6.5 t/ha) was the best among check varieties, followed by hybrid check US 314(6.1 t/ha).

9.2. Advanced Variety Trial 2-Early

AVT-2 E TP is the third year testing trial for early group of rice entries under transplanted condition. During Kharif 2015, check varieties used were Sahbhagidhan (NC), PA 6129 (HC), Tulasi (RC) and Kanchana (LC). Among the seventeen entries, 802 - IET 23949 (8.8 t/ha), 810 - IET 24705 (6.1 t/ha) and 805 - IET 23392 (5.6 t/ha) outyielded the best check variety 809 - Tulasi (5.3 t/ha).

Evaluation of AICRIP Best entry : AICRIP Best entry IET 22095 had 108 days duration and produced 6.8 t/ha grain yield, whereas the check varieties Jaya (120 days) and Swetha (125 days) had 7 and 5.5 t/ha respectively. Pooled grain yield of these three entries for 2014 and 2015 were 6.2, 5.6 and 5.3 t/ha respectively.

9.3. Advanced Variety Trial-1 Biofortification

AVT-1 Biofortification is the second year testing trial for rice entries biofortified with Iron and Zinc. During kharif 2015, check varieties used were BPT 5204 and DRRH 3 for yield whereas Kalanamak and Chittimuthyalu for micronutrient content. Among the thirty entries, promising ones with high zinc and iron content along with >5 ton/ha yield were IET Nos. 24771 (3301), 24440 (3305), 24555 (3308), 24557 (3324), 24291 (3329) and 24779 (3326).

9.4. Advanced Variety Trial-2 Biofortification

AVT-2 biofortification is the third year testing trial for rice entries biofortified with Iron and Zinc. During kharif 2015, check varieties used were IR 64 and BPT 5204 for yield whereas Kalanamak and Chittimuthyalu for micronutrient content.Among the eleven entries, IET 23834 (3203) was the best entry with short bold grains, 4.8 ppm Iron content, 23 ppm Zinc content, and 4.1 t/ha yield among the eleven entries.

10. Breeding for high yielding varieties of rice with resistance to important rice diseases of Kuttanad

The nucleus seeds of the promising cultures M87-5, M 95-1 were multiplied. These two cultures are high yielding medium duration red kernelled cultures with tolerance to diseases like Sheath blight, Bacterial blight, False smut etc.

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

During 2015-16 cultures KAUM 236-1-2-1-1-1 (MO 15/IET 20020) and KAUM 240-1-3-2-2-2 (MO 9/ IET 20034) were the best performers with respect to grain yield. These cultures have given grain yield comparable with the check variety Uma. All the cultures showed resistant reaction to sheath blight while the check variety was moderately resistant to sheath blight.

12. Evolving high yielding multiple resistant rice varieties through gene pyramiding

Promising entries from the crosses Swetha x Kuruka, Pranava x Chettadi, Pranava x Vellari were screened for pests like stem borer, leaf folder and whorl maggot during 2015-16. Among the tested cultures 0627-2-11, 0627-2-14, 0614-1-6-21, 0614-10-14-17 and 0615-15-16-8 exhibited moderate resistance to major pests screened.

13. Breeding for drought tolerant rice varieties suitable for upland ecosystem

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

14. Physiological and biochemical basis of heat tolerance in rice.

Evaluation of 39 traditional rice genotypes for high temperature stress were completed. 21 selected entries from AICRIP trials are under evaluation process.

15. Evaluation of fungicides against brown spot

New fungicide formulations ICF-110 (Tricyclazole 45% + Hexaconazole 10% WG) -1.0g/l, Merger (Tricyclazole 18% + Mancozeb 62% WP) - 2.5g/l, Tricyclazole 75% WP- 0.6 g/l, Hexaconazole 5% EC - 2.0 ml/l and Companion (Mancozeb 63% WP + Carbendazim 12% WP) - 1.5 g/l were evaluated against brown spot. The fungicides Hexaconazole 5% EC (8.3 %) and ICF-110 (10.0%) are effective for the management of brown spot.

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

In all the trials conducted KAUM 112-10-6-5 & KAUM 109-1-2-1 were found promising with respect to yield and tolerance to gall midge biotype 5. Quality of the cultures were analysed. The cultures recorded high hulling, milling and head rice recovery percentage. The release proposal of the culture KAUM 112-10-6-5 was submitted and approved by the Variety Evaluation Committee. The culture has been released by the State Seed Sub-committee as MO 22 (Shreyas) on 25-04-2015. KAUM 109-1-2-1 was promoted to AVT 1-IME in which it was tested with 27 entries in 37 locations.Trials to fix the fertiliser requirement of the culture are taken up at RRS, Moncompu during 2014-15 and continuing for conclusive results.The culture KAUM 109-1-2-1 has been recommended by 34th ZREAC for release.

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

During 2015-16 KAUM 164-1, KAUM 174-6 and KAUM 173-3 were found to be promising with respect to grain yield. These cultures were on par with the check variety Uma in grain yield.

18. Conservation and Utilisation of Rice Biodiversity in Kuttanad

Thirty traditional varieties were collected and added to the germplasm. One hundred and eighty traditional varieties collected were planted in the field for evaluation of morphological characters. Morphological characterisation based on Rice Descriptor of one hundred and fifty fifty accessions have been completed and these accessions were evaluated under various stresses to identify varieties showing resistance/ tolerance reaction.

Artificial screening for diseases were done for fifty varieties and the results indictaed that 1 variety ie., Thondi showed resistance to BLB (score- 0), 28 vars. resistant to sheath blight (score-3), and most of the varieties were resistant with 0 score for sheath rot, brown spot and glume discoloration.

19. GoK Plan Scheme- Network project on Seeds and Planting materials production

A total quantity of 3026.48kg Breeder seeds, 933.5kg Foundation seeds and 4204.3kg Truthfully labelled seeds were produced during 2015-16 period and distributed to various agencies, depatmental farms, farmers etc.

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

Three cultures viz.Culture 23, 28 and 35 were recommended for farm trial in the ZREAC meeting. It was also recommended to compare the cultures with Hraswa selection HS 16.at RARS, Kumarakom. Seed multiplication for conducting farm trial was done during 2015-16 mundakan season

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

During 2015 -16 CYT was conducted with 4 cultures along with 3 checks. During the additional crop 2015 KAU M 230-2-1-1 from the cross Remya/Resmi recorded the highest grain yield of 7562 kg/ha followed by KAU M 230-1-2-1(7143kg.). Both these cultures out yielded the check variety Uma. During Punja 2015-16 heavy incidence of stem borer attack was noticed. Hence in general grain yield was poor. The highest yielder was KAU M 230-1-2-1 which was closely followed by KAU M230-2-1-1. KAU M 230-1-1-1 showed high susceptibility to stem borer with a score of 7.0

22. Breeding for high yielding rice varieties with submergence tolerance

During 2015-16, CYT was conducted with 2 selected cultures. KAUM 179-1 and KAUM 180-2 were found to be on par with each other and the check variety Uma. During 2015 additional crop KAUM 179-1 has given the highest grain yield of 6674 kg/ha. During Punja 2015-16, the same culture KAUM 179-1 stood first in grain yield which is found to be on par with the check variety Uma. During 2015-16 Punja high incidence of stem borer attack occurred. KAU M 179-1 and KAU M 180-2 have showed low score value compared to the check varieties

23. Testing the adaptability and stability of high yielding varieties of rice in Onattukara

Field demonstration was done with MDU-5, Athira and Aiswarya during virippu and all the three varieties recorded a grain yield equal to or higher than the check variety Onam. High yielding varieties identified for mundakan season are Aruna and ADT 16.

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

During 2015-16, 4 cultures selected from PYT were advanced to CYT along with the check variety Njavara Yellow. Njavara 2 and Njavara 24 A were found to the highest yielders with a per ha yield of 2175kg and 2107kg respectively. 12 mutant cultures which attained uniformity were advanced to Initial Evaluation Trial. Among them NYM 3-1-1-1 performed better when compared to other cultures

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

During 2015-16, 5 promising cultures were carried forward to comparative yield trial. During additional crop 2015 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 (9521 kg). These cultures out yielded the check variety Uma in grain yield (9219kg/ha.). During Puncha 2015-16 also cul. KAUM 242-4-2-1-1-1 ranked first in yield.

26. Breeding for Hybrids in Rice

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 was continued in Rabi 2015-16 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). Jyothi, Uma and Kanchana were used as checks. Short duration hybrid KRH4 yielded highest with 7.4 t/ha and showed 8.2% superiority over the best short duration varietal check Kanchana. Hybrids with high yield and acceptable cooking quality identified from the study will be released for the state. Hybrid seed production package for Kerala is to be finalized utilizing the parental lines of superior hybrids identified from the study.

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

The presence of AMF *Glomus sp.* is confirmed up to the harvest stage in roots of paddy by staining technique in both direct seeded and transplanted condition in wetlands of Kuttanad.

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

Experiment was conducted in farmers field at Purakkad. 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, high in available P and K 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 11.21 %. The genotypes responsive to liming were 27P- 63, PA 6444, US 312, Karishma, Shreyas, Uma and 109-1-2 1and genotypes tolerant to native soil acidity were PA 6444, HRI-174,109-1-2-1, Karishma and Uma as they recorded superior yields in comparison to other genotypes in the treatment without liming.

Scoring index for iron toxicity tolerance indicated that V10 (RP-5715-350-3-11-2-1B) manifested acute iron toxicity symptoms. V 1 (GSR119), V4 (DRR DHAN 39), V13 (27 P 22), V 14 (27 P36), V 15 (27 P 63), V16 (PA 6444), V17 (US 312), V18 (HRI 174), V21 (Uma) and V22 (Shreyas) proved to be the most tolerant varieties to iron toxicity with a scoring index of 1.

The varieties 27 P 63, PA 6444 and US 312 recorded minimum iron toxicity scores coupled with the higher grain yields. The highest yield was observed with NPK + liming treatment for the genotype 27P- 63 (7.51 t/ha). Among KAU varieties, Karishma recorded highest grain yield (6.64 t/ha) with minimum iron toxicity score under limed condition followed by Shreyas and Uma and 109-1-2-1, Karishma and Uma were tolerant to native soil acidity also. Liming significantly increased the grain yield and reduced the iron toxicity symptoms in these varieties. PA6444 performed better both under limed and unlimed condit1ions.

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

During Kharif 2015, soil analysis data revealed that the soil was clay textured, exhibiting strongly acidic pH with a high content of organic carbon. The soil was medium in available N and K with very high level of available P and deficient in available Ca, Mg and B. Available Zn, Cu and Mn were sufficient with very high level of available Fe.Transplanted rice recorded significantly higher grain yield (3.37 t/ha) compared to Direct Sown Rice (2.98 t ha^{-1}). Transplanted rice recorded 13 per cent higher yield than direct sown rice. Straw yield also recorded the same trend with 10 per cent higher straw yield in transplanted rice production system. With regard to nutrient sources, 100 % RDF+Zn+S recorded the highest grain and straw yield (3.44 t/ha and 4.97 t/ha) and was on par with all other treatments except 100 % NPK through organics, which recorded the lowest yield.

During Puncha 2015, Transplanted rice recorded significantly higher grain yield (2.69 t/ha) compared to Direct Sown Rice (2.06 t ha^{-1}). Straw yield also recorded the same trend with higher straw yield in transplanted rice production system. With regard to nutrient sources, 100 % RDF +50 % through organics recorded the highest grain and straw yield (2.51 t ha^{-1} and 3.61 t ha^{-1}) among all the five treatments and was on par with all other treatments except 100 % NPK through organics, which recorded the lowest yield.

Data on change in soil organic carbon stock indicated that conjunctive use of organics and inorganics increased the soil organic carbon stock whereas 100 % NPK through organics alone decreased the soil organic carbon stock. This indicates that soil test based nutrient management also needs the use of organic matter addition to sustain soil quality.

30. Gall Midge Biotype monitoring trial (GMBT)

During Kharif 2015, the trial was carried out with 17 entries. The evaluations revealed that three entries (DUKONG 1, W 1263, ARC 5984) were found highly resistant against gall midge.

31. Gall midge screening trial (GMS)

During Kharif 2015, the trial was carried out with 155 entries. The evaluations revealed that twenty five entries were found highly resistant without gall midge damage.

32. Insecticide evaluation trial

Rynaxypr 20 SC @ 150 ml/ha treated plots had no dead heart incidence indicating that it was highly effective in controlling stem borer at 50 DAT and 90 DAT. Flubendiamide + Thiacloprid 48% SC @250 ml/ha treated plots showed the lowest incidence of BPH at 70 DAT. Flubendiamide 480 SC @ 50 ml/ha treated plots showed the lowest incidence of Leaf folder at 70 DAT. Maximum yield was observed in plots treated with Rynaxypr 20 SC (Coragen) @ 150 ml/ha

33. Botanical Insecticide Evaluation Trial (BIET)

Neemzal 1.0% EC@ 2.0 ml/ha treated plots had no dead heart incidence indicating that it was highly effective in controlling stem borer at 30 DAT. Neem oil @ 5ml/ha treated plots showed the lowest incidence of BPH at 70 DAT. Multineem 0.03% EC@ 5.0 ml/ha treated plots showed the lowest incidence of Leaf folder at 50 DAT. Maximum yield was observed in plots treated with Neem oil @ 5ml/ha.

34. Gall midge Screening Trial (GMS)

Among 120 entries screened, only one entry Kavya showed moderate resistance with '0' and 2.50 per cent silver shoot damage at 30 and 50 days after transplanting while entries showed higher gall midge damage above 10% at both days after transplanting.

35. National Screening Nursery

Among 141 entries screened, IET 24951 showed multiple resistances to stem borer and leaffolder. Hybrids IET 24926, IET 24935 and Sureksha showed less damage of gallmidge and hybrids IET 24941 showed nil damage to blue beetle. For stem borer and leaffolder, entries IET 24938, IET 24957, IET 24954, 24887 and IET 24891, IET 24937, IET 24944 Aganni showed less damage respectively.

36. Insecticides Evaluation Trial

During Kharif'2015, five insecticides *viz.*,DPX-RAB, flubendiamide + thiacloprid, flubediamide, thiacloprid and rynaxypyr were tested with dianotefuran as a check insecticide. Among the insecticides, rynaxypyr @150ml/ha were found effective against stem borer damage (dead heart and white ear) while flubendiamide were found effective only to dead heart damage by stem borer. Flubendiamide @ 50 ml/ha and rynaxpyr @150ml/ha were found effective to gallmidge at 30 DAT. No significant difference among the treatments was observed in reducing whorlmaggot and blue beetle damage. Incidence of leaf folder was found low in flubendiamide + thiacloprid @250ml/ha, flubendiamide @ 50 ml/ha and rynaxpyr @150ml/ha treated plots. There was no significant difference among the treatments in grain yield.

37. National Screening Nursery

Two experiments viz., National Screening Nursery 1(NSN-1) and National Screening Nursery- 2(NSN-II) are taken up under this programme.

38. National Screening Nursery 1

NSN – 1 trial was constituted with 364entries and screening was done against gall midge, leaf folder and stem borer. Three entries (NSN-I 224, NSN I 225, NSN I 345) were found highly resistant without gall midge damage.

39. National Screening Nursery-2

NSN – II trial was constituted with 725 entries and screening was done against gall midge, leaf folder and stem borer. Eight entries were found highly resistant without gall midge damage

40. Gall Midge Special Screening Trial

The trial was carried out with 120 entries. The evaluations revealed that eighteen entries were found highly resistant without gall midge damage

41. Gall midge biotype screening trial

The gallmidge population was characterized as biotype 5, only two entries W1263 ('0' damage) and Kavya (< 10% silver shoot) while all the other differentials showed high susceptibility.

42. Pesticides compatibility trial

During Kharif 2015, two insecticides, chlorantraniliprole and dinotefuran were tested alone as well as in combination with two fungicides carbendazim + mancozeb and validamycin. The results showed that the insecticides chorantraniliprole alone as well as in combination with fungicides were found effective against stem borer damage (dead heart and white ear). Chorantraniliprole alone as well as in combination with fungicides carbendazim + mancozeb and validamycin were found effective against leaf folder. The incidence of sheath blight disease was low in fungicides treatments as well as in combination with insecticides Chlorantraniliprole and dinotefuran treated plots. Highest grain yield was obtained in chorantraniliprole + validamycin (3630 kg/ha) followed by chorantraniliprole + carbendazim + mancozeb (3420 lg/ha) and chorantraniliprole (3114 kg/ha) treated plots respectively.

43. Pest Survey Reports (RRS, Moncompu)

An area of 2660 ha of agricultural land Covered during the year 2015. About 1375 numbers of farmers field also visited. Champakulam, Ramakary, Nedumudi, Moncompu, Kainakary, Pulikunnu, Muttar, Veliyanadu Kavalam,Cheruthana, Purakadu,Nilamperoor, Ambalappuzha, Nedumudi, Thalvadi, Haripad etc are the blocks visited which are affected by Major pests such as Case worm-(*Nymphula depunctalis),* Yellow Stem Borer- *(Scirpophaga incertulas),*Leaf folder-(*Cnaphalocrocis medinalis),*Brown Plant Hopper- (*Nilaparvata lugens),* Gall Midge- (*Orseolia oryzae),* Rice Thrips-(*Baliothrips biformis),*Yellow hairy caterpillar-(*Psalis pennatula)*Black bug-*(Scotinophara bispinosa),* Leaf miner – (*Hydrellia griseola)* etc.

Farmers are advised to apply Buprofezin 25% SC @ 330ml/acre 150-200 L against BPH, Flubendiamide 125g of 20 WDG/ha against Stem borer & case worm, Feterra 4 Kg/ acreagainst Gall Midge, Acephate 1kg/ha / Flubendiamide 20%WG 125g/ha. against Yellow Hairy caterpillar, Chlorantraniliprole (0.4% G) 4 Kg/acre against Leaf miner, Acephate 2

gm/l. or Contaf 2 ml/l. against Leaf folder, Feterra 4 Kg/ acre against Black Bug and also advised to Flood to submerge the infested field for 24 hours if infestation is severe. Where ever submergence is not possible, apply Imidacloprid 17.8% SL 125ml/ha against Rice leaf Thrips.

44. Light Trap Collection of Insects (LT)

Peak population of YSB (255) was recorded during March 2015. During this month, max. temp (33.5) min. temp (29.5), RH (98%) and SSH(4.5) were recorded. Peak population of Leaf folder (42) were recorded January. During this month, max. temp (31.6) min. temp(23.4), RH(82%) and SSH(8.1) were recorded.High population of GLH(Green leaf Hopper) occurred during Kharif season with peak population(*N. v* 438 + *N. n* 398)during December. During this month, max.temp (33.0) min. temp (23.0), RH(88%) and SSH(8) were recorded.

High population of BPH(Brown Plant hopper) occurred during June with peak population(350). During this month, max.temp (32.0) min. temp(23.8), RH(95%) and SSH(8.8) were recorded. Peak population of water beetle (419) were recorded in January. During this month, max. temp (31.6) min. temp (23.4), RH (82%) and SSH (8.1) were recorded.

45. Monitoring of Pests and their NaturalEnemies (MPNE)

Three species of stem borers viz, the Yellow Stemborer (*Scirpophaga incertulas*); White Stemborer (*Scirpophaga nivella*) and the Pink Stemborer (*Sesamia inferens*) were reported. The parasitoid species collected were Trichogramma, Telenomus and Tetrastichus sp. In the case of gall midge the mean parasitisation was 28.3%.

46. National Hybrid Screening Nursery (NHSN)

NHSN trial was constituted with 141 entries and screening was done against gall midge, leaf folder and stem borer. Nine entries were found highly resistant without gall midge damage.

47. Screening for Sheath blight and Sheath rot resistance to diseases

The project was taken up with the objective of assessing the resistance of National level pre releasing entries to major diseases with special emphasis upon field reaction including disease spread and to evaluate sheath blight and sheath rot resistance. The NSN-1, NSN-2, National Hybrid Screening Nursery (NHSN) and Donor Screening Nursery (DSN) entries from DRR along with appropriate local susceptible and resistant checks were screened. During Kharif 2015, 1382 AICRIP entries (354 NSN-1, 715 NSN-2, 131 NHSN, 182 DSN cultures) were screened against sheath blight and bacterial leaf blight incidence. Out of 1382 cultures 689 entries shows their multiple resistance against sheath blight and bacterial leaf blight incidence. DuringRabi 2015-16, 1382 AICRIP entries (354 NSN-1, 715 NSN-2, 131 NHSN, 182 DSN cultures) were screened against sheath blight and bacterial leaf blight incidence. Out of 1382 cultures 252 entries shows their multiple resistance against sheath blight and bacterial leaf blight incidence.

48. Screening for sheath blight resistance

In National Screening Nursery 1 (NSN1), 354 entries were screened for sheath blight resistance. Among these one entry showed resistance reaction to sheath blight with score 1.The National Screening Nursery 2 (NSN-2) consisted of 715 entries of which 13 entries showed resistance reaction with score 1. None of the 131 entries tested in National Hybrid Screening Nursery (NHSN) showed resistance reaction. Out of the 182 entries tested in the Donor screening nursery (DSN) no entries showed resistance reaction with score 1. Six entries showed moderate resistance to sheath blight with score 3.

49. Screening for leaf blast resistance

Out of the 354 entries screened in National Screening Nursery 1 (NSN1), 62 entries showed resistance to leaf blast with score 1. In the National Screening Nursery 2 (NSN-II) 715 entries were screened, of which 94 entries showed resistance reaction with score 1. Out of the 131 entries tested in National Hybrid Screening Nursery (NHSN), 45 entries were resistant with score 1.In the Donor screening nursery (DSN), out of the 182 entries tested 42 were resistant to blast with score 1.

50. Disease Observation Nursery

During Kharif 2015, moderately high incidence of BLB was observed in the normal sown crop (June 3rd week) of Shreyas (14.36 %) and Uma (12.03 %). It was very low in early sown (4th of May) and late sown (2nd week of July).Sheath blight was low in early and normal sown crop of above varieties when compared to late sown crop. During Rabi 2015-16, Sheath blight disease was low in the early and late sown crop of Shreyas (0.77 % and 1.81%) and Uma (0.83% and 1.11%).In Normal sown crop the incidence was high in Uma (15.79%) followed by Shreyas(12.86%). Bacterial leaf blight incidence was low in late sown crop of Shreyas (1.81%) followed by Uma (1.24%). It was moderately high in normal sown crop of Uma (12.25%) and Shreyas (9.80%).

51. Evaluation of fungicides to location specific diseases - AICRIP

During Kharif 2015, the combination fungicide Mancozeb 63% WP+Carbendazim 12%WP (Companion) @1.5g/l. was found superior in controlling sheath blight disease. During Rabi 2015-16, the combination fungicide Mancozeb 63% WP+ Carbendazim 12%WP (Companion) @1.5g/l was found superior in controlling sheath blight disease followed by Carbendazim 50% WP @1g/l and Tricyclazole 18% + Mancozeb 62% WP @2.5 g/l and others were on par except untreated check.

a. Effect of fungicides on Sheath blight severity (%) and grain yield

During Kharif 2015, out of seven commercially available fungicides tested, Hexaconazole 5% EC @ 2 ml/ lit was found superior against grain discolouration disease followed by Mancozeb 63% + Carbendazim 12% WP (Companion)@1.5g/l and Tricyclazole 45% + Hexaconazole 10% WG (ICF-110) @1g/l. Others were on par except Mancozeb 75% WP@2g/l. There was no significant difference in the grain yield data. During Rabi 2015-16, Out of seven commercially available fungicides tested, Tricyclazole 45% + Hexaconazole 10%WG (ICF110) @ 1g/l was found superior against grain discolouration disease in rice and it was on par with all the fungicides.

52. Production Oriented Survey

Production oriented survey was conducted in Alappuzha and Kottayam districts at booting to maturity stages from Kharif 2015 to Rabi 2015-16.The survey covered three taulks in Alappuzha District, viz., Ambalapuzha, Kuttanad, and Pattanakkad, while in Kottayam district two taluks namely Kottayam and Vaikom could be surveyed. 4078 acres of rice area was surveyed at Alappuzha district during Kharif 2015.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). Vytilla 6, Chettivirippu, Pokkali, Mundakan, etc. were cultivated in some area of northern region of the district.

Moderate incidence of the biotic constraints like sheath blight, sheath rot, bacterial leaf blight, false smut, leaf blast, brown plant hopper, leaf folder, ,case worm, rice bug and rats were observed during the season. Most of the farmers applied bleaching powder@2kg/acrein irrigation water to prevent the BLB spread. Fresh cowdung extract @ 20g/lit was applied in many padasekarams to the BLB. Fungicides like Bavistin (200 g/acre), Contaf (250 ml/acre), Taqat (250 g/acre), and Folicur (250 ml/acre) were commonly sprayed against sheath blight and other foliar diseases like brown leaf spot and sheath rot. Tilt, Zineb and Mancozeb were used as foliar spray at the time of flowering stage against false smut disease and Streptocycline @ 6g/acre was used against Bacterial leaf blight disease control. The systemic fungicides Cartap (5kg/acre), Azataf (250g/acre), Takumi (50ml/acre), Fame (20 ml/acre) Regent (5kg/acre), Startin (350 ml) and Indane (5kg/acre) were applied against leaf folder and stem borer. Tatamida (60ml/acre) and Applaud (120ml/acre) were sprayed to control Brown plant hopper.The biocontrol agent *Pseudomonas fluroscens* was very much popular among the organic farmers. It was used as seed, soil and foliar application to control the major rice diseases.

3072 acres of rice area was surveyed during Kharif 2015 in Kottayam District. The predominant cropping sequences were rice-fallow, rice-rice and fallow-rice. The predominant varieties in the district were Uma and Jyothi. Moderate weed infestation was noticed in almost all the areas during the visit. *Cyperus difformis, C.iria, Echinochloa crusgalli, Sacolepis interrupta* etc were the major weeds observed. *Echinochloa spp* was the important weed found in both Alappuzha and Kottayam districts along with wild rice. The farmers used weedicides were Nominee gold (120 ml/acre), Almix (8 g/acre), 2,4 D (500 g/acre) and Sathi (80g/acre) for all broad leaf weeds and selective weedicide Clincher (320 ml/acre) against Echinochloa spp. *Echinochloa spp* and wild rice infestation was very high in some padasekharams of Vaikom block.

Moderate incidence of the biotic constraints like sheath blight, sheath rot, bacterial leaf blight, brown plant hopper, leaf folder, black bug were observed during the season. Severe incidence of BLB was found in Varambinakam padam of Champakulam block. Moderate incidence of bacterial leaf blight was observed in Govendapadam, Manakarypadam of Champakkulam block, etc. Moderate incidence of the biotic constraints like sheath blight, bacterial leaf blight, leaf blast, brown spot, brown plant hopper, leaf folder, and stem borer were observed in many padasekharams of Thalayazham village. Severe incidence of BLB

was found in Palliyarpadinjaru padam of Aymanam village and Sheath blight was found in Madapallikkadu padashekaram of Thiruvarppu village. Out of 3072 acres surveyed area, 345 acres were severely affected with BLB and sheath blight disease was serious in 175 acres of rice area.

3145 acres of rice area was surveyed during Rabi 2015-16 in Kottayam District. Moderate weed infestation was noticed in almost all the areas during the visit. *Cyperus difformis, C.iria, Echinochloa crusgalli, Sacolepis interrupta*etc were the major weeds observed. *Echinochloa spp* was the important weed found in both Alappuzha and Kottayam districts along with wild rice. The farmers used weedicides were Nominee gold (120 ml/acre), Almix (8 g/acre), 2,4 D (500 g/acre) and Sathi (80g/acre) for all broad leaf weeds and selective weedicide Clincher (320 ml/acre) against Echinochloa spp. *Echinochloa spp* and wild rice infestation was very high in some padasekharams of Vaikom block.The populations of weeds were moderate. The farmers used weedicides were Nominee gold (120 ml/acre), Almix (8 g/acre), 2,4 D (500 g/acre), Sathi (80g/acre), Tarak for all broad leaf weeds and the selective weedicide Clincher(320 ml/acre) was used against Echinochloa spp. Weeds like *Cyperusdifformis, C.iria, Echinochloacrusgalli, Sacolepisinterrupta*etc were the major weeds observed during the visit. *Echinochloaspp* was the major weed found in Alappuzha along with wild rice infestation. The wild rice problem was increased past3-4 years due to introduction of combined harvester, tenant farmers ignorance to remove the weeds in time and not follow the proper land preparation methods.

53. Field monitoring of virulences in Xa*nthamonas oryzae* pv. *Oryzae*(Pattambi)

Virulence analysis of bacterial blight pathogen of rice *Xanthomonas oryzae* pv *oryzae* has been carried out using 22 near isogenic lines (IRBB background) with different bacterial blight resistance genes singly or in combinations. The differentials DV 85, Ajaya, TN1 and Improved Samab Mashuri (RP Bio 226) were also included. Three NILs, IRBB58 (Xa 4 + Xa 13 + Xa 21), IRBB59 (Xa 5 + Xa 13 + Xa 21), IRBB60 (Xa 4 + Xa 5 + Xa 13 + Xa 21) and RP Bio - 226 (Xa 5 + Xa 13 + Xa 21) showed moderate resistance.

54. Field monitoring of virulence in *Pyricularia grisea* (Pattambi)

Virulence analysis of blast pathogen of rice *Pyricularia grisea* on 25 differentials/ NILs revealed that Tetep (Score 1), Raminad STR-3 (Score 1.5), Tadukan and Dular (Score 2) were resistant to local isolate of blast pathogen .

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

26 AICRIP entries were tested against BLB pathogen during Kharif 2015 and Rabi2015-16. Among them 25 entries showed their multiple resistances against native BLB pathogen in both the seasons.

56. Integrated disease management (Sheath blight) (RARS, Pattambi)

IDM practices involving host plant resistance, nutrient management, seed treatment and need based application of fungicide was evaluated against sheath blight of rice. IDM package involved seed treatment with Carbendazim (2g/kg seed) and nutrient management in nursery (Application of FYM 1t/1000m^2 ; Basal dose –NPK 20:50:50 kg/ha; Top dressing – 25kg N/ha) and main field (Application of compost 10t/ha; NPK 90:45:45kg/ha; N- 3 splits, P –

basal and K – 2 splits and a spray of Hexaconazole 5 EC - 2 ml/l at the time of appearance of disease). Varieties included were Jyothi (Susceptible), Aiswarya (Moderately resistant) and Aathira (Moderately resistant). Among the three varieties sheath blight severity was significantly less in Aathira and Aiswarya compared to Jyothi. Disease severity in IDM plots was significantly lower than that in non IDM plots in all the three varieties. The sheath blight severity was significantly less in IDM plots of Aathira and Aiswarya compared to Jyothi. But significant reduction in disease severity was recorded even in susceptible variety Jyothi when IDM was practiced.

57. Integrated disease management in rice (RRS, Moncompu)

During Kharif 2015, Sheath blight disease was moderately low in Uma variety (11.57%) with FYM + PGPR1 + *Psuedomonas* (seed+soil+foliar+Neemcake+Neem based chemical treated plot. Blast was moderate in Jyothi (17.13%) with FYM + PGPR1 + *Psuedomonas* (seed+soil+foliar+Neemcake+Neem based chemical followed by Uma (12.49%). Leaf folder attack was very low in Uma (3.05%). BLB disease was very low in Prathyasa (8.83%) variety when compare to Uma and Jyothi in the organic management plot. During Rabi 2015-16, Sheath blight and BLB diseases were low in Uma variety (16.41% and 13.46%) in the FYM + PGPR1 + *Pseudomonas* (seed+soil+foliar)+Neemcake+Neem based chemical treated plot when compared to Jyothi and Prathyasa. Blast disease was very low in Prathyasa (8.45%) variety than the others.

58. Identification and field evaluation of promising bio-control agents against major rice pests in Kuttanad.

During 2015, the smaller rice leaf miner, *Hydrellia griseola* Fallen (Diptera: Ephydridae) was identified as a new pest affecting rice seedlings from 7 to 25 DAS. This is the first confirmed report of the presence of this pest in India. Three parasitoids obtained from the pupae of smaller rice leaf miner was identified as *Trichomalopsis* sp. (Hymenoptera: Pteromalidae), *Chorebus sp*. (Hymenoptera: Braconidae) and a new species of parasitoid of genus *Neochrysocharis* (Hymenoptera: Eulophidae) respectively. The larval parasitoids, *Ischnojoppa* sp. and *Amauromorpha* sp. (Hymenoptera: Ichneumonidae) parasitizing the larvae of Yellow Stem Borer were identified. The parasitoid obtained from the Rice Case worm (*Nymphula depunctalis*) was identified as *Dolichogenideasp*. (Hymenoptera: Braconidae).

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

Survey was conducted in different parts of Kuttanad and plant samples were collected from 98 locations of lower Kuttanad regions. The special medium Tryptic Soya Agar was made for culturing and isolating endophytic bacteria. Bacterial leaf blight pathogen was isolated from Mangalam Kayal and Sheath blight pathogen was isolated from Moncompu location for pathogenicity studies. 96 endophytic *Pseudomonas spp.* and 68 endophytic*Bacillus spp.* were isolated. Seven *Bacillus spp.* isolated from Padachal (B 33), Thayenkari chirayakam (B 38), Kuruvapadasekaram (B 40), Ezhamkari (B 42), Kuruvapadasekaram (B 47), Ampalapadam (B 48), Chunkam (B 51) and five *Pseudomonas spp*. from Kollamkari (P 69), Ampalapadam

(P 70), Vezhatharpadasekaram (P 75), Madathil padam (P 78), Iramallur (P 79) were found effective against sheath blight and BLB pathogen under *in vitro* condition.

Five efficient cultures namely B 15, B17, B 33, B 42, P 69 were sent to Cashew Exporting Promotion Council Laboratory and Technical Division, Kollam and the identification report was received. Out of 5 cultures, three were reported as biocontrol agents namely *Bacillus atrophaeus* (B 15 and B 17) and *Bacillus licheniformis* (B 33).Further studies of the cultures are in progress.

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

The mean grain yield after harvest was increased by 9% by Imidazol application and Siloxol treatment enhanced the mean grain yield for all the varieties by >8% over the control.

61. Evaluation of rice genotypes for terminal heat tolerance

Twenty five entries (Nine hybrids and 16 HYV) were evaluated for high temperature stress from seedling stage to maturity. Highest yield was produced by IET 23356 followed by IET 23354, PA 6129, IET 29347, IET 23339 and Somali under elevated temperatures. Based on their heat tolerance indices entries like DRRH 106, 107, IET 24075, Somali, IET23979, IET 24082 could be selected as relatively heat tolerant genotypes.

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

Fifty one entries were evaluated under rain-fed upland condition, among the entries, IET 25112 recorded the highest yield (6523 Kg/ha) compared to the local check, Vaishakh (3250 Kg/ha).

63. Physiological characterization of rice genotypes for multiple abiotic stress resistance (PTB)

Among the Twenty entries, IET 23216, 24674, 23335 and all 5 selections of NICRA were found to germinate well under the abiotic stress situations. The severity of the abiotic stress in inhibiting seed germination was in the order of anaerobic / submergence, followed by Nacl and Water stress.The order of abiotic stress inhibiting shoot length was Aaerobic, Nacl and water stress respectively. The grand mean root length recorded in the 20 genotypes was 8.2cm across the locations but in PTB and REWA center, it was 17.4 cm which was relatively higher over the other locations. All the NICRA selections and IET lines under the study responded positively and relatively superior. Seedling vigour's mean was 1044 and maximum was 1283 (IR 82635-B-B-47-1).

64. Establishment of Plant Health Clinic at RRS Moncompu.

During 2015-16, the clinic visited 13,074 acres of rice (1.3 acres of coconut farms, 1.5 acres of Banana field and1acre of vegetable crops (Cow pea, Amaranthus, Bitter gourd, Bottle gourd etc) were visited by the clinic. Fields were visited by giving priority to the severity of attack, extent of damage caused by the pest and disease to the crop and also to the fields which were in immediate need for a remedy in accordance with the soil conditions. Soil, Pests and Plant samples were collected from padasekharams coming under 12 blocks viz; Alappuzha,Ambalappuzha, Champakulam, Ramankary, Harippad, Mavelikkara, Chengannur, in Alappuzha district and Kottayam, Vaikkom and Kaduthuruthy in Kottayam district. Total 18 panchayaths were visited during the period from April 2015 to March 2016.

Diseases like Sheath blight, BLB, Sheath rot and Glume discoloration were observed in rice from panicle initiation to maturity stages at many padasekaharams of Alappuzha and Kottayam districts. Severe incidence of BLB was found in Chembady Chakkaomkari padam (125ha) of Champakulam block during Kharif 2015. Changakary chirayakam, Puthenkari arunooru padam of Champakkulam block were also affected with moderate incidence of sheath blight, glume discoloration, and brown spot. Moderate incidence of the biotic constraints like sheath blight, bacterial leaf blight, leaf blast, brown spot, were observed in many padasekharams of Thalayazham village of Kottayam district. Severe incidence of BLB was found in moonumvelikkarikil padam of Vaikkom (156ha) block.

Severe incidence of BLB was found in Madapallikkadu padam (126 ha) of Ettumanoor block and Vanam south padam of Vaikom block in Kottayam district. Moderate incidence of bacterial leaf blight were observed in Panakary padam,padavinakam padam of Pulikeezhu block in Pathanamthitta district and Vezhatharupadam of Mavelikkara block, Nanekkadupadam of Ampalappuzha block, in Alappuzha district during Rabi 2015-16.

Leaf folder, Rice bug, Stem borer were found to be the common pests in most of the padasekharams visited during the study. Among the pests attacking rice, leaf folder caused much damage between 30 and 60 days after transplanting.In case of severe infestation, the leaf margins and tips became dry and crop gives a whitish appearance. The damage is more conspicuous during active tillering to booting stage. Massive destruction to the crop mainly occurred due to Brown Plant Hopper infestation. Climatic conditions such as high temperature, low humidity and low rainfall favours BPH infestation.

Soil nutrient status showed differences in different fields. Organic carbon status was high in all the soil samples analysed. 80% of samples are moderately /slightly acidic (pH 5.5-6.5). Available P and K status were high in most of the samples analysed. Available Zn and Cu contents were adequate while Boron status was deficient in all the locations. Ca and Mg were found to be low and S content comes in high range. Available K status was low in Achanaryputhankary padasekharams (50 DAS) of Veeyapuram panchayath coming under Haripad block and in Edasserrykonam padasekharams (33 DAS) of Ramankary panchayath in Ramankary block.

65. Development of molecular markers in rice associated with genes responsible for salinity tolerance, exploring new genetic variations and development of rice cultivars with strong tolerance to salinity through molecular breeding. (Pilicode)

a) Validation of Saltol Markers in newly identified salt tolerant Germplasm lines of Kerala

Newly identified photo insensitive traditional rice genotypes for salinity tolerance namely ‘Kuthiru’, ‘Orkayama’ and ‘Kuttoosan’ were screened preliminarily with 12 SALTOL markers. The genotype’ Kuthiru’ has 42% non-Pokkali type alleles, ‘Orkayama’ has 67% non-Pokkali type alleles and ‘Kuttoosan’ has 58% non-Pokkali type alleles. Among the newly identified saline tolerant traditional genotypes, the most distant one from Pokkali is ‘Orkayama’ followed by ‘Kuttoosan’ and ‘Kuthiru’.

The commercially released saline tolerant rice varieties namely 'Ezhome-1', and 'Ezhome-3', and pre-release genotypes namely JK 59 and JK 15 developed through hybridization using the traditional saline tolerant genotype 'Kuthiru' as male parent has 42%, 50%, 50%, 50% non-Pokkali type alleles respectively.

The commercially released saline tolerant rice varieties namely 'Ezhome-2', and 'Ezhome-4', and pre-release genotype namely JO 583 developed through hybridization using the traditional saline tolerant genotype 'Orkayama' as male parent has 58%, 83%, 58% non-Pokkali type alleles respectively.

b) Screening for parental polymorphism for one type of mapping population- Orkayama x IR28

Out of two new genetic resources for salinity tolerance in rice namely 'Orkayama' and 'Kuthiru 'which are traditional land races of North Kerala, in previous year's study through screening with SALTOL markers, it was revealed that the genetic mechanism of salinity tolerance in 'Kuthiru' is similar to that of Pokkali genotype, but it is different in 'Orkayama' genotype. Hence hybridization of 'Orkayama' was done with saline susceptible 'IR 28' in last year for production of mapping population. DNA of saline tolerant Orkayama and saline susceptible IR 28 were screened with 58numbers of SSR primers to find out parental polymorphism. Out of 58 SSR markers screened for parental polymorphism, the markers RM11757 500bp, RM 25022 $_{175bp}$, RM 7643$_{175,}$ RM 10115$_{200bp,}$ and RM 26063$_{120bp}$ showed polymorphism with presence of amplicon in saline tolerant 'Orkayama' genotype. At the same time the SSR markers RM 12713 $_{250bp,}$ RM 228 $_{150bp,}$ and RM 547 $_{280bp}$ showed polymorphism with absence of amplicon in saline tolerant 'Orkayama' and presence in susceptible genotype.

c) Genotyping of mapping population of Orkayama x IR 28 and IR 28 x Orkayama

DNA isolation and screening of progenies of mapping population with markers showed polymorphism between parents Orkayama and IR 28.

d) F_2 mapping population of IR 29 x Ezhome-2

The F_2 generation of the mapping population using a high yielding non- lodging saline tolerant rice variety namely 'Ezhome -2' as saline tolerant parent and IR 29 as saline susceptible parent produced during last year was raised during this year. 'Ezhome -2' is a saline tolerant high yielding rice genotype derived from the newly identified traditional saline tolerant genotype namely 'Orkayama' whose salinity tolerance mechanism is found to be different from that of Pokkali. The crop is in the field.

e) Screening for parental polymorphism for second type of mapping population- IR 29 x Ezhome -2:

DNA of saline tolerant 'Ezhome-2' and saline susceptible IR 29 were screened with 58 numbers of SSR primers to find out parental polymorphism. Out of 58 SSR markers screened for parental polymorphism, the markers RM12713$_{225bp}$, RM5356$_{125bp}$, RM122$_{180bp}$, RM20224$_{125bp}$, RM10115$_{180bp,}$ RM26063$_{100bp}$, and RM490$_{200bp}$ showed polymorphism with presence of amplicon in saline tolerant 'Ezhome-2' genotype. At the

same time the SSR markers RM11008 $_{100bp}$ and RM 243_{100bp} showed polymorphism with absence of amplicon in saline tolerant ‘‘Ezhome-2’ and presence in susceptible genotype.

f) Field screening of saline tolerant rice genotypes in saline Kaipad field for various physiological and salinity tolerance traits.

The salinity index yield characteristics namely grain yield, biomass, sterility %, physiological traits namely content of Na, K, Ca and ratio of Na/K in root, sheath, stem, leaves at vegetative stage and Na, K, Ca and ratio Na/K in root, sheath, stem, leaves and flowers at flowering stage were estimated by growing 15 saline tolerant genotypes of various geographical origin in replicated trial in saline sea coastal field condition. Out of 23 genotypes raised in saline field during kharif season, two traditional genotypes namely ‘Orpandy’ and ‘Kandorkutty’ which are photo sensitive did not flower even though survived. The genotype CSR 30 and CO 47 didn’t survive in Kaipad field.

Identification of two more additional resources for salinity tolerance. Based on survival % and yield in saline field condition, two more traditional land races namely, ‘ Kuttosan’ (a photo insensitive genotype) and ‘ Punchakayama’(a photo sensitive genotype) were identified as new genetic resources for salinity tolerance.

g) Validation of the already indicated SSR marker RM 165 from previous study: The SSR marker RM 165_{200}bp was indicated as a putative marker in the previous study, when a collection of rice genotypes were screened with a large number of SSR markers. The newly identified saline tolerant traditional genotypes along with their derivatives were screened with this marker. It was found that this marker is present in the traditional genotype ‘Kuthiru’, ‘Pokkali’ and in the derived varieties, ‘Ezhome -1’, ‘Ezhome-4’, and in pre-release genotypes, JO 583, JK 59 and JK 15.

66. Advanced rice breeding cum seed production centre (Pilicode)

a) Germplasm collection of traditional rice genotypes of North Kerala

Collected nine more numbers of traditional rice germplasm from North Kerala and multiplied. Including last years collection, deposited 39 traditional rice genotypes of North Kerala in NBPGR, New Delhi.

b) Evaluation of rice genotypes under organic management during rabi season

Out of 65 rice genotypes evaluated under organic management during rabi season in organic rice farmers’ field, considering grain yield and other organic varietal traits ‘Jaiva’, the first organic rice variety released by Kerala Agricultural University for non saline wetlands, developed based on the concepts and strategies of organic plant breeding ranked first followed by the organic pre release culture MK 115.

Out of 99 varieties of Kerala Agricultural University developed for conventional farming in ordinary wetland using chemical fertilizers, 32 varieties were evaluated under organic management. The conventional varieties which can be considered for organic farming for short and medium term periods are, photo sensitive long duration varieties ‘Anashwara’ and Dhanu, and photo insensitive medium duration variety ‘Aishwarya’.

Out of eighteen growth and yield parameters studied under organic management, four parameters namely, number of tillers plant^{-1} at harvest, number of productive tillers plant^{-1}, number of grains panicle^{-1} and straw yield plant^{-1} showed both positive significant correlation and direct effect with grain yield plant^{-1}. Hence these four characters can be considered as organic varietal yield component traits.

Parents for different organic varietal traits are varieties 'Kanakom', 'Dhanu', 'Anashwara', 'Jaiva', Culture MK-115, 'Makam', 'Remanika' and 'Vytilla-4' for straw yield plant^{-1}, Badhra', 'Dhanu', 'Anashwara', ' Makam' and 'Jaiva' for number of productive tillers plant^{-1}, 'Dhanu', 'Anashwara' and 'Badhra' for number of tillers plant^{-1} at harvest, 'Mahsuri' for number of grains panicle^{-1}, the genotypes 'CO-47', a Coimbatore variety, 'Jaiva' - the organic variety of Kerala Agricultural University, 'Valankunhivithu' a traditional land race of Kerala and Culture MK-115 for volume expansion ratio, and 'Pusa Basmathi' an aromatic rice variety, followed by 'Ezhome-3', 'Culture MK115', 'Dhanu', 'Jaiva', 'Gandakasala', 'Mahsuri', 'Asha', 'Haryana Basmathi', 'Swarnaprabha', and 'Aishwarya' for good cooking qualities. The genotypes that can be selected as parents for tolerance to major pests are, 'Anashwara', Athira, 'Mahsuri', 'Dhanu', 'Culture Mk115', 'Remya', and 'Culture JK15'. The parents that can be selected for tolerance to major diseases are 'Jaiva', 'Kasthuri', 'Pusa Basmathi', 'Anashwara', 'Ayirankana' , 'CO-47' 'Kuthiru' and 'Karishma'. Validation through artificial screening is necessary.

c) Evaluation of rice genotypes under organic management during Kharif season

One hundred and seventy six numbers of rice genotypes were evaluated during 2015 Kharif season under organic management. The materials include 54 traditional genotypes, 73 conventional varieties released by Kerala Agricultural University, 20 national/ international genotypes, five organic varieties released by Kerala Agricultural University, and 24 organic cultures of Kerala Agricultural University. In addition to scientific evaluation, farmer participatory evaluation was also done. Observations were taken on various morphological, physiological and cooking qualities. Tabulation work is in progress.

67. Evolution of high yielding rice varieties suitable for Pokkali tract of Northern Kerala through farmer's participatory breeding approach (KAU plan project) (Pilicode)

The state committee on variety release held on 25.04.2015 Technically approved the release of the first ever high yielding organic rice variety of Kerala Agricultural University for non saline wetland christened as ' JAIVA',and release of one more high yielding variety for the saline prone naturally organic Kaipad rice tract of North Kerala christened as 'Ezhome-4'. Maintenance of all released varieties / pre-release cultures from North Kerala through breeder seed production programme is in progress.

The pre release cultures JK 14, JK 59, MK 115and JK71 were grown in farm trial in the organic wetland of Arayidam Padasekharam of Mayyil Panchayath during Rabi season of 2015. The grain and straw yield performance along with other characteristics are given in table below.

Area – 5 cents for each culture

Name of culture	Av.No. of tillers /plant	Av.Height (cm)	Grains/panicle	Grain yield (kg/ha)	Remarks
JK 59	9.5	1.34	120	5400	Lodging
JK 71	8.5	1.37	100	5800	Non lodging
MK 115	7.5	1.43	103	6100	Lodging, Cattle prefer straw of this more than others
JK 14	7.0	1.32	120	6200	Lodging
Jaiva	9.0	1.27	125	6400	Non lodging

As a result of series of discussion between Kerala Government with 'Malabar Kaipad Farmers' Society' (MKFS) and local governing bodies, Government has decided to form a new agency for the comprehensive development of Kaipad tract of North Kerala in the name KADS(Kaipad Area Development Society) which is awaiting for government order. As a result of convincement of Kerala Government and Central Government the relevance of development of naturally organic Kaipad tract at the present global scenario of organic farming, Agriculture Production Commissioner and Joint secretary of central Agriculture Minister separately visited the tract. APC visit later led to infrastructural work to Kaipad by KLDC for 10.0 crore. Visit of Joint secretary led to submission of a comprehensive network project to ICAR involving various related state and central institutes for the over all development of Kaipad tract and there by enhancement of organic rice production from Kerala.

68. Adaptability testing of high yieldling rice varieties in kole lands

During 2015-16, rice varieties Shreyas and Prathyasha, recently released from RRS, Moncompu along with popular varieties Uma and Jyothi were raised in kole lands for adaptability testing. All varieties performed well and in terms of grain yield, all were on par. But the new varieties showed tendency for lodging under kole land situation. During 2015-16, rice varieties Shreyas and Prathyahsa, recently released from RRS Moncompu along with popular varieties Uma and Jyothi were raised in kole land for adaptability testing.All varieties performed well and in terms of grain yield, all were on par. But the new varieties showed tendency for lodging under kole land situation.

69. Organic pest management in upland rice of Onattukara

i. Survey on the incidence of pests and diseases in upland rice of Onattukara from ten selected locations

A survey was conducted at ten selected locations of Onattukara where upland rice was raised. The rice varieties *viz*., Onam, Bhagya, Uma, Jyothy and Njavara were used for upland cultivation. The stage of the crop ranged from tillering to grain filling stage.

Though there was very low incidence of stem borer attack, thrips and leaf roller attack ranged from no incidence to moderate incidence. Similarly leaf spot, blast and glume discoloration diseases ranged from no incidence to moderate incidence. No severe incidence of any of the pests or diseases was observed

ii. Production of bicontrol agents and organic pesticides

Production of bio control agents like *P. fluorescens, B. bassiana, B. bassiana* ITCC 6063, *Lecanicillium lecanii*, trichocards and organic pesticides like dasagavya, fish jaggery extract and jeevamrutham were prepared for experiment purpose, farm use and distribution to farmers

iii. Conducting experiment in upland for drawing out an IPM strategy against the major pests and diseases of upland rice.

An experiment was conducted in the upland area of the station using the rice variety Bhagya in a randomized Block design with 11 treatments replicated thrice. The treatments used were entomopathogens and organic pesticides in various combinations. Spraying with 1% azadirachtin (0.004%) at tillering and milky stage (T2) and Dasagavya 3% at tillering and milky stage(T3) gave cent percent reduction in dead heart symptoms. Dasagavya 3% at tillering and milky stage (T3) recorded significantly low white earhead symptoms.

Application of Jeevamruthum 5% at tillering stage + fish jaggery extract at milky stage(T7) and Dasagavya 3% at tillering stage + fish jaggery extract at milky stage(T8) gave cent percent control of leaf roller attack at 5days after first treatment.

Though all the treatments were significantly superior over control,1% azadirachtin 0.004% at tillering stage+ fish jaggery extract at milky stage (T6)recorded the lowest incidence of thrips damage.

Spraying with Dasagavya 3% at tillering and at milky stage (T3) and Dasagavya 3% at tillering stage + fish jaggery extract at milky stage (T7) recorded significant reduction in rice bug population. The highest grain yield was recorded in treatments T3 andT6.

Ongoing PG Project

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

The objective of the programme is to detect linkage between markers and genomic region influencing iron toxicity tolerance in native rice genotype through bulk segregant analysis (BSA)

Polymorphism at molecular level between the genotypes PGC (Cul-8709) and PGC (Tulasi) the most susceptible and resistant parents respectively to iron toxicity were ascertained by genotyping them with 338 simple sequence repeats (SSR) markers. The 338 rice microsatellites markers selected for the parental polymorphism study comprised of 36 markers each distributed on each chromosome of 1 and 2 while 28, each were distributed on the 3rd and 4th linkage group, Twenty nine markers each were linked to chromosome number 5 and 6. Others included 25, 27, 17, 21, 30 and 32 numbers located on Chromosome 7, 8, 9, 10, 11 and 12 respectively.

Thirty seven markers were identified to differentiate the two parents. These 37 polymorphic rice microsatellites markers (SSR markers) were found to be distributed over all 12 linkage groups of rice varying between one marker located on chromosome 7, two each on chromosome 3, 4, 6, three each were located on chromosome 1, 5, 8, 11 and 12, five each on

chromosome 2, 9 and 10. The parental survey revealed 10.95 per cent polymorphism between the two parents (Tulasi and Cul-8709) used in the present study.

The F_1s obtained by hybridizing genotype Tulasi (PGC 14) was found to be most tolerant to iron stress (800ppm of Fe) with the most susceptible genotype Cul-8709 (PGC 31). They were raised and selfed to produce F_2 generation for conduct of Bulk generation analysis (BSA).

Name of the Project Coordination Group (02)

Spices and Plantation Crops (including palms)

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

Concluded Projects: 3 Nos
Ongoing Projects: 34 Nos

Concluded Projects

1. **Development of technologies including alternative for banned pesticides for the management of pests and diseases of major crops in Kerala - Black Pepper**

   For the management of *Phytophthora* foot rot in black pepper spraying and drenching with Fenamidon (10%) + Mancozeb (50 %) @ 0.2 % was the most effective fungicide closely followed by Copper hydroxide 77% WP @ 0.2 %. Soil application of talc based formulation of PGPM mix @ 50 g/vine and foliar spray at 2% concentration was equally effective as that of chemical fungicides and could be recommended as an alternative strategy for combating *Phytophthora* foot rot in black pepper in organic cultivation**.**

2. **Fertilizer application in high density cashew plantation**

   Pooled analysis data for 10 years revealed that tree densities and fertilizer doses did not significantly influence any of the growth parameters. Analysis of pooled data for 2012-16 showed that duration of flowering (days), flowering laterals/panicle, sex ratio, cashew apple weight, annual nut yield (per tree yield) and cumulative nut yield per tree was non-significant with respect to different levels of spacing and different levels of fertilizer doses. Economic analysis of the data on cost of cultivation and returns showed that the highest density with lowest doses of fertilizer was found more economical than other treatments. It was concluded that high density planting at a spacing of 6m x 4m and 5m x 4m with a fertilizer dose of NPK @ 75:25:25 kg per ha is economical and can be recommended to farmers, for getting good returns.

3. **Analysis of inbreeding depression in West Coast Tall coconut (*Cocos nucifera* L.)**

   With the intention of developing inbred line in coconut, the programme was initiated by selecting the eighteen WCT palms and developed S_1 generation. The S_1 plants were selfed and sibmated to produce the S_2 progenies and the seedlings are planted at RARS Pilicode in replicated trial. This served the present experimental material to characterize and analyze inbreeding depression in S_2 palms and to study the effect of continued selfing and sibmating to produce S_3 generation from S2 palms of West Coast Tall (WCT). Vegetative, reproductive and nut characters were recorded in S_2 WCT families and seedling characters in S3 families.

   The analysis of variance revealed significant differences among the twelve families of six groups of WCT for all the characters studied. The tallest palms were observed in IVS_2-2 and IAS_2-2 and was on par with the WCT. The shortest palms were recorded from IIS_2-1 and $IIIS_2$-2 but taller than dwarfs. In general the sibmated families were showing more tall stature indicating heterotic behavior.

   Inbreeding depression studied for S_2 nut yield and its attributes. The family IIS_2-2 and VS_2-1 expressed positive inbreeding depression for palm height and internodal length, but no inbreeding depression for stem girth. The leaf characteristics also exhibited positive inbreeding depression in S_2.

   The S_3 germination showed that germination percentage was low in all the families (less than 50%) indicating the operation of deleterious effect of inbreeding in S_3 seed nuts. The semi-tall seedlings were more in selfed and talls in sibmated families of S_3. The percentage of occurrence of stouter collar girth was more in S_3. The leaf production was moderate in all the

S_3 seedlings of selfed and four sibmated families. Both the third and fifth leaves, the length, breadth and petiole length showed moderate values.

The germination percentage revealed positive inbreeding depression in all the selfed families of 12 families. The molecular study using the promising inbreds in each family was done using 10 primers. Among the primers, highly polymorphic bands between the tall and dwarf were noticed by the OPBA 03 and OPAU 03. The primer OPAW 19 has identified specific for the dwarfs, inbred IBS_3-1 and $IIIS_3$-1 and also noticed the similarities of the family IAS_3-1 with the WCT, CGD, COD, and inbred IBS_3-1. The analysis by the primers signifies that the family $IIIS_3$-1 was unique.

Ongoing projects

1. **Germplasm collection, characterization, evaluation and conservation in Black Pepper**

   At present 290 cultivated types, 54 wild types and 3 exotic types of black pepper are being maintained in the Panniyur Research Station. The survey work was carried out and 9 new genotypes were collected during the year.
   During the year 2015, the genotypes PRS 64, PRS 154 and PRS 137 were the top yielders. PRS 64 ranked first with 4.29 kg green berry yield and 1480 spikes/vine. Spike length was maximum for PRS 155 (15.1 cm). The number of developed berries / spike was more for PRS 137 (49.0). 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 - Black Pepper**

   The hybrids PRS160 and PRS 161 were found to be promising with mean green berry yield of 4.35 kg/vine and 3.99 kg/vine respectively. Number of spikes /vine was 489 and 463 for PRS 160 and PRS 161 respectively. Spike length was maximum for PRS 161 (20.0 cm).

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

   The seedlings of PRS 4 x PRS 8, P 1 x PRS 78 and P1 x PRS 48 are planted. The hybridization of P1 x PRS 64 and P1 x PRS 4 were carried out during the year

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

   The trial was started during 2007. During 2015, HB 20052 (PRS) and Acc. No 53 (Sirsi) recorded the highest green berry yield of 3.0 kg/vine and 2.97 kg/vine respectively. The highest plant height was recorded for HP 39 and Panniyur 1 (4.7 m).

5. **Evaluation of grafts, orthotropic and runner shoots in black pepper**
   The trial was started during 2011. During 2015, the highest plant height (4.54 m) and green berry yield (3.60 kg) were recorded by runners of Panniyur 1 grafted on *Piper colubrinum.*

6. **Standardization of drip fertigation in black pepper**
   The trial was started in 2012-13. During 2015-16, different treatments did not show any significant difference with respect to yield. However, among the different treatments T_5 (50 RDF + 8 l drip) recorded comparatively higher green berry yield of 2.34 kg/vine and followed by T_3 (100 RDF + 8 l drip) where yield recorded was 2.29 kg/vine. Observations on disease intensity showed that in T_2 *i.e*. 100% RDF 2/3 as basin+ 1/3 through drip (8 l) weekly

in summer, the disease was significantly low (13.4%) and a better plant stand was noticed and followed by T_1 (100% RDF full as basin application + Conventional irrigation) and T_5 (50% RDF through drip (8 l) weekly) where disease intensity recorded were 21.2 and 22.2% respectively. As the amount of fertilizer applied though drip was increased *i.e.* in T_3 (100% RDF through drip (8 l) weekly), disease was also much high (36.6%).

7. **Black pepper based mixed cropping system for sustainable productivity and food security**

   The trial was started during 2013-14. During 2015-16, good yield was obtained from the intercrops in black pepper garden except arrowroot and tapioca. Colocasia (T1) yielded 3.0 kg, Elephant foot yam (T3) – 7.99 Kg, Greater yam (T5) – 6.5 Kg and Pineapple – 3.5 kg from the interspace of 4 x 2 m spacing between black pepper. Due to severe wild animal attack tapioca and arrowroot was lost completely.

8. **Biological Management of slow wilt in black pepper**

   All the treatments were significantly superior to control in reducing yellowing due to slow decline disease in black pepper during 2015. Among the various biocontrol agents tested, intensity of disease was minimum recorded (7.5%) in T_1 (*Trichoderma viride* + Neem cake @ 2 kg/vine). Same result was also recorded in T_3 *(Pochonia chlamydosporia* multiplied in partially decomposed farm yard manure and applied @ 2 Kg/vine and drenched with *P. fluorescens* @ 2%). This was followed by T_2 -the application of *T. viride* + soil drenching with *P. fluorescens* (11.9%) and T_4 – *Pochonia chlamydosporia* @ 50 g/vine (14.4%) and were on par. The effect of these treatments was also statistically on par with T_5 and T_6 where chemical control measures were applied

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

   Results showed that under organic farming PS 27 had the highest number of tillers(including productive tillers) and panicles per clump. SI registered maximum tiller height (152.7 cm) followed by ICRI 2 (152.6 cm) and PV1 (152.2 cm). PV1 recorded the highest fresh (2823.93 g plant -1) and dry (449.12 g plant -1) yield followed by ICRI-2. The occurrence of pests such as thrips (3.34) and stem borer (0.78) and azhukal disease incidence (0.51) was found to be less in PV1 compared to other varieties. Pest and disease incidence was more in variety PV2 even though they are considerable yielders.

10. **Coordinated Varietal Trial 2006 – Series VI - Cardamom**

    Observations on plant growth parameters showed significant differences among accessions studied (eg.) vine column height, leaf length and leaf width.

11. **Coordinated Varietal Trial 2007/2009 - Series VI- Cardamom**

    All the plant growth parameters evaluated viz., plant height, leaf length, leaf width and number of tillers per clump showed significant differences among the accessions tested. The data revealed that incidence of shoot borer was severe for the accession PV2 (3.33), however they recorded maximum plant height (303.23), leaf length (66.41), leaf width (12.86) and intermodal length (11.267) followed by MCC346. The maximum number of panicle (21.407)

and panicle length (52.723 cm) was observed in MCC346. The no of capsules/ panicle was more in IC547167 (19.18). The accession SKP104 recorded the lowest growth parameters, but the attack of shoot borer was less for this.

12. 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 Jeevamruta + *Azospirillum* (10g/clump) + 10g, PSB/clump+ *Trichoderma* 10/clump (T8) resulted in the highest fresh yield (2393.6g plant $^{-1}$) which is on par with application of recommended dose of CPC 15 t/ha (2392.904 g plant $^{-1}$). The incidence of thrips and *azhukal* disease was also less in the treatment T8. There is no significant difference among treatments with regard to 100 capsule weight and stem borer attack

13. Liming in cardamom

The result showed that application of Dolomite 2 kg/plant gives more plant height (321.38 cm), tiller/clump (12.013) and more capsule/ panicle (31.547). Application of Dolomite @ 2 kg/plant was found to be the best treatment with highest wet (2667.427g/plant) and dry capsule (941g/plant) yield. The incidence of pest and disease was also less for this treatment compared to other treatments. The effect of liming on dry weight of capsule was found to be non-significant. The next best treatment was for burnt lime @1 kg/plant which was on par with waste lime@ 2 kg/plant

14. Germplasm collection, characterization, evaluation and conservation- Cardamom

Among the top ten high yielding accessions, HY14 has superior performance with regard to biometric characters during the year 2015-16 followed by PS1XGG. HY15 has reported higher *azhukal* incidence (6.07 %). HY14 showed more tolerance to thrips (0.25 %) incidence) while HY 6 reported a maximum incidence of thrips (2.17 %). HY-14 was superior in all biometric traits than others tested. Among top 10 high yielding accessions, HY14 has registered a maximum wet (2718.7 g/plant) and dry capsule yield (454g/plant) followed by PS1XGG and HY 13. HY12 reported highest *azhukal*incidence (1.88%), while the highest yielder (HY14) has showed no incidence or symptoms of *azhukal* disease. In addition to this, HY11 also exhibited higher tolerance to thrips (3.05% incidence). Variation in disease incidence was greater among the top accessions than those of insect pest incidence. Significant higher yield was reported for HY-14, and HY-15 was the lowest yielder both in wet and dry terms.

15. AICRP- Project mode centre on nutmeg

Morphological and biochemical characterization of the mother trees of the accessions identified during 2014-15 (Accns.1 to 15) has been done. GC-MS analysis of the volatile oil has been carried out in 7 accessions. Pass port data of ten 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 five unique accessions (Acc.1, 8, 12, 14, 23) were made and five each of these accessions have been supplied to IISR Kozhikode, KKVV Dapoli and TNAU Pechipparai for evaluation.

16. Strengthening Research on Nutmeg - State Plan Project

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, 16 clones have been characterized morphologically and biochemically. Five clones have been found superior with respect to the economic characters. Morphological characterization of mother plants of the remaining trees is partially completed and has to be continued for the remaining parameters. Budded plants of these elite clones have been made and germplasm block and close planted budwood nursery established. Chemoprofiling of the mace and nut volatile oil has been done in 15 accessions. 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 and other safe chemicals 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 viz., 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 has to be carried out using bulk quantities of nut and mace.

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 and pickle (two processes). All the products got good overall acceptance as indicated by the high scores obtained in appearance, colour, flavor, texture, odour and taste. 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. Over all acceptability was highest for sweet chunda, and lowest for jam. Syrup tasted good but could not be stored. Except pickle and syrup all other products could be stored up to six months under ambient conditions. Bakery products like cookies and cake were prepared in bulk which got very good acceptability. The product preparation has to be scaled up and a pilot unit has to be set up, which will help in the transfer of technology.

17. Germplasm collection and maintenance of cocoa

One set of germplasm consisting of 41 clones reported to be resistant to black pod disease (ICGD Database) was introduced from the University of Reading, U K.

18. Breeding for Vascular streak dieback disease resistance in cocoa

Selfing of superior vascular streak dieback disease resistant hybrid

19. Breeding for Phytophthora pod rot resistance in cocoa

Hybrids evolved and identified as tolerant to *Phytophthora* under field condition were selfed to assess its incompatibility position. Thirty hybrids were selfed to assess the incompatibility position and fruit set was observed in one 26.4 (GVI 188×GVI 304), confirming its self

compatibility status. Hybrid seedlings from this cross were evaluated in the nursery for vigour and combining ability was estimated following the top cross design.

Selfing of 36 inbreds were done to advance the next generation. Three pod set was obtained from 2 genotypes (S_3H7.3 (86), S_4 M 18.7). Seedlings raised in the nursery and evaluated for planting in the field. It resulted in identification of thirty hybrids in the field which showed no symptom. It is very much necessary to confirm the resistance by artificial inoculation to prove that the disease is due to the genetic makeup and not due to environmental influence. For this pod inoculation method was carried out.

Pod inoculation method

Pods at full maturity but before ripening were collected, surface sterilized with distilled water and 70 per cent alcohol, inoculated under high humid condition with fresh culture of *Phytophthora* without pricking. *Phytophthora* culture disc of seven days old were used and above which wet cotton was placed. Observations were taken after ten days of inoculation and percentage of infection was calculated using the formula (Length x breadth of lesion / length x breadth of pod) x 100.

Genotype SIV 1.26 X PII 12.11 (9.8), GVI 216 X GVI 304 (36.6) showed 100 percent infection in non pricked condition. Genotype GVI 188 X GVI 304 (27.4) showed zero percentage infection in non pricked condition.

20. Strengthening Cocoa Research Centre, Kerala Agricultural University

The hybrids identified as self incompatible has to be tested for their general combining ability before taking to polyclonal garden. For this they are crossed with a tester. GI 5.9 is used as the tester. General combining ability (GCA) of self incompatible VSD resistant hybrid was assessed.

Eight pods were obtained from seven hybrids. These pods will be raised in the nursery.

Top cross analysis was employed for analysis of variance.

Breeding value (A) represents the general combining ability effect (GCA) of individual test entries. It is the main parameter in initial screening through top cross analysis. The GCA effects of four parents were estimated. VSD 15.7 and VSD 5.11 considered as good combiner and can be used for establishment of polyclonal garden.

21. Multi location Trial lll in Cashew- ICAR

There was significant difference among genotypes for duration of flowering. Flowering duration was maximum for H32/4(113) days and minimum for BH 6 (84) days. There was significant difference among genotypes for sex ratio and flowering laterals. Sex ratio was maximum for genotype Dhana (0.495) and flowering laterals was maximum for genotype H1593 (10.29).There was no significant difference among genotypes for apple weight. There was significant difference among genotypes for mean nut weight and yield. The Maximum nut weight recorded by Dhana (8.90g) followed by BH6 (8.01g).The highest nut yield was recorded by H-1593(5.766kg/tree) followed by H11 (5.643kg/tree).The highest cumulative yield was recorded by H1593 (46.39kg/tree) followed by H662 (42.17kg/tree).

22. Multilocation Trial –V - Cashew

Significant difference was observed among genotypes for flowering duration and variety Raghav recorded the maximum flowering duration (124) days. Maximum sex ratio was recorded by genotype K-22-1 (0.27).The maximum number of flowering laterals was recorded by Sulabha (10.38). There was significant difference among genotypes for apple weight, nut weight and nut yield during the current season.The highest apple weight was recorded by Priyanka (65.35g) followed by Anagha *(*58.70g) and highest nut weight by Priyanka (10.16g) followed by Anagha (9.85g).The maximum nut yield was recorded by Amrutha (1.289kg/tree) followed by Sulabha (1.162kg/tree).The highest cumulative yield was recorded by Dhana (9.074kg/tree) followed by Kanaka (9.056kg/tree).

23. Intercropping in Cashew -ICAR

Objective of the experiment was to identify suitable tuber crops/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- AICRP

There was significant effect for different treatments on yield parameters of cashew. Highest duration of flowering was observed in T7, 100 % N as FYM, (120days), maximum flowering laterals/panicles in T2100 % N as FYM + Bio-fertilizers (*Azatobacter* + *Azospirillum* + PSB) 200 g, (8nos.) and highest nut weight in T7(25 % N as FYM + Recycling of organic residue + In situ green manuring / green leaf manuring+ Biofertilizers ,200 g) (8.13). Lowest nut weight (6.20g) was recorded in T6 (In situ green manuring / green leaf manuring to meet 100% N). Highest annual nut yield was recorded in T5 (3.84kg/ha) followed by T3 (3.52kg/ha) and maximum cumulative nut yield in T3 (50 % N as FYM + Biofertilizers, 200 g) (11.04kg/tree) followed by T6 (10.80kg/tree).

25. Varietal screening of cashew apple for preparation of RTS and Jam

Length and weight of cashew apple was observed to be maximum in the variety Panama (10.00cm &195.06g, respectively). Highest TSS (14.5%) was observed in Madakkathara- 1 and the lowest in Kanaka (10.01%). Kanaka had the maximum tannin content (0.56%) and Amrutha, the minimum (0.23%). Acidity was minimum in the variety Panama (0.25%) while it was maximum in Madakkathara-1, Dhana and Raghav (0.44%). K-22-1 gave maximum juice yield (95.75%) followed by Kanaka (83.78%), and Madakkathara-2 had the least juice recovery (49.01%). High score was recorded for Dhana with respect to colour and appearance. The variety Priyanka had the highest score for taste and flavour and Sulabha had the highest score for sweetness. Priyanka had highest score for overall acceptibility followed by Sulabha and K-22-1.Vridhachalam-3 scored maximum for colour and Priyanka for appearance. Variety Sulabha scored maximum with respect to flavour, taste, sweetness and over all acceptability of the product.The results indicate that the cashew variety Sulabha is superior for RTS drink and jam preparation.

26. Evaluation of insecticides for control of TMB and other insect pests - ICAR

Tea mosquito bug intensity was very low during the season. At seventh day after second spray, comparatively less damage was observed in *Beauveria bassiana* @2g/l. The damage score in control was also less. On panicle, at seventh day after second spray, all the treatments including control except thiamethoxam 0.2g/l, carbosulfan and buprofezin recorded comparatively less damage. At 15thday, ƛ-cyhalothrin recorded least damage.In third spray, thiamethoxam @2g/l recorded least damage followed by thiamethoxam@1g/l, *Beauveria*@2g/l and these three were on par among each other. The red ants might have checked the multiplication of tea mosquito bug present in low intensity during the reporting year. As far as yield data were concerned, the highest yield (5.52 kg/ tree) was recorded in ƛ-cyhalothrin treatment, followed by *Beauveria bassiana*, untreated check and buprofezin. However no significant difference in yield was observed among treatments and also with control.

Insect pests other than tea mosquito was practically nil during the experiment season. During third spray observation, control itself harboured maximum red ant population though statistically significant from other treatments. Spider population was practically nil in the experiment plot both during pre spray and post spray observations.

27. Control of cashew stem and root borer Curative control trial - ICAR

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

28. Influence of biotic and abiotic factors on the incidence of pest complex of cashew- ICAR

The objective of the project was to investigate the population dynamics of pests of regional importance and to correlate it to prevalent weather parameters. There was no significant correlation either positive or negative observed between biotic factors and tea mosquito bug. Insect pests other than tea mosquito bug was practically nil during the reporting year and the data was not sufficient for correlation studies. However, significant positive correlation was observed between black ants and spiders in the present investigation. 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.

29. Screening of germplasm to locate tolerant / resistant types to major pests of the region- ICAR

The objective of this project was to identify germplasm accessions tolerant / resistant to the major pests of the region. The various accessions were screened to locate the tolerant/ resistant types to tea mosquito bug, leaf & blossom webber, leaf miner and leaf caterpillar. Tea mosquito bug infestation was very low during the reporting year and the damage was not observed in ODR to and 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.

Thrips infestation was absent in K-2, K-3, Kottukkal and ARL-2. During last year also, thrips infestation was comparatively in a lower range in Kottukkal and ARL-2.

30. Evaluation of entomopathogenic fungi against tea mosquito bug (*Helopeltis antonii* Signoret) in cashew (under the plan project "IPM for tea mosquito bug in cashew using rationales).

Objective of the study was to evaluate the field efficacy of entomopathogenic fungi against tea mosquito bug, to evaluate the effectiveness of new molecules alone and in combination with nonchemicals for tea mosquito bug management and compare with entomopathogens and to derive a sustainable package for tea mosquito management. Analysis of data revealed that no significant difference was observed among treatments with respect to nut yield. However, highest nut yield was recorded in quinalphos treated trees followed by control and *Beauveria* treated trees. Comparatively higher nut yield in control plants was due to the high yield recorded by one tree among the replication, which was inhabited by red ant.

31. Evaluation of alternative management technologies against tea mosquito bug, *Helopeltis antonii* Signoret in cashew

Objective of the project was to evaluate the potential of insecticide molecules among the new generation categories, to exploit the possibility to include non chemicals in the management schedule against tea mosquito bug and to evaluate the pesticide residue problems in the products harvested after spray with insecticides. During the year 2015-16, the promising botanicals and bioagents were evaluated under field for confirmation of the result. Nut yield data revealed that neem oil 2% + pongamia oil 2% recorded highest nut yield (6. 35kg/ tree), though not significantly superior to other treatments.

32. 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.

33. 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 ordinary and 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.

34. Utilization of Existing Germplasm and Description of Varieties

Among the 16 different genotypes evaluated, a tall cultivar, Philippines Lono was found to be superior than WCT. Pooled analysis of yield and quality data proved the superiority of the same over all other genotypes and WCT.

Name of the Project Coordination Group (03)

Vegetables

Project Coordinator: Dr. George T.E

Concluded Projects: 6 Nos
Ongoing Projects: 14 Nos

Concluded PG Projects: 7 Nos
Ongoing PG Projects: 12 Nos

Concluded Projects

1. **Standardizations of agrotechniques for organic production of yard long bean (*Vigna unguiculata* subsp. *sesquipedalis)***

   The experiment with 20 organic treatments (3 sources of organic manure – FYM, Vermicompost and poultry manure) and 4 organic preparations (Fermented oil cake, Jeevamrutham, Fermented plant extract, Fish amino acid and rock phosphate + P solubiliser) was completed. Among the organic manures vermi compost and fish amino acid were superior to all other treatments. Vermicompost was superior to FYM and poultry manure for germination percentage, pods per plant, pod girth, pod weight, yield per plant and yield per plot. Among the organic preparations *viz.*, fermented oil cake (FOC), Jeevamrutham(JEE), fish amino acid (FAA), fermented leaf extract(FLE) and rock phosphate+ PGPR mix 1(RP) FAA was superior for germination percentage, das to flowering, pods per plant, pod girth, yield per plant and yield per plot. Soil chemical analysis was done after the experiment which revealed very high rating for N, P, K and organic carbon.

2. **Standardisation of precision farming in vegetables**

   i) Fertigation and mulching studies in bhindi variety Arka Anamika

   The trial was carried out to standardise fertigation techniques in bhindi, Experiment was laid out in RBD with four replications. Fertigation and mulching studies were under taken with two levels of irrigation and three levels of fertilizer with and without mulching. Higher level of irrigation (80% PE) is needed for good performance of bhindi. All the yield attributing characters including number of fruits and fruit weight and yield were higher at higher level of irrigation. Mulching significantly improved plant height, fruit yield, number of fruits and fruit weight than non-mulched treatments.Fertilizer had no significant influence on yield attributing characters like fruit weight, number of fruits and fruit length. All levels of fertilizer (75%, 100% and 125% of recommended dose of fertilizer) were on par. The treatment combination of $I_2F_3M_1$ (Irrigation at 80% PE, 125% of fertilizer + mulch) recorded significantly higher plant height, fruit number yield in the study

   ii) Fertigation and mulching studies in cabbage

   The trial was carried out to standardise fertigation techniques in cabbagevariety NS 43, Experiment was laid out in RBD with four replications. Fertigation and mulching studies were under taken with two levels of irrigation and three levels of fertilizer with and without mulching. All the yield attributing characters including gross and net head weight were higher at lower level of irrigation (60%). Mulching significantly improved plant height, plant spread, gross and net head weight than non-mulched treatments.Fertilizer had no significant influence on yield attributing characters like head breadth, gross head weight and net head weight. All levels of fertilizer (75%, 100% and 125% of recommended dose of fertilizer)

were on par. The treatment combination of $I_1F_3M_1$ (Irrigation level at 60% PE, 125% of fertilizer + mulch) recorded significantly higher net head weight in the study.

3. **Productivity assessment of cucurbitaceous crops in rain shelter and open conditions**
   Experiments were conducted to assess the comparative performance of cucurbitaceous vegetables namely, cucumber (AAU C -2, Mahyco Hybrid) and bittergourd (Priya, Preethi) under rainshelter and open. Varieties were grown in rain shelter and open simultaneously. Both cucumber (AAUC 2) and bittergourd (Preethi) performed better under rainshelter

4. **Productivity assessment of solanaceous vegetables in rain shelter and open conditions**
   Experiments were conducted to assess the comparative performance of solanaceous vegetables under rainshelter and open. The crops and varieties evaluated were: tomato: Sakthi, Mukthi, Anakha, LE 643-1; Brinjal: Neelima and chiili: Anugraha, Ujwala, Athulya. Varieties were grown in rain shelter and open simultaneously. Yield increase was noticed in most of the vegetable varieties cultivated in rain shelter compared to open. The difference was more prominent in brinjal variety Neelima; chilli varieties Anugraha and Athulya and tomato variety LE 643-1.

5. **Development of high yielding varieties of bitter gourd for open condition suited for Kerala**
   Thirteen genotypes including released varieties as check were evaluated. Of the 13 genotypes evaluated, culture BG -20 recorded the highest yield (760 g / plant), BG-16-2 recorded highest number of fruits per plant (19.75), BG-10-fruit length (21.15 cm) and BG-23-fruit girth (18.03 cm). Confirmation of genetic variability using ISSR markers revealed that culture BG -20, BG-16-2, BG -10 and BG-23 exhibited distant relationship according to the dendrogram generated through the WinBoot software. Therefore, these superior cultures were genetically divergent from the standard variety used in the study *viz*., Priyanka and Preethi.

6. **Identification of photoinsensitive genotype(s) of winged bean (*Psophocarpus tetragonolobus* (L.) DC.)**
   Twenty one winged bean genotypes collected from different parts were evaluated in randomised block design with three replications. Analysis of variance revealed that the genotypes under study differed significantly for almost all the characters studied.

   The genotype PT 21 showed earliness for flowering (flowering commences in 75 DAS *i.e.*, in June which receives long photoperiod). The genotypes PT 21, PT 1 and PT 4 showed prolonged harvest up to February irrespective of photoperiod and temperature. These genotypes recorded maximum yield and the peak period of harvest falls under short day periods (September – January).

   Variability studies revealed high phenotypic and genotypic coefficient of variation for yield per plant, pods per plant, days to first flowering, days to 50 per cent flowering and primary branches per plant. High heritability coupled with high genetic advance was observed for characters like vine length, days to first flowering, days to 50 per cent flowering, days to first

harvest and days to final harvest suggesting additive gene action for these traits and hence simple and early selection will be effective. Correlation studies revealed that at both phenotypic and genotypic levels characters like pods per plant, pod length, pod weight, pod girth, days to edible maturity and days to final harvest had significant and positive correlation with yield indicating that selection for these characters may improve yield. Path analysis indicated that pods per plant had the highest positive direct effect on pod yield followed by pod length, pod girth, days to first flowering and days to final harvest.

Genetic divergence analysis showed appreciable divergence among the twenty one genotypes of winged bean. The clustering pattern indicated that cluster III had the maximum number of genotypes (six) followed by cluster I and II with five genotypes each and cluster IV consist of one genotype and cluster V with four genotypes. Based on selection index values PT 21 from cluster I was ranked first.

Ongoing Projects

1. **Development of F_1 hybrids of tomato (*Solanum lycopersicum* L.)**

   Twenty seven tomato accessions were evaluated for yield and disease incidence. The best performers were LE 15 for fruit weight (107.35 g) followed by LE 3 (77.06g) and LE 4 (75.35g); LE 2 for fruit number (38.75) followed by LE 22; LE 20 for yield /plant (1.12 kg) followed by LE 22. Incidence of major diseases like bacterial wilt and spotted wilt were recorded.Incidence of major diseases like bacterial wilt and spotted wilt were recorded. Nine accessions (LE 2, LE 4, LE 16, LE 20, LE 21, LE 24, LE 32, LE 38, LE 39 and LE 53) were field resistant to bacterial wilt. The resistant accessions LE 16, LE 20, LE 24, LE 38 and LE 39 showed very low incidence of spotted wilt. As second part of the experiment 12accessions were selected for hybridization based on yield and disease tolerance. The hybrids obtained by crossing the 12 parents were evaluated and the hybrids LE 28 x LE 21, LE 3 x LE 4 and LE 2 x LE 16 were superior for yield fruit weight and fruits/ plant respectively .

2. **Development of F_1 hybrids of chilli (*Capsicum annuum* L.).**

   Experiment was laid out in RBD with 55 diverse accessions of chilli collected from different parts ofIndia.Best parents based on yield, resistance and quality parameters like green long thin fruits were selected from the first experiment for production of hybrids. The high yielding selected parents are CA 3, CA 5, CA 6, CA 7, CA 8, CA 9, CA 15, CA 16, CA 23, CA 32, CA 35, CA 47. They were crossed to produce F_1hybrids. Hybrids were evaluated along with parents and hybrid check ArkaHaritha and 15 hybrids were found promising. The crosses CA 23 x CA 32 (1048 g), CA 6 x CA 23 (993 g), CA 8 x CA 32 (917 g), CA 6 x CA 32 (910g), CA 5 x CA 32 (822g) were the top yielders.

3. **Development of F_1 hybrids of brinjal (*Solanum melongena* L.) for commercial cultivation**

   Forty genotypes of brinjal collected from different sources will be evaluated in the field. Seven parents will be selected based on the yield, fruit characters, purple colour and other desirable morphological appearances. The parents will be crossed in all possible combinations excluding reciprocals. The 21 F1 s along with the seven parents will be

evaluated in the field for yield and its attributes following the Package of Practices Recommendations of KAU. For the estimation of standard heterosis brinjal hybrid Neelima released from KAU will be used as resistant check Pusa purple long as susceptible check.

Fifty genotypes were collected from different sources were evaluated four superior hybrids were identified from the PG project. The hybrids will be evaluated for one more season. Five superior parents were identified.

4. Development of F1 hybrids in cucumber suited for Kerala

Gynoecious line GY-14 (EC 709119) was maintained by applying silver thiosulphate @ 200 ppm at 6 leaf stage. 12 monoecious lines were maintained through selfing. Twelve F_1 hybrids were generated by crossing GY-14 as female parent in a top cross fashion with 12 monoecious inbred lines. They were evaluated under rain shelter condition during 2014-15. These hybrids were grown on raised beds covered with polythene mulch at a spacing of 1.5 x 0.5 m. Crop was irrigated through drip and nutrients were applied through fertigation. Hybrid GY-14 x CS-123 was the best performer for yield (17.93 kg/plant) and yield contributing characters such as number of fruits and number of harvests. The next best crosses with respect to number of fruits per plant and yield per plant were GY-14 x IC 410617 and GY-14 x IC 410638 respectively. The performance of these hybrids regarding qualitative characters was also good. Among the 12 crosses, the cross EC 709119 x IC 538155 was highly crisp. Rest of the three best crosses was moderately crisp.

5. Development of F1 hybrids in watermelon suited for Kerala

Watermelon cultivar 'Sugar Baby' was used as the female parent for crossing with CL-4 and CL-5, two promising lines of watermelon. Two seedless watermelon hybrids and Sugar Baby were tested along with these hybrids during 2014-15 under poly house for two seasons. Observations were recorded on days to harvest, fruit weight, number of fruits/ plant, fruit perimeter, yield/ plant, number of seeds/ fruit and TSS. Both diploid hybrids were found to be high yielding than seedless hybrids and parent Sugar Baby. Hybrid Sugar Baby x Cl-4 found to be the top yielder (14.5 kg/plant) followed by the hybrid Sugar Baby x Cl-5 (11.65 kg/plant).

6. Developments of F1 hybrids in Ridge gourd suited for Kerala

Four F_1 hybrids were developed in ridge gourd using male sterile line as female parent and Deepthi, Haritham, Arka Sumeet and LA-102 as male parent. These hybrids were tested under open condition on raised beds covered with polythene mulch at a spacing of 2 x 0.5 m during 2014-15. Crop was irrigated through drip and nutrients were applied through fertigation. Observations were recorded on days to flowering, nodes taken for flowering, days to harvest, average fruit wt., fruit girth, fruit length and yield per plant. Hybrid MS LA-1x Arka Sumeet was the best performer for yield (50.04 t/ha). This hybrid is male fertile and can be exploited commercially as there is no requirement for a pollinizer. F_1hybrid seed production of this hybrid is possible under open condition using MS –LA-1 line as the female parent which is male sterile. Cost of labour and input towards emasculation and covering of female flower can be saved with this technology.

7. **Development of F1 hybrids in okra (*Abelmoschus esculentus*L.Moench)**

Thirty two genotypes of okra were evaluated in the field out of which five diverse genotypes were selected and crossed in a diallel fashion and F_1 hybrid seeds were collected. The ten hybrid combinations were raised in a replicated trial for further analysis along with okra variety Arka Anamika and F_1 hybrid Manjima. Promising hybrid combinations located were AE 202 x AE 198, AE 202 x AE 210, AE 202 x AE 303 and AE 198 x AE 210. They recorded high yield, earliness and YVMV symptoms were expressed only late in the season. Among the four promising hybrids maximum yield was given by AE 202 x AE 303 (450g/plant) followed by AE 202 x AE 210 (400g/plant).

8. **Development of F1 hybrids in Ash gourd**

The selected 10 accessions were crossed in a diallel mating design and 45 F1 hybrids were produced.The F1 hybrids developed will be evaluated along with the parents.

9. **Development of bitter gourd varieties resistant to bitter gourd distortion mosaic virus (BGDMV).**

Fourteen promising recombinants selected from the evaluation of the F_9 populations of the cross VKB 135 (Resistant Source) X Preethi were subjected to CYT along with Preethi as check in Randomised Block Design with 3 replications. Among these recombinants evaluated, F_{10}-V-12-2 gave the highest yield of 7.42 kg/pit (32.97 t/ha). This was on par with F_{10}-V-11-6 (7.40 kg/pit), F_{10}-V-12-5 (7.37 kg/pit) and F_{10}-V-7-10 (7.13 kg/pit). All the recombinants were resistant to to bitter gourd distortion mosaic virus (BGDMV) (CI: 0) while check variety Preethi was susceptible (CI: 56). Qualitative characters like fruit colour, fruit shape, fruit surface etc. were same as check variety Preethi.

10. **Identification of yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) varieties with high yield and tolerance to soil borne fungal diseases**

To evaluate yard long bean germplasm for yield and tolerance to diseases caused by soil borne fungal pathogens *viz.Rhizoctonia salani*, *Fusarium oxysporum* and *Pythium* spp. and to develop high yielding lines with disease tolerance. The 58 accessions evaluated for yield and yield attributes. Highest yield was recorded by VS 29 (16.27 kg/plant) followed by VS 50 (14.28 kg/plant) and VS 16. Pod length was highest for VS 50 (68.03 cm) followed by VS 52 and VS 58. They were also scored for the incidence/ tolerance to soil borne diseases and classified into five categories (Moderately resistant -12; Tolerant -4; Moderately tolerant -10; Susceptible- 5; Highly Susceptible-13). Twelve promising types based on yield and disease incidence were selected for CYT. Screening under artificial epiphytitic conditions for Fusarium, Rhizoctonia and Pythium resistance was done. Two CYTs were carried out with 17 treatments and two replications. The pooled data on yield revealed the superiority of VS 50 with a pooled mean of 0.875 kg/ plant.

11. **Development of high yielding varieties resistant to yellow vein mosaic disease from segregating generations in okra (*Abelmoschus esculentus* (L.) Moench)**

    Selection of desirable recombinants with high yield and resistance to yellow vein mosaic disease was carried out in F_4 and F_5 generations.10-15 superior cultures with good yield and resistance to YVM were identified and selected from F_5 generation and is continued as M.Sc. project.

12. **Standardization of agro techniques for precision farming in Chilli(*Capsicum annuum* L.)**

    Experiment was conducted with different levels of mulching, irrigation and fertilizers. The ad- hoc recommendation with mulch and 100% irrigation and fertilizer (100% of crop removal) was found superior for yield (2139.55 g/plant) followed by the treatment with much, 80% irrigation and 125% fertilizers.

13. **Development of F1 hybrids of bittergourd (*Momordica charantia*L.*)***

    The project was concluded since there was severe incidence of mosaic in the two inbreds. Hence it was decided by the Review team while reviewing the research projects of the Dept of Plant Breeding &Genetics, College of Agriculture, and Vellayani on 17-6-2014 to conclude the project.

14. **Development of high yielding anthracnose resistant varieties of chilli (*Capsicum annuum* L.)**

    Eighteen promising recombinants were selected from the F_5 generation and were subjected to CYT. CYT I was laid out in 18x3 RBD. The results revealed that culture 11-3-2-1 was the highest fruit yielder (268 g/ plant) followed by culture 11-1-6-1 (228 g/plant) and culture 5-3-5-1 (210g/plant). Number of fruits was maximum for culture 11-3-2-1 (42) followed by culture 4-5-3-1 (48) and culture 18-7-1-1 (42). Average fruit weight ranged from 2g to 8 g (culture 12-7-1-1). Fruit length ranged from 4.1 cm to 8.7cm (culture 11-3-2-1). Fruit girth ranged from 3.8 cm to 6.2 cm (culture 11-6-1-1). The fruit colour varied from yellowish green (culture 4-1-1-1), light green (4 cultures), green (9 cultures) and dark green (6 cultures). There was no incidence of anthracnose in culture 12-5-1-1 while lower incidence was noticed in cultures 11-6-1-1 (6%), 18-7-1-1 (11%),4-5-3-1 (10%) ,18-7-1-2 (12%) and the maximum was recorded in 4-1-1-1 (78%).

Concluded PG Projects

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

   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.

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.

2. Seed invigoration to overcome dormancy in ash gourd (*Benincasa hispida*(Thunb.) Cogn.)

a) Effect of seed invigouration on seed dormancy:

The analysis of variance revealed that, there existed significant differences in seed quality parameters like germination per cent, germination index, mean time to germination, coefficient of velocity of germination, energy of germination, seedling vigour index I and II among various seed treatments within 35 days of invigoration.

Untreated seeds of ash gourd var. KAU Local exhibited delayed and uneven germination for a period of 34 days. Germination in the untreated seeds of var. KAU Local reached above the

minimum standards for seed certification (MSCS) prescribed for ash gourd (*i.e.*, 60 per cent) only on the 35th day after extraction. In other words, the inherent dormancy period in ash gourd var. KAU Local is 34 days after extraction.

Results indicated that all treatments except seed invigoration with salicylic acid (@ 60 ppm (for 12 hrs or 24 hours) and vinegar at pH 3.7 for 2 hours was highly effective in breaking dormancy in ash gourd. Although germination in seeds invigorated with PEG 6000 (-0.5 MPa for 24 hours) reached 75.00 per cent on the 19th DAI, it declined to 62.60 per cent by 35th DAI. The germination was also found to be inferior to control throughout the period of observation.

Germination reached above the MSCS earliest *i.e.*, on the 11th DAI in seeds treated with 0.4% KH_2PO_4 for 24 hours and those treated with kinetin 10 ppm for 24 hours, while, in majority of the treatments it was attained on the 13th DAI. In seed invigoration treatments such as hydropriming and treatment with thiourea, germination above MSCS was attained on the 15th and 17th DAI respectively.

Within 35 days of extraction, seeds treated with *Pseudomonas fluorescence* @ $1x10^6$ cfu.ml^{-1} for 12 hours, cytokinin 10 ppm for 12 hours and $CaCl_2$ 50mM for 24 hours (T13) recorded significantly higher germination per cent, germination index, coefficient of velocity of germination, energy of germination, vigour index-I and vigour index-II and reduced mean time to germination compared to other treatments. As observed earlier, seed treatment with salicylic acid, vinegar and PEG 6000 had also exhibited a negative impact on the seed quality and seedling performance. The performance of seeds in these treatments was inferior to the untreated seeds.

Considering the earliness in breaking dormancy as well as the impact on seed quality parameters, invigoration of seeds with 50mM calcium chloride for 12 hours or 24 hours, or *Psuedomonas fluorescens* for 12 hours, or cytokinin 10ppm for 24 hours can be adjudged the best seed invigoration treatment that can be resorted to for breaking dormancy in ash gourd.

b) Effect of seed invigouration on seed quality and viability during storage:

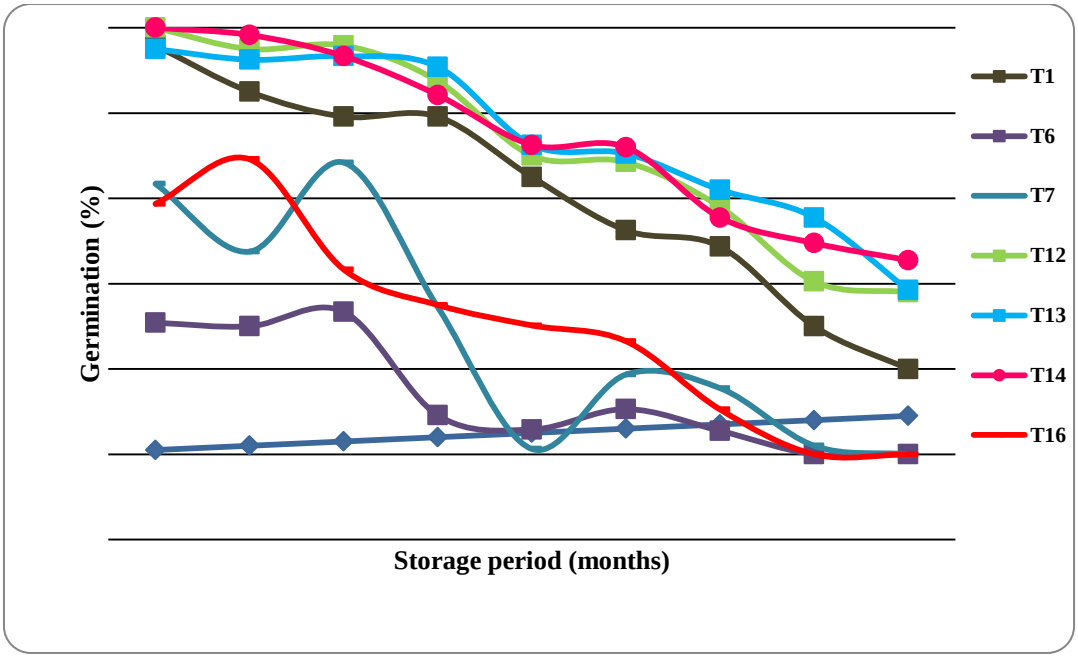
Significant differences in germination and other seed quality parameters like germination index, coefficient of velocity of germination, mean time to germination, energy of germination seedling vigour indices, seed moisture content and seed infection and seed coat parameters like total seed coat thickness, thickness of testa, thickness of tegmen, seed length and embryo length was observed in ash gourd seeds during nine months of storage.

A general decline in seed quality parameters like germination, germination index, coefficient of velocity of germination, energy of germination, seedling vigour indices and progressive increase in mean time to germination, total seed coat thickness, thickness of testa, thickness of tegmen was observed during the period of storage in both treated and untreated seeds.

Germination declined (Fig. 1) with increase in the storage period both in untreated control as well and invigorated treatments. However, in most treatments the decline set in after an initial increase as evident at one month after storage (MAS). Treatment with CaCl2 for 24 hours

recorded the highest per cent increase in germination, germination index, coefficient of velocity of germination, energy of germination, seedling vigour indices and low mean time to germination, electrical conductivity, total seed coat thickness, thickness of testa, thickness of tegmen and per cent seed infection for most part of storage period.

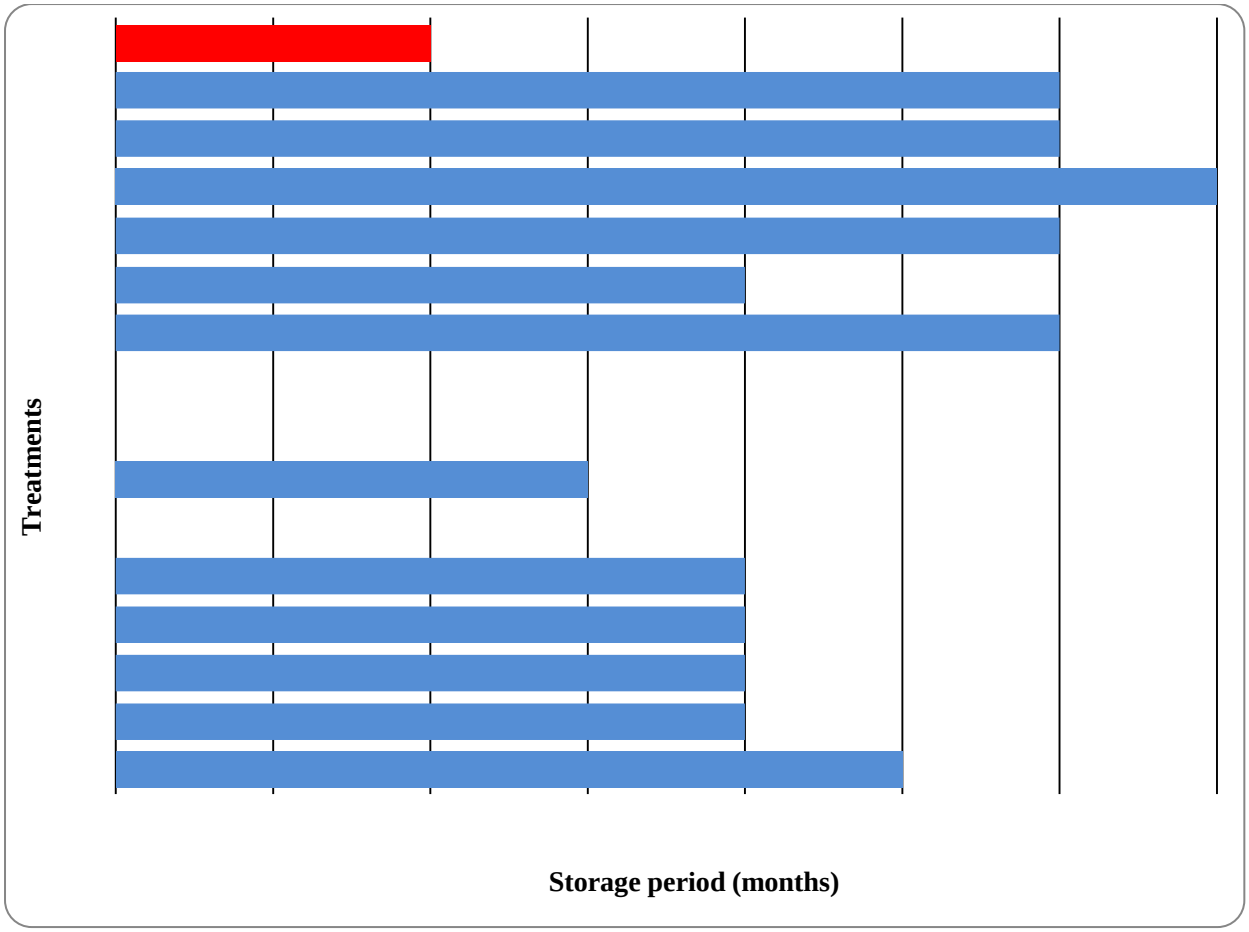
Fig. 1. Effect of seed invigoration on germination in ash gourd during storage



All the seed invigoration treatments exerted a positive influence on extending the period of seed viability (Fig. 2), while the untreated seed had sustained germination above 60 per cent for two MAS only. However, as discussed earlier (section 5.1), seed invigoration with salicylic acid for 12 hours or 24 hours, and those treated with vinegar for 2 hours and PEG 6000 for 24 hours proved to be detrimental to the seeds. Germination in seeds treated with salicylic acid and vinegar failed to reach above MSCS (60 %) required for ash gourd during the storage period. Seeds treated with salicylic acid also failed to germinate after one month of storage (MAS) while in seeds treated with polyethylene glycol 6000 (@-0.5 Mpa for 24 hours), although MSCS was reached on 19th DAI, germination was poor and not sustained above MSCS beyond 1 month.

For most part of storage period, seeds treated with $CaCl_2$ (50 mM for 24 hours) and *Pf* or kinetin for 12 hours recorded high germination. It was evident that seed invigoration with $CaCl_2$ was the best among the seed invigoration treatment. Germination in the treatment was maintained above MSCS for 7 MAS, while in the seeds treated with $CaCl_2$ for 12 hours or *Pf* for 24 hours, viability was retained above MSCS up to 6 MAS. Seed treatment with thiourea, KNO_3, KH_2PO_4 and kinetin were helpful in retaining viability retained above MSCS for 4 MAS.

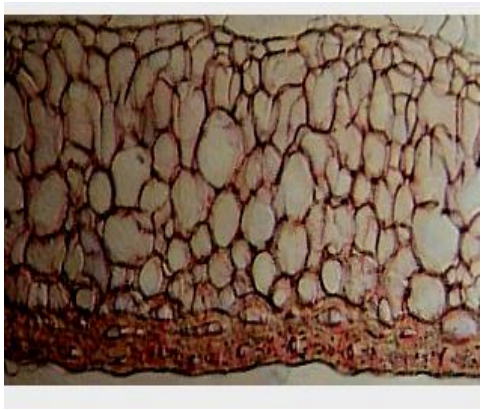
Fig. 2. Impact of seed invigoration on retention of seed viability during storage



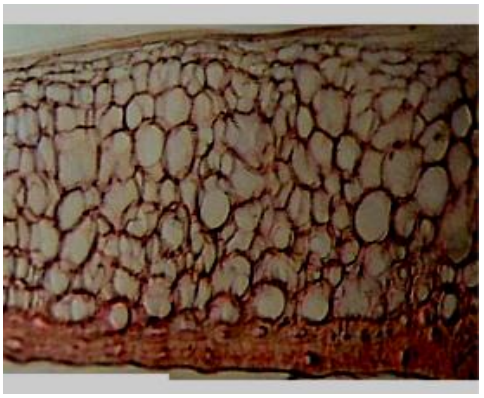
Thickening of seed coat (Fig. 3) was observed over the period of storage although seeds that registered higher germination had thinner seed coat compared to untreated seeds as well as those exhibiting poor or no germination. Thicker seed coat (Plate 1) is reported to act as a mechanical barrier for water imbibitions. At the end of storage period seeds treated with *Pf* $1x10^6$ $cfu.ml^{-1}$ (T14) for 12 hours had registered lower total seed coat thickness and were found to be significantly superior to other treatments whereas treated with vinegar (T6), PEG 6000 (T7), salicylic acid (T8 and T9) and untreated control (T16).

Plate 1. Seed coat thickness in ash gourd

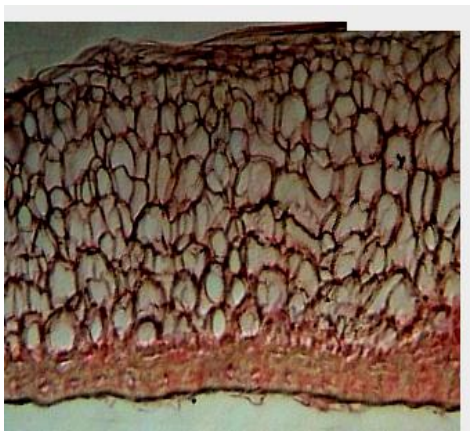
a) Seed coat thickness immediately after invigoration



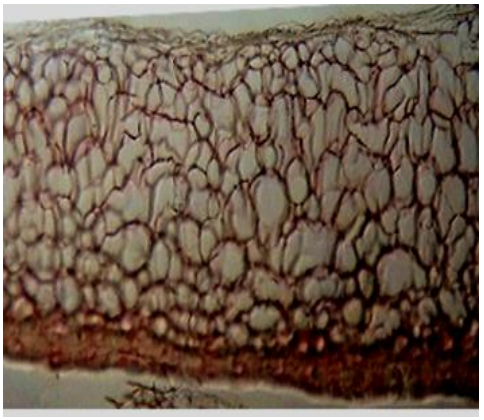
T14 (*Pseudomonas flourescens* for 12 h.)



T13 (50mM $CaCl_2$ for 24 h.)

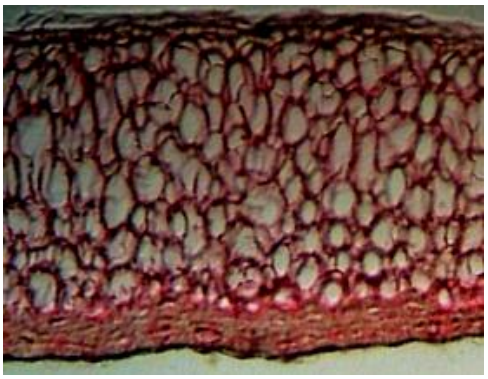


T9 (Salicylic acid for 24 h)

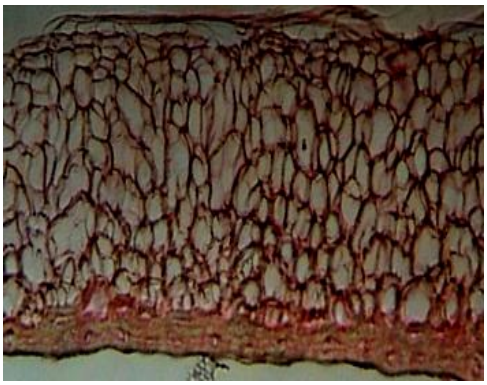


T16 (untreated seeds)

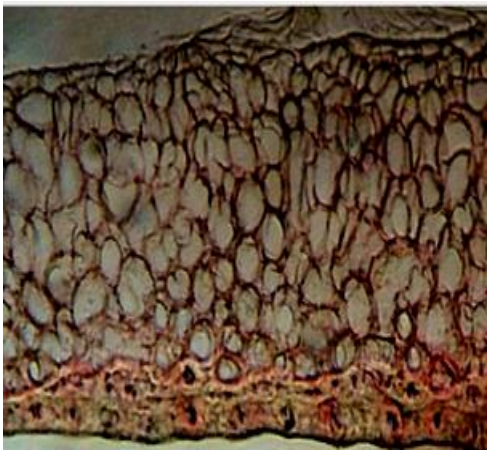
b) Seed coat thickness at seven months of storage



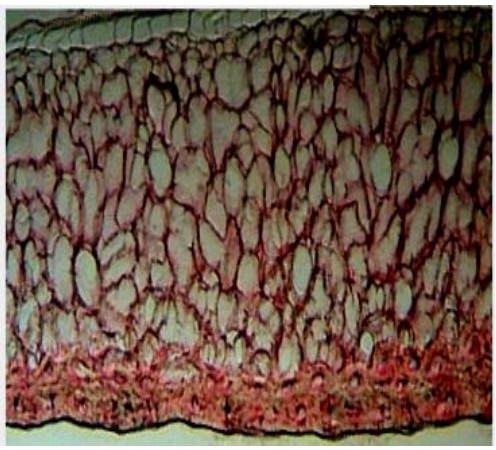
T14 (*Pseudomonas flourescens* for 12 h.)



***T13* (*50mM CaCl2 for 24 h.*)**

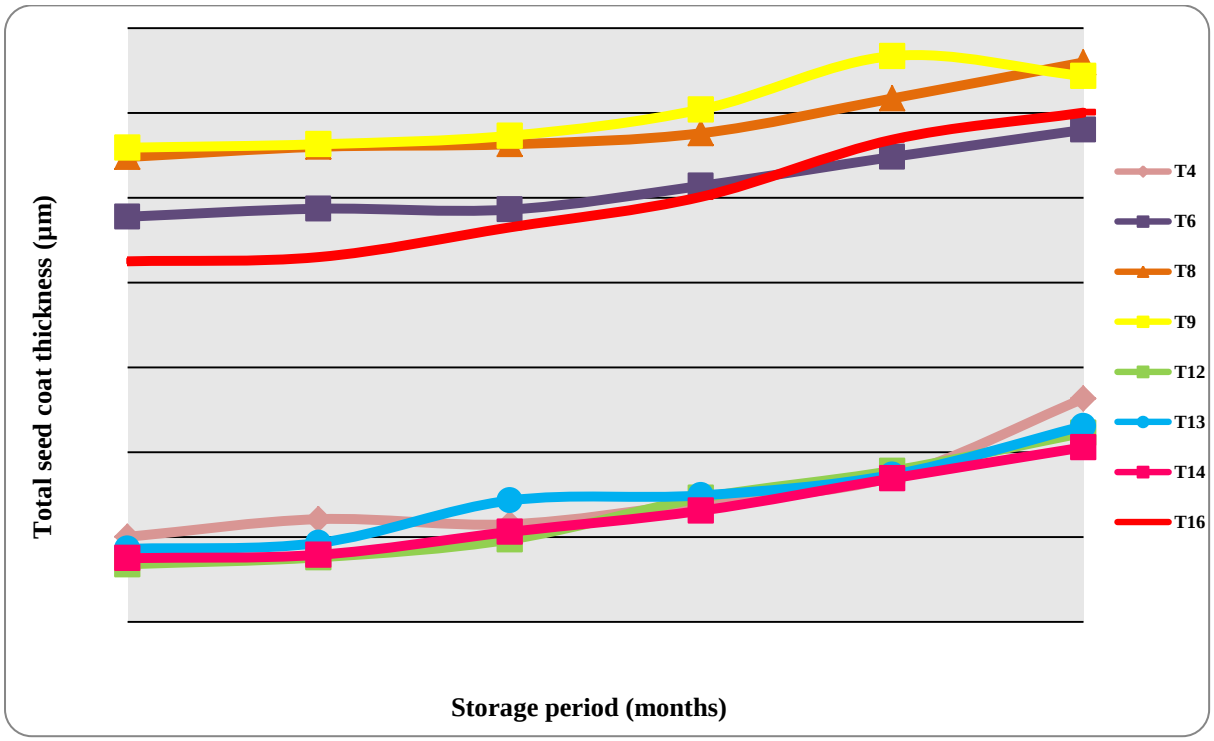


T16 (untreated seeds)



T9 (Salicylic acid for 24h.)

Fig. 3. Effect of seed invigoration on total seed coat thickness in ash gourd during storage



The infection by seed microflora was found to be the highest in untreated control throughout the storage period while it was the least in seeds treated with *Pf* for 12 hours and KNO_3 for 24 hours. The results once again reaffirmed the advantage of seed invigoration treatments with either $CaCl_2$ for 24 hours or *Pf* for 12 hours.

3. Effect of seed invigoration treatments on seed dormancy

Untreated seeds of ash gourd var. KAU Local exhibited delayed and uneven germination for a period of 34 days. Germination in the untreated seeds of var. KAU Local reached above minimum standards for seed certification (MSCS) prescribed for ash gourd (*i.e.*, 60 per cent) only on the 35th day after extraction. In other words, the inherent dormancy period in ash gourd var. KAU Local is 34 days after extraction.

Results indicated that all treatments except seed invigoration with salicylic acid (@ 60 ppm (for 12 hours or 24 hours) and vinegar at pH 3.7 for 2 hours were highly effective in breaking dormancy in ash gourd. Although germination in seeds invigorated with PEG 6000 (-0.5 MPa for 24 hours) reached 75.00 per cent on the 19th DAI, it declined to 62.60 per cent by 35th DAI. The germination was also found to be inferior to control throughout the period of observation. Seed treatment with salicylic acid, vinegar and PEG 6000 had also exhibited a negative impact on the seed quality and seedling performance. The performance of seeds in these treatments was inferior to the untreated seeds.

Germination reached above MSCS earliest *i.e.*, on the 11th DAI in seeds treated with KH_2PO_4 (10^{-1} M for 24 hours) and those treated with kinetin 10 ppm for 24 hours, while, in majority of the treatments it was attained on the 13th DAI. In seed invigoration treatments such as hydropriming and treatment with thiourea, germination above MSCS was attained on the 15th and 17th DAI respectively.

Within 35 days of extraction, seeds treated with *P f* @ $1x10^6$ cfu.ml^{-1} for 12 hours, kinetin 10 ppm for 12 hours and $CaCl_2$ 50 mM for 24 hours (T13) recorded significantly higher germination per cent, germination index, coefficient of velocity of germination, energy of germination, vigour index-I and vigour index-II and reduced mean time to germination compared to other treatments.

Considering the earliness in breaking dormancy as well as the impact on seed quality parameters, invigoration of seeds with 50 mM $CaCl_2$ for 12 hours or 24 hours, or *Pf* for 12 hours, or kinetin 10 ppm for 24 hours can be adjudged the best seed invigoration treatment that can be resorted to break seed dormancy in ash gourd.

4. Effect of seed invigoration treatments on seed viability during storage

A general decline in seed quality parameters *viz.*, germination, germination index, coefficient of velocity of germination, energy of germination, vigour index-I and vigour index-II were observed during the period of storage in both treated and untreated seeds.

All the seed invigoration treatments except treatement with salicylic acid for 12 hours or 24 hours, vinegar for 2 hours and PEG 6000 for 24 hours exerted a positive influence on extending the period of seed viability while in the untreated seeds, germination was sustained above 60 per cent for two months only.

For most part of storage period, seeds treated with $CaCl_2$ for 24 hours recorded the highest per cent increase in germination. Seed viability was maintained above MSCS for 7 MAS. Germination in the seed treatment with *Pf* or $CaCl_2$ or kinetin for 12 hours had retained above MSCS upto 6 MAS while seed treatment with thiourea, KNO_3, KH_2PO_4 and kinetin were helpful in retaining viability above MSCS for 4 MAS.

Considering the higher retention period of viability above MSCS, and higher germination per cent over the storage period, high estimates of germination index, coefficient of velocity of germination, energy of germination, vigour indices I and II and finally lower estimates of mean time to germination, electrical conductivity of seed leachate, total thickness of seed coat, thickness of testa and tegmen, embryo length to seed length ratio and microbial infection of seed, seed treatment with $CaCl_2$ 50 mM for 24 hours could be adjudged as the best seed invigoration in ash gourd. This treatment had broken dormancy at 13 MAI and retained the viability for the maximum period after invigoration (7 MAS).

Seed invigoration treatment with *Pf* ($1x10^6$cfu.ml^{-1}) or $CaCl_2$ for 12 hours were found to be the next best treatments that can also be recommended for seed invigoration in ash gourd.

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

Analysis of variance revealed significant differences among the treatments for all character studied. The results showed that VS 26 had the highest vine length among the parents (455.83 cm). Among the 28 hybrids, VS 16 x VS 13 had the longest vine (482.50 cm) and VS 34 x VS 16 had the shortest (273.23 cm). The primary branches plant^{-1} for parents ranged from 3.06 (VS 54) to 5.17 (VS 29). Among hybrids, the range was 3.20 (VS 34 x VS 38) to 5.70 (VS 13 x VS 26). The parents exhibited a range of 33.12 days (VS 34) to 40.83 days (VS 29) for days to first flowering. Among the hybrids, VS 50 x VS 38 was the earliest to flower (31.23 days) and VS 34 x VS 26 was latest (44.23 days). Peduncle length for parents ranged from 18.68 cm (VS 34) to 21.37 cm (VS 54). Among hybrids, the range was 12.85 cm (VS 34 x VS 16) to 25.85 cm (VS 50 x VS 16).

Pod length of parents showed a range from 45.23 cm (VS 29) to 66.28 cm (VS 50). The results revealed a greater range of variation for pod length among the hybrids. VS 54 x VS 26 had the highest pod length (71.27 cm) and VS 34 x VS 16 had the lowest (36.40 cm). Pod girth was highest in VS 34 (3.82 cm) and lowest in VS 29 (3 cm) among the parents while the hybrids VS 54 x VS 26 (3.77 cm) and VS 16 x VS 13 (2.67 cm) showed the maximum and minimum pod girth, respectively.

VS 50 had highest pod weight (27 g) and VS 38 had the lowest (13.53 g) among the parents. The magnitude of variation among the hybrids with respect to pod weight ranged from 11.33 g (VS 34 x VS 16) to 30.67 g (VS 50 x VS 16). The magnitude of variation among the parents with respect to pods plant^{-1} was 24.07 (VS 54) to 56.67 (VS 29). In this study a wide variation for pods plant^{-1} was noticed among hybrids with a range of 24.67 (VS 13 x VS 29) to 107.17 (VS 34 x VS 13).

Seeds pod^{-1} for parents ranged from 17.67 (VS 54) to 19.83 (VS 38). Among hybrids, the range was 15.33 (VS 34 x VS 16) to 21.83 (VS 34 x VS 50). A range of 12.77 g (VS 29) to 23 g (VS 16) was recorded for 100 seed weight among the parents. Among hybrids, the range was 10.67 g (VS 34 x VS 38) to 20.50 g (VS 50 x VS 26).

The highest yield was recorded for VS 29 (848.74 g plant^{-1}) among the parents and which was statistically on par with VS 50 (741.33 g plant^{-1}). Yield plot^{-1} for parents ranged from 4.41 kg (VS 54) to 8.49 kg (VS 29). Among hybrids, the range was 3.53 kg (VS 13 x VS 29) to 14.14 kg (VS 34 x VS 50). The hybrid VS 34 x VS 50 recorded highest yield plant^{-1} (1414.55 g) which was on par with VS 50 x VS 26 (1358.05 g).

The parents exhibited a range of 43 days (VS 34) to 56 days (VS 29) for days to harvest. The hybrid VS 50 x VS 16 was the earliest for harvest (43 days) which was on par with VS 50 x VS 29 (43.47 days) and VS 13 x VS 29 was the latest to harvest (61.33 days). The crop duration among parents ranged between 117.33 days (VS 50) and 129 days (VS 29). The hybrids VS 16 x VS 13, VS 54 x VS 38 and VS 54 x VS 29 exhibited the longest duration of 134 days whereas the shortest duration was recorded in VS 50 x VS 38 (121.33 days).

VS 16 had highest pod protein among parents. The hybrids showed a range of 4.29% (VS 16 x VS 13) to 7.01% (VS 34 x VS 13) for pod protein. Among the parents, VS 38 had the best keeping quality with the minimum physiological loss of weight of 15.75 % and VS 54 had the poor keeping quality (34.92 %). The physiological loss of weight showed a range of 13.04 % (VS 13 x VS 38) to 36.13 % (VS 50 x VS 38) among the hybrids.

Mild incidence of pod borer (*Lampides boeticus*), cowpea aphid-borne mosaic virus and fusarium wilt was noticed among the parents and hybrids. No pod borer infestation was noticed in VS 54 among the parents and among hybrids VS 34 x VS 26, VS 34 x VS 38, VS 34 x VS 29, VS 50 x VS 54, VS 16 x VS 29 and VS 13 x VS 29. Two parents, VS 50 and VS 13 and 14 hybrids showed resistance to cowpea aphid-borne mosaic virus (CABMV). Fusarium wilt was only observed in two parents, VS 34 (2.60%) and VS 13 (1.99%) and six hybrids *viz.* VS 50 x VS 26 (1.76 %), VS 50 x VS 13 (1.99%), VS 54 x VS 26 (1.99%), VS 54 x VS 29 (2.16 %) and VS 26 x VS 29 (2.16 %).

Heterosis

The relative heterosis, heterobeltiosis and standard heterosis over the variety Vellayani Jyothika and the hybrid NS 634 were worked out for all yield and quality characters in yard long bean. The data on standard heterosis revealed superiority of some outstanding cross combinations.

In this study, only one hybrid VS 16 x VS 13 showed positive significant heterosis for vine length over the checks. The highest standard heterosis for primary branches plant^{-1} recorded in VS 13 x VS 26 whereas VS 50 x VS 38 had highest desirable heterosis for days to first flowering. The hybrid VS 50 x VS 16 exhibited desirable standard heterosis for peduncle length, days to harvest and pod weight (52.82%; 28.46%) while VS 54 x VS 26 exhibited maximum heterosis for pod length (35.66% ; 34.34%) and pod girth over variety Vellayani Jyothika and hybrid NS 634, respectively. The hybrid VS 34 x VS 13 exhibited the highest standard heterosis for pods plant^{-1} (210.39%; 295.30%) and pod protein (61.40% ; 28.08%). For 100 seed weight, the highest standard heterosis recorded in VS 50 x VS 26 over NS 634 while no hybrids showed significant positive heterosis over Vellayani Jyothika.

The hybrid VS 34 x VS 50 recorded the highest standard heterosis (129.05%; 197.46%) and heterobeltiosis (90.81%) for yield plant^{-1} whereas highest relative heterosis recorded in VS 34 x VS 13 (104.16%). Maximum standard heterosis for crop duration was observed in three hybrids *viz.* VS 16 x VS 54, VS 54 x VS 38 and VS 54 x VS 29, while VS 13 x VS 38 had the best keeping quality.

Combining ability effects and gene action

The estimates of general combining ability revealed that VS 50 was an outstanding general combiner for seven characters *viz.* days to first flowering, peduncle length, seeds pod^{-1}, pod weight, yield plant^{-1}, yield plot^{-1} and days to harvest. VS 34 was the best general combiner for primary branches plant^{-1} and pods plant^{-1} while VS 13 was the best combiner for pod protein and keeping quality. VS 54 was the best combiner for pod length and crop duration

whereas VS 26 was the best combiner for vine length at harvest, pod girth and 100 seed weight.

The estimates of *sca* effects revealed that the cross combinations VS 34 x VS 50, VS 34 x VS 13, VS 50 x VS 26, VS 16 x VS 54, VS 16 x VS 38, VS 54 x VS 26 and VS 13 x VS 38 were superior for pods plant^{-1}, yield plant^{-1}, yield plot^{-1} and pod protein. The specific combining ability of the crosses for pod characters and yield were given in

Analysis of variance for combining ability revealed that the estimates of *sca* variance were higher than *gca* variance for all characters except pod weight indicating the predominance of non additive gene action.

Pod and seed colour inheritance

In the present investigation pods of parents and hybrids were observed to study the pod colour inheritance and it was found that dark red colour was dominant over green and light green colour as evident from all the seven crosses involving VS 13, which had dark red pods. The presence of red tip was observed among crosses involving red tipped VS 38, indicating that red tip was dominant character. Seed colour of parents and hybrids were observed to study the inheritance of seed colour and found that black seed colour was dominant in all hybrids in which black seeded VS 38 as one of the parents.

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 present study reveals 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.

6. Evaluation of hybrids for yield and quality in chilli (*Capsicum annuum* L.)

Analysis of variance revealed significant difference among the treatments for all the characters studied for two seasons. Plant height for parents ranged from 55.05 cm (P1) to 86.63 cm (P3). The minimum plant height was recorded in the hybrid P1 x P5 (71.93 cm). The tallest hybrid were P1 x P2 and P1 x P4 (81.86 cm). The primary branches per plant for parents ranged from 2.82 (P3) to 4.65 (P5). Among hybrids the range was from 3.00 (P1 x P5) to 5.05 (P3 x P5).

The results revealed that parent P1 (27.43) was theearliest for flowering and P3 (28.91) was the latest for flowering. Among the hybrids the range was from (24.16) P3x P4to (27.40) P1x P3.Days to harvest for parents ranged from (46.43) P1 to (47.80)P3. Among the hybrids P2x P5 (43.23) was earliest for harvest and late harvest was observed in P1x P3 (46.40).

Fruits per plant among the parents ranged from P4 (47.00) to P3 (78.13) and among the hybrids maximum fruits per plant was observed in P3 x P4 (148.76) followed by P4 x P5 (143.26) and P3 x P5 (137.36). Fruit length was maximum for parent P1 (11.17 cm) and

minimum for P3 (8.34 cm). The fruit length of hybrids ranged from 10.49 cm (P2 x P3) to 12.61 cm (P1 x P5).

The parent P4 (4.30 cm) recorded maximum fruit girth. Fruit girth among the hybrids ranged from 3.15 cm (P2 x P4) to 4. 43 cm (P3 x P5). The result revealed a great variation for fruit weight. Among the parents fruit weight ranged from 4.82 g (P3) to 6.73 g (P5). Among the hybrids the fruit weight ranged from 5.36 g (P2 x P3) to 9.66 g (P4 x P5).

The parent P5 (2.61mm) had maximum and P4 (1.62mm) had minimum flesh thickness among the parents respectively. Among the hybrids flesh thickness was maximum in (P4 x P5) 2.81 mm and minimum in (P2 x P4) 2.06 mm. Among the parents flesh to seed ratio ranged from 3.90 mm (P2) to 8.84 mm (P5) and among the hybrids it ranged from 4.36 mm (P2 x P3) to 10.47 mm (P1 x P5). Among the parents P1 (114.06) had maximum and P4 (79.50) had minimum seeds per fruit. The magnitude of variation among the hybrids with respect to seeds per fruit ranged from 103.60 (P2 X P3) to 149.80 (P2 x P5).

Maximum green fruit yield per plant was recorded by the parent P5 (448.70 g) and minimum by P2 (247.50 g). The hybrid P4 x P5 (962.93 g) recorded maximum green fruit yield per plant followed by P3 x P5 (886.53 g) and P2 x P5 (798.70 g). Minimum yield was recorded in the hybrid P2 X P4 (483.60 g).

Among the parents P5 (79.98 g) had maximum and P2 (40.42 g) had minimum dry fruit yield per plant. The hybrid P4 x P5 (144.05 g) showed maximum dry fruit yield per plant which was on par with P3 x P5 (139.93 g). Yield per plot for parents ranged from 7.12 kg (P2) to 12.91 kg (P5). Among the hybrids maximum yield per plot was recorded in the hybrid P4 x P5 (27.72 kg) followed by P3 x P5 (25.52 kg) and P2 xP5 (22.99 kg).

Driage percentage among the parents ranged from (P3) 21.56 % to (P5) 25.11 % and among the hybrids (P2 x P4) 19.66 % to (P4 x P5) 26.91 %. Among the parents the maximum seed yield per fruit was observed in P2 (0.83) and minimum was recorded in P5 (0.41). Seed yield per fruit of hybrids ranged from P1 x P5 (0.20) to P2 x P3 (0.80).

Capsaicin among the parents ranged from 0.40 % (P3) to 0.45 % (P5). Among the hybrids it varied from 0.69 % (P2 x P4 and P3 x P5) to 0.78 % (P2 x P3). Parent (P5) 15.10 % had maximum oleoresin and (P4) 12.00 % minimum. Among the hybrids maximum oleoresin was recorded in (P2 x P5) 18.90 % and minimum 10.90 % by (P1 x P2) and (P2 x P3).

Among the parents (P4) 98.38 mg/100 g recorded maximum ascorbic acid content. The hybrids showed a range of 94.50 mg/100 g (P1 x P5) to 122.66 mg/100 g (P2 x P5). Colour value among the hybrids ranged from (P1) 121.33 ASTA units to (P5) 169.41 ASTA units and among the hybrids colour value ranged from 141.19 ASTA units (P3 x P4) to 195.39 ASTA units (P2 x P5). The crop was monitored for incidence of diseases and pests during the cropping period. The crop was free from leaf curl, fruit rot, mosaic, bacterial wilt and white fly. Thrips and mites were predominant ones exhibiting characteristic damage. The leaf curl index of thrips ranged from 1.00 to 1.96 and mites ranged from 0.16 to 1.83.

Correlation analysis

Green fruit yield per plant had positive correlation with primary branches per plant (0.3937), fruits per plant (0.5601), fruit length (0.6721), fruit weight (0.4651), flesh thickness (0.4311), and seeds per fruit (0.6232) and negative correlation with days to first harvest (-0.6665).

Plant height had positive correlation with primary branches per plant (0.3283), fruit girth (0.3327) and fruit weight (0.3325). Primary branches per plant exhibited positive correlation with fruit girth (0.3694), fruit weight (0.4003) and negative correlation with days to first harvest (-4012).

Days to first harvest exhibited negative correlation with fruit length (-0.7742), fruit girth (-0.5212), fruit weight (-0.6502), flesh thickness (-0.6083) and seeds per fruit (-0.8006).Fruits per plant had negative association with the fruit girth (-0.3380).

Fruit length recorded significant positive association with fruit girth (0.5114), fruit weight (0.6694), flesh thickness (0.6817) and seeds per fruit (0.8355).

A positive correlation was observed for fruit girth with fruit weight (0.8991) and flesh thickness (0.6628). Fruit weight had positive correlation between flesh thickness (0.7606), and seeds per fruit (0.5995). Flesh thickness exhibited positive correlation with seeds per fruit.

7. Stress induced source-sink modulation in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis (L)*

The experiment was laid out in split plot design with four irrigation levels as main plots and four sub plots (combination of N levels and methods of application) to assess the influence of moisture –nutrient stress and foliar nutrition on source sink relationship, productivity and profitability of yard long bean. The different levels of irrigation did not have any significant influence on the yield of yard long bean. Irrigating the crop once in three days upto flowering followed by irrigation in alternate days recorded the maximum pod length and daily irrigation registered the maximum pod girth. Daily irrigation favoured the crop duration and inducing stress by increasing irrigation interval reduced the crop duration. Application of N at recommended dose and 25 percent less of RD N resulted in comparable yield. Yield attributes like pod weight, number of pods per plant and pod yield per plant were significantly superior in soil application which resulted in higher yield.

A better (lower) source: sink ratio (0.75) was recorded by irrigation once in three days at 20mm depth. Regarding nitrogen levels, application of N@ 25% less than RD registered the ideal source: sink ratio (0.79). The total uptake of N, P and K were higher in soil application of nutrients. Providing irrigation at wider intervals recorded the highest WUE (14.38 kg ha/mm)and water productivity. Among the methods of application, soil application registered significantly superior WUE and water productivity. Hence it could be inferred that yard long bean can be irrigated once in three days with 25 percent less RD N (22.5kg).soil application of nutrients in four splits was found ideal than soil application of one third on N and K followed by foliar nutrition of 13:0:45@0.5 percent concentration.

Ongoing PG Projects

1. **Breeding, biology and cross compatibility of close wild relatives of brinjal (*Solanum melongena* L.)**
2. **Development of Bacterial wilt Resistant F1 hybrids in chilli (*Capsicum annum*)**
3. **Standardisation of hydroponics in Tomato**
4. **Evaluation of cabbage (*Brassica oleracea* L. var. capitata) genotypes for compactness and internal tip burn resistance under protected cultivation.**
5. **Evaluation of hybrids for yield and quality in chilli (*Capsicum annum* L)**
6. **Evaluation of hybrids of indeterminate Tomato (*Solanum lycopersicum* L.) under protected cultivation.**
7. **Development of hybrids with bacterial wilt resistance in tomato (*Solanum lycopersicum L.*).**
8. **Development of hybrids in yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis* (L)Verd court)**
9. **Evaluation of superior cultures for yield and yellow vein mosaic resistance in okra (*Abelmoschus esculentus* (L)Moench.)**
10. **Studies on Fertigation in Bittergourd (*Momordica charantia L.*)**
11. **Studies on Fertigation in yard long bean (*Vigna unguiculata* subsp.*sesquipedalis* (L.) Verdcourt)**
12. **Productivity of spinach beet as influenced by varieties and nutrient doses.**

Name of the Project Coordination Group (4)

Fruits

Project Co-ordinator : Dr.Jyothi .M.L

Concluded Projects: 5 Nos
Ongoing: Projects 29 Nos

Concluded PG Projects: 3 Nos
Ongoing PG Projects: 9 Nos

Concluded projects

1. **Clonal selection in banana** (BRS, Kannara)
   Manjeri Nendran, a clonal selection from Nendran was included in the Package of Practices and recommendations of KAU during June, 2015.

2. **Evaluation of promising clones of banana** (BRS, Kannara)
   In the Cavendish group, KBS-8 was significantly superior to Grand Naine. But crop cycle was delayed by almost 5 months. It was also prone to choking, a condition where the inflorescence cannot come out of the pseudostem. In the Poovan group, H 513 recorded lower bunch weight than local check Palayamkodan. Appearance and color were attractive in H 513. In plantain group, Manjeri Nendran was significantly superior in bunch weight than Nendran, though taller in stature and longer in crop duration. Manjeri Nendran displayed tolerance to Sigatoka leaf spot and pseudostem borer.

   In the ABB Monthan group, Bangrier (NRCB sel 7) and BCB-2 recorded higher bunch weight than control. BCB-2 resembles Ashy Batheesa which is a high yielding cultivar under ABB genome. In the ABB, Pisang Awak group, BCB-1 was superior to local Karpooravalli in respect of yield. There was not much difference in the quality parameters.

Mean growth and yield characters of promising clones evaluated

Sl. No.	Clones	Plant height (cm)	Stem girth (cm)	Bunch weight (kg)	Hands/ bunch	Fruits/ bunch	Duration (days)
1	KBS-8	242.0	77.5	29.0a	13.5	175	452.0
2	Grand Naine	227.5	57.5	22.4b	11.3	133	318.0
3	H513	275.0	51.0	11.5a	7.6	119	303.0
4	Palayamkodan	297.5	52.5	13.5b	9.5	137.5	313
5	Manjeri Nendran	312.5	57.5	14.7a	6.5	64.0	332
6	Nendran	297.5	50.5	11.6b	5.4	55.5	302.5
7	Bangrier (NRCB-7)	317.5	63.5	17.8a	8.0	85.0	355.0
8	BCB-2	342.5	61.5	23.0b	20.3	177.5	365.0
9	Monthan	322.5	64.0	15.75c	6.7	67.5	362.5
10	BCB-1	362.5	69.0	19.73a	14.5	173.0	385.0
11	Karpooravalli	352.5	66.5	17.5b	13.6	169.0	390.0
12	SEM	3.18	2.02	0.55	0.410	3.62	3.93
13	CD(0.05)	9.94	6.31	1.71	1.28	11.31	12.28
14	CV	2.48	4.68	4.36	5.50	4.16	2.57

3. **Standardization of stage wise requirement of nutrients in Banana (BRS, Kannara)**
   The experiment was conducted for four seasons. Among the different fertilizer levels, 100%RDF (L1) (RDF-Recommended dose of NPK (190:115:300 g NPK/pt), L1-100%RDF) performed better with respect to bunch weight, hands per bunch, fruit weight and early to bunching and harvest. Within each fertilizer level, there was no significant difference among

the stage wise application of treatments for bunch weight and yield. 100% RDF under stage wise application is the best treatment in Nendran for higher yield and better returns. Application of 100% RDF in respect of nitrogen and potassium at 10:10, 40:20, 30:30, 20:40 at 3rd, 5th , 7th, 9th MAP after planting is recommended for the maximum productivity of banana cv. Nendran.

4. **State Plan Project on "Developing Systems recommendation for nutrient, disease and insect management in major cropping systems of Kerala"** (BRS, Kannara)

Experiment I

Mainplot	**Subplot**
i. Banana + Turmeric	a. 100% Recommended dose of fertilizers (190,115,300 g/plant of N,P2O5 and K2O)
ii. Banana +Ginger	b.75% Recommended dose of fertilizers
iii. Banana + Amorphophallus	c. 50% Recommended dose of fertilizers
iv. Banana + Colocasia	d. organic manure alone
v. Banana + Tapioca	
vi. Banana +green manure crops	

Growth characters of banana

Plant height recorded in the main plots ranged from 305.5 cm (M4) to 310.0 cm (M3) and were found to be on par. Significant differences were observed in subplot treatments with S1 (100% RDF) recording the highest value (316.7 cm) followed by S2 (75%) RDF and were significantly superior to S3 (50% RDF). S4 corresponding to organic application of manures had the least height (297.7cm).

In main plots days taken for shooting ranged from 206.6 to 215.6 days and total duration ranged from 292.8 to 298.9. Among sub plots though bunch emergence was marginally delayed in S4, crop cycle as a whole remained unaffected. Thus the growth of the main crop was not affected by any of the intercrops.

The bunch weight in M1-M5 ranged from 9.0 to 9.44 Kg in comparison to 8.02 Kg in M6. On the other hand, bunch weight across subplots corresponding to different levels of fertilizer application, pronounced effect was seen. The range in bunch weight noticed was 10.08 Kg(S1 with 100%RDF) to 8.12 Kg (S4 with 0 % RDF and only organic manures).Bunch weight in plots supplied with inorganic fertilizers (S1 – S3) was not only significantly superior to S4 (organic manures alone) but differed among themselves.

Variation in number of fruits per bunch was non significant at main plot level but significant differences among subplots were seen. The range in number of fruits was 54.7(S1) to 49.1(S4). Similar differences were evident in the case of fruit weight (g), fruit length (cm) and fruit girth(cm). TSS was comparatively higher in plots supplied with organic manures both at main plot and subplot levels. Keeping quality remained unaffected by various treatments.

Among intercrops, turmeric recorded the highest fresh yield/plot (46.3 to 33.7 Kg) followed by Tapioca (32 to 19 Kg) and ginger (20 to 12.8 Kg). Colocasia recorded the lowest fresh yield (13 to 8 Kg) among intercrops.

Turmeric proved to be the most remunerative intercrop with highest returns and with a BC ratio varying between 1.79 to 1.42 among sub plots S1 –S4. This was followed by Tapioca where the BC ratio varied between 1.76-1.29 among sub plots. Thus growing of intercrops was remunerative though profitability varied. Banana intercropped with only green manure crops fetched the least returns, BC ratio ranging from 1.51 to 1.14. The profitability is also subject to change based on price realized. Another advantage of the system was that crop cycle of both main crop and intercrops are over by January and plots are ready for planting of next season crop by February. When combined economics of cultivation was worked out, the same trend prevailed. Thus it can be concluded that turmeric is the most feasible and remunerative intercrop with rainfed Nendran.

Incidence of pests and diseases

Disease severity of Sigatoka leaf spot was calculated as infection index which ranged from15.98-20.2% in different treatments without a common pattern. Average severity recorded for both periods was17.54 - 21.07 %. Prophylactic spray in the pre monsoon period with Bavistin (0.1%) followed by a repeat spray combined with field sanitation could control the spread.

Banana Bunchy top virus (BBTV), Banana Bract Mosaic Virus (BBrMV), Cucumber Mosaic virus (CMV) are the three viral diseases normally encountered in banana plots. Use of healthy planting material coupled with scientific management practices including sanitation and systematic removal of infected plants followed during the study reduced the percentage of infected plants.

Attack of Pseudostem borer could be effectively managed by a prophylactic spray of Chlorpyriphos (0.5%) at 5 months after planting followed with Neem oil spray. Field sanitation and regular removal of dried leaves from plant were crucial in the control of the pest.

Pest and disease incidence in intercrops was observed. Shoot borer infestation in turmeric and rotting in ginger were observed. These could be effectively managed through spraying Quinalphos 0.25% for turmeric and drenching Fytolan0.3% for ginger.

Experiment II

Treatments

Mainplot	**Subplot**
i. Banana-Tapioca- Banana	a. 100% Recommended dose of fertilizers (190,115,300 g/plant of N,P2O5 and K2O)
ii. Banana-Banana-tapioca	b.75% Recommended dose of fertilizers
iii. Banana-Banana-Banana	c. 50% Recommended dose of fertilizers
iv. Banana-vegetables-Banana	d. organic manure alone
v. Banana +green manure crops	

Growth characters of Main crop banana I year

During the first year when banana was grown and supplied with inorganic fertilizers apart from organic manures, plant height ranged from 296.0 to 315.1 cm. In M5 supplied with only organic manures, plant height was significantly lower (296.0 cm). Significant difference

among subplots supplied with various levels of fertilizers was observed in plant height which ranged from 296.0 cm (S4-organic manures) to 321.0cm (S1-100% RDF) and indicated significantly lower height with organic manures alone.

Stem girth values ranged from 48.80(M5) to 53.1(M2). Stem girth across all main plots was significantly lower (48.8cm) with organic manures alone (S4) as against 55.4 cm in S1(100%RDF).

Number of leaves and leaf area among main plots was in the range of 8.9 to 9.6 and 9.29 to 10.73 respectively with M5 displaying significantly lower values. Variation observed among subplots revealed similar pattern. Phyllacron indicating the average number of days taken for leaf emergence was more in organically fertilized plots which also produced comparatively lesser number of suckers. On an average a delay of about one week was seen for bunch emergence and harvest in plots supplied with organic manures alone. But the delay did not affect the crop cycle as a whole

Yield characters

Main crop I year

Bunch weight ranged from 9.07(M5) to 10.62 (M3) in the main plots and the weight recorded in M5 corresponding to organic manures alone was significantly lower. In subplots the bunch weight varied between 9.06 Kg (S4) to 11.55 Kg (S1) with significant differences among all. The number of hands in M5 was significantly lesser than the rest. Similar observations were made on number of fruits/bunch, fruit weight, fruit girth and fruit length. No pronounced differences was seen in TSS, but keeping quality of fruits in organically manured plots was slightly more as compared to plots supplied with chemical fertilizers

Main crop II and III year

The yield of banana during third year following a crop of tapioca in the second year (M1) was highest in S1 with 100% RDF (10.90 Kg) and lowest in S4 with organic manures alone (9.05Kg).The yield in S2(75% RDF) and S3 (50% RDF) were 10.22 and 9.05 respectively.

In M2 during second year the mean yield across subplots ranged from 10.76 Kg (S1) to 8.32Kg(S4). In M3 where banana was grown continously the mean yield range across subplots were 11.03Kg (S1) to 9.23 Kg(S4) in the second year and 9.98Kg(S1) and 8.5 Kg(S4) during the third year. In M4 the yield of banana in the third year following crop of vegetables ranged from 11.8 Kg (S1) to 9.3Kg (S4). Correspondingly in M5(organic manures alone),where green manure crops in the second year preceded banana, the mean bunch yield across subplots was 9.5 Kg(S1), 9.4 Kg(S2), 9.0 Kg(S3) and 8.76Kg(S4). Bunch yield in organically manured crops was the lowest.

Yield of rotation crops

In M1, Tapioca following banana crop in the second year gave a plot yield ranging from 81.8 to 108 .0 kg corresponding to S4 and S1.In M2 where tapioca in the third year followed two crops of banana recorded yield of 117.0, 105.0, 88.0 and 85.0 Kg in S1, S2, S3 and S4 respectively. In M4, growing vegetables after the first crop of banana, could realize yields (from cowpea and Okra) of 67.9, 58.4, 47.3 and 48.1 Kg per plot respectively from S1,S2,S3 and S4.

Economics of cultivation

The highest returns was realized in M1 where tapioca is grown as an intervening crop between two crops of banana. The BC ratio was also highest (2.14 to 1.84 corresponding to S1 and S4) for this schedule .The second remunerative crop combination was M2 with crop of tapioca following two banana crops, BC ratio ranging from 2.09 (S1) to 1.80(S4). Growing banana consecutively for three seasons over a three year period (M3) was also profitable in terms of returns and BC ratio (1.99 to 1.74 corresponding to S1 and S4).The other two combinations involving cultivation of vegetables(M4) or green manure crops (M5) in the second year between two crops of banana in the first and third year were also profitable with BC ratio of 1.95 to 1.69 and 1.67 to 1.64 respectively. Growing banana organically fetched the lowest returns with less profitability.

Incidence of diseases and pests

a. Sigatoka leaf spot

The disease severity calculated as infection index ranged from 16.3 to 21.2 in different treatments at bunch emergence without a common pattern. Mean incidence indicated a range of 18.54 to 21.94%. Prophylactic spray with Bavistin(0.1%) combined with field sanitation could control the spread.

b. Viral diseases

Banana Bunchy top virus (BBTV), Banana Bract Mosaic Virus(BBrMV), Cucumber Mosaic virus(CMV)diseases were recorded in varying intensities. Among the viruses, incidence of BBrMV at bunch emergence (4%) and harvest (2.80%) was comparatively higher. This was followed by CMV (2 to 2.34%). Bunchy top incidence was the least (1.32 to 1.08%). Use of healthy planting material coupled with scientific management practices including sanitation and systematic eradication of infected plants followed during the study reduced the percentage of infected plants.

c. Pseudostem borer

Incidence of Pseudostem borer was random in the experimental plot. Only 2.53 of the plants at bunch emergence and 3.2 % plants at harvest were infested by the pest. Pest could be effectively managed by a prophylactic spray of Chlorpyriphos(0.5%) at 5 months after planting followed by Neem oil spray. Field sanitation and regular removal of dried leaves from plants were effective in the control of the pest.

d. Nematode

Nematode species identified in the experimental plots are given below. Nematode population in soil samples was well below threshold limits. No damage symptoms were observed.

Nematode species recorded: *Pratylenchus coffeae, Helicotylenchus multicinctus, Hoplolaimus sp, Tylenchorhynchus sp, Rotylenchus sp*

e. Weed control

The major weed species observed in the experimental plots were: 1. *Cynodon dactylon,* 2. *Cyprus rotandus,* 3. *Mimosa pudica,* 4. *Centella asiatica* 5. *Sida sp., 6. Euphorbia hirta,* 7. *Ageratum conizoides,* 8. *Lipia nudiflora* 9. *Mikenia micrantha*

5. Post-harvest handling, storage and value addition in banana and pineapple for domestic and export market - GOK plan

a. Experiment on Ripening

The response of six varieites- Nendran, Palayamkodan, Njalipoovan, Amritsagar Grand Naine and Yangambi Km 5 was studied. Exposure to ethylene initiated the ripening process as evidenced by the change of color of hands in all varieties. There was a progressive increase in color development and in 48 hours after ethylene treatment the color development was complete and uniform, each variety acquiring its characteristic color. Uniform ripening was possible by this method. Color and appearance were attractive. Quality of fruits in terms of color, texture and taste were not affected by ethylene treatment. In control treatment where the fruits were allowed to ripen naturally, ripening was erratic and delayed. Color development was not uniform. Ripening using 1000 and 2000 ppm were equally effective.

b. Standardization of maturity indices

1. Harvesting bunches of 80-90% maturity is optimum for long term storage
2. Fruits stored at 13°C and 90 to 95% RH remained fresh and green even after 14 days of storage. There was no loss of weight. No spoilage due to post harvest rots was observed.
3. Fruits kept under ambient condition (25°C and 71% RH) ripened completely when observed after 10 days of storage and were in senescent stage.
4. Fruits could be uniformly ripened using ethylene treatment (1000ppm) for 24 hrs at 18°C and 90-95% RH and also under ambient conditions.
5. Color development was uniform during ripening. Color, texture and flavor of fruit pulp were normal.
6. Fruits reached marketable stage 48 hours after ethylene treatment.
7 The same procedure can be applied to domestic produce tomanage glut and price fluctuation

Flow chart indicating harvest and post harvest handling operations for long term storage/ripening of banana

Harvest bunches at 80-90 % maturity

↓

Transporting bunches wrapped in thin foam sheet to packing houses

↓

Dehanding by giving a clean cut with a sharp knife

↓

Delatexing by allowing the cut surface to drain latex for 10 minutes

↓

Washing the hands in clean water for 10 minutes for complete delatexing

↓

Washing in alum solution (500 ppm) to prevent latex staining on fruits

↓

Dipping in fungicidal solution (Bavistin 500 ppm)

↓

Drying

↓

Packing hands/clusters in corrugated cartons of 5 – 10 kg capacity lined with polythene sheets of 100 gauge thickness and 2% ventilation

↓

Storage at 13^{o}C and 90-95% RH within 12 hours of harvest

↓

Transportation /storage at 13°C and 90-95% RH

↓

Increasing the temperature to 18°C at destination and maintaining RH at 90-95%

↓

Ripening under controlled conditions – Ethylene treatment at 1,000 ppm at 18°C and 95% RH for 24 hours

↓

Ventilate after 24 hours

↓

Holding ripe fruits at 13 – 14°C and 85% RH

↓

Marketing in 2 – 3 days

d. Value addition in banana

Suitability of banana varieties for preparation of jam:

Nendran and Popoulu varieties yielded better product when blended with jackfruit or pineapple pulp. The color of the product varied with variety used.

e. Suitability for preparation of chips

Variety Popoulu had the highest chips recovery (33.0%) followed by the horn plantain cultivar Zanzibar (32.6%) and Big Ebanga (32.5%). Chips yield per bunch was highest in TMB x 5295-1 (7.0 Kg) followed by Popoulu (5.28 Kg). Chips produced by Popoulu closely resembled Nendran Chips.

f. Evaluation of banana varieites for fig preparation

Kapooravalli, Nendran, Popoulu, FHIA-17, FHIA-21, Mysore Ethan, Karimkadali and PisangNangka produced good quality figs. The figs had a storage life of 2 months under ambient conditions and could be stored for up to 1 year under refrigeration.

Ongoing Projects

1. **Collection, characterisation, conservation, evaluation and utilization of banana germplasm** (BRS, Kannara)

   Pisang Madu(AA), Chinese Cavendish (AAA), Figue PommeGeante (AAB) and Pelipita (ABB) were superior in yield in the respective groups. Three AAB plantain cultivars Obubit Ntanga, Akpakpak and MbiEgome were also evaluated during the period. They are French plantain types and resemble Nendran. A new accession located in a farmers plot in Idukki dist was collected and characterized.

2. **Clonal Selection in banana** (BRS, Kannara)

   Manjeri Nendran, a clonal selection from Nendran was included in the Package of Practices and Recommendations of KAU during June, 2015. Performance of three exotic AAB Plantains, Obubit Ntanga, Mbe Egome and Akpakpak, was assessed during 2015. All the three were French Plantains characterized by a persistent male phase and rachis characterized by persistent neutral flowers on the entire stalk. They resembled similarity to local Nendran in plant and bunch morphology. Mbe Egome had higher bunch weight (15 kg).

   Two high yielding local clones of Nendran collected from Thrissur and Palakkad were taller and superior to Nedunendran in bunch weight. Another accession located in a farmers field in Nadathara (Thrissur District) with tall and robust stature yielding bunch of 35 Kg was collected for evaluation.

3. **Standardization of organic nutrient schedule in banana**(BRS, Kannara)
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. These treatments were on par with inorganic control with respect to plant height, stem girth, days to bunching, days to harvest as well as other yield contributing characters. No significant difference was observed among treatments for quality characters (TSS and shelf life) and sigatoka leaf spot incidence. Analysis of soil microflora revealed that the population of beneficial microorganisms is far less in inorganic control than organic treatments. Soil dehydrogenase activity also increased considerably upon application of organic manures. Dehydrogenase level increased from 5.87 (initial) to 31.20 mg TPF/day/kg soil, with inorganic control recording 17.93 mg TPF /day/kg soil. B : C ratio was highest in inorganic treatment (3.10).

4. **Enhancing input use efficiency in banana**
Considering benefit : cost ratio, the treatment with drip irrigation + fertigation + SOP bunch spray was the best (2.14) with a bunch weight of 27.2 kg/pt and 81.6 t/ha of yield, compared to control (B:C ratio 1.50 and 66 t/ha yield) and the rest of the treatments. The same treatment had the maximum finger weight (168.76 g), finger girth (12.95 cm), early to bunching (186.60 days) and harvest (271.60 days) along with an additional returns of 24% over control. Drip irrigation + Fertigation + Micronutrient foliar spray (T3) had the quality attributes (20.37 ^{0}Brix and 0.34% acidity), on par with control (20 ^{0}Brix and 0.3% acidity).

5. **Assessment of post-harvest loss in banana** (BRS, Kannara)
Post harvest loss in Nendran banana from farmer's field – whole sale – retail markets comes to an average of 26.93% in Thrissur district and 24.81% in Palakkad, excluding the stage of storage and ripening. PHL at storage and ripening is negligible since bulk of the produce harvested does not pass through the stage. Overall PHL for Nendran in the state was observed to be 25.87%.

6. **Survey on emerging insect pests of banana** (BRS, Kannara)
Fixed plot survey
In fixed plot survey, incidence of major pests like pseudo stem borer, rhizome weevil, leaf eating caterpillars *viz., Spodoptera litura* and *Pericallia ricini* was regular. Mirid bugs, lace bugs, whiteflies etc. were observed in wet season sporadically. Infestation of *Pericallia ricini* coincided with the appearance of monsoon from June, 2015 and persisted till October, 2015. Heavy incidence of *Spodoptera litura* was observed during September and October. Infestation of pseudo stem borer (PSB) was observed intermittently and increased with the age of the plants. Nendran variety remained the most susceptible one to pseudo stem borer.

Maximum infestation of pseudostem weevil and rhizome weevil were 25.0 and 20.0 percent respectively during the reporting period. White flies *(Dialeurodicus disperses)* infestation was also seen in February and March months. Incidence of Banana skipper butterfly (*Erionota torus*) was observed from May to September, 2015 coinciding with monsoon in Kerala, subsiding during dry periods with scattered presence of leaf rolls. But the incidence was persistent in hot spots like Kannur, Kasargod,Wayanadu districts and parts of Palakkad, the larvae cause severe defoliation in the months of February and March, 2016.

Roving survey

About twenty insect pests were observed infesting banana in Kerala during the survey period. Pseudostem and Rhizome weevils were observed to infest banana in all the surveyed areas from Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Palakkad, Ernakulam, Thrissur, Idukki, Wayanad, Kannur and Kasargod Districts. Nendran and Red banana were the preferred banana varieties.

Isolated occurrences of Root mealy bug, *Geococcus* spp. and pseudostem weevil was observed on Nendran in Calicut and Kannur districts. Banana cultivation in midlands and hilly terrains showed distribution of Mealy bug (*Ferrisia virgata)* and White flies (*Dialeurodicus disperses*). Severe infestation of banana spittle bug, *Phymatostetha deschampis* was reported from Pathanamthitta where more than 100 adults were seen sucking the plant sap on leaves of individual plants.

Red spider mite infestation was observed from Thrissur (Chalakudy, Cherpu, Vellanikkara), Palakkad (Nenmara and Pazhayannur), Malappuram (Thanoor and Thavanur) and Idukki (Kodikulam) districts as seen in previous year.

7. **Skipper butterfly infestation on banana in Kerala** (BRS, Kannara)

The presence, nature and extent of damage, life cycle etc. of Red skipper butterfly (*Erionota torus*) was reported from the Kannara centre in the previous survey period as an emerging threat to banana cultivation. Nendran (AAB), Poovan (AAB), Njalipoovan (AB), Yangambi Km 5 (AAA), Robusta (AAA), Palayankodan (AAB), Pisang Lilin (AA) are prone to their attack. *Erionota torus* turned out to be a major defoliator in all 14 surveyed districts of Kerala (Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Kottayam, Ernakulam, Thrissur, Palakkad, Idukki, Wayanad, Malappuram, Kozhikode, Kannur and Kasargod). DNA barcoding of the Banana Skipper butterfly was done along with supporting taxonomic studies and the results validated that the specimens collected across Kerala and parts of South India is *Erionota torus.*

8. **Integrated management of banana pseudostem weevil (*Odoiporus longicollis*)** (BRS, Kannara

Results proved that T1- Swabbing chlorpyriphos 0.05% and T2-Pseudostem trapping with EPF, *Beauveria bassiana* are suitable management options for the management of pseudostem weevil infestation.

Significant differences among the treatments existed only in the case of bunch weight and plant height. T1- Swabbing chlorpyriphos 0.05% (2.5ml/litre) at 5^{th}, 6^{th} and 7^{th} months after planting recorded the highest bunch weight (9.903 kg), which was significantly higher than control (7.808Kg) and also the bunch weight seen in treatments T2 (8.538 Kg), T3 (9.015 Kg) and T4 (9.105 Kg) respectively. Plant height varied significantly among the treatments, the highest (322.375 cm) was recorded in T1(Swabbing chlorpyriphos, 0.05% 2.5ml/litre). The least plant height was recorded in T2 (pseudostem trapping with EPF, *Beauveria bassiana*) and T5 (control).

9. **Survey of plant parasitic nematodes associated with banana** (BRS, Kannara)
Survey of nematode pests of banana was conducted across the state of Kerala for *Radopholus similis, Pratylenchus* sp., *Helicotylenchus multicinctus, Meloidogyne* sp. and *Heterodera oryzicola*.

Major banana nematodes *viz., Meloidogyne incognita Helicotylenchus dihystera, Pratylenchus penetrans, Heterodera oxyzicola* were recorded at Thiruvananthapuram, Pathanamthitta, Kollam, Palakkad, Thrissur, Ernakulam, Idukki and Wayanad districts. From the survey conducted in Thrissur (Thriprayyar) and Ernakulam (Chalakkudy block) districts, severe incidences of *Meloidogyne incognita* was observed in banana monoculture and in banana plants intercropped with tubers and vegetables. This was attributed to the intensive management options like proper phytosanitary measures and use of healthy suckers.

10. **Biological control of banana nematodes** (BRS, Kannara)
Among the biocontrol agents, combined application of *Pseudomonus fluroscens* @ 12.5 g/m2 + *Paecilomyces lilacinus* @ 12.5g/m2 and the application of EPN *Heterorhabiditis bacteriophora* @ $1x10^9$ (IJs/ml) was able to significantly reduce the soil nematode population

11. **Biorationals for the management of nematodes of banana.** (BRS, Kannara)
During 2015-16, the treatment cartap hydrochloride @ $10g/m^2$ effectively reduced the nematode population in both soil and root when observed in vegetative and shooting stages of the banana cv. Nendran. It could bring 67.37 % and 58.56% reduction of soil population at vegetative and shooting stages. Similarly 72.32 % and 70.50% reduction of root population at vegetative and shooting stages was also observed. This was followed by *Paecilomyces lilacinus*@$25g/m^2$ (63.27% and 63.00% reduction of root population at vegetative and shooting stages) and EPN *Heterorhabiditis baceriophora* @$1X10^9$ 1Js / ml (63.51% reduction of soil population). Lowest root necrosis was recorded in T6-cartap hydrochloride @ $10g/m^2$ (26.41%) followed by T3- *Paecilomyces lilacinus*@$25g/m^2$ (27.49 %). The highest bunch weight was recorded in the treatment of cartap hydrochloride @ $10g/m^2$ (9.7kg) followed by *Paecilomyces lilacinus* @$25g/m^2$ (9.317 kg) and EPN *Heterorhabiditis bacteriophora* application (9.0kg) . The lowest bunch weight was recorded in untreated control (6.707 kg), which was significantly less than other treatments. The treatment cartap hydrochloride @ $10g/m^2$ effectively reduced the nematode population followed by *Paecilomyces lilacinus* @ $25g/m^2$.

12. **Screening of banana germplasm against pseudostem weevil, *Odoiporus longicollis***
(BRS, Kannara)
Three out of 27 accessions maintained at Kannara (ITC0591-Kasaka(AA), ITC0825-Uzhakan (AAB) and ITC0217-Akpakpak (AAB) were moderately susceptible to PSB as reported in the previous year. Among the 8 accessions screened in contained condition, ITC 0277 (Leite) was found to be Moderately Resistant (Score Value : 1) to PSB infestation, whereas ITC 0258 (Pisang Madu) proved to be most congenial for successful completion of the life cycle and breeding of pseudostem weevil, thus susceptible among the screened accessions with a score value of 4.

13. Biological control of banana stem weevil, *Odoiporus longicollis Oliv.* *(BRS, Kannara)*

Among the biocontrol agents T5 (Stem trap swabbed with *Heterorhabditis* sp. @ $1x10^9$ IJs/ml at 5^{th}, 6^{th} and 7^{th} month after planting) and T1 (Fungus, *Beauveria bassiana* ($1x10^7$ spores/ml) spray at 5^{th}, 6^{th} and 7^{th} month after planting + stem trapping) were the most effective in reducing the number of holes/plant and was on par with T6 (treated check – chlorpyriphos 0.1% 2.5 ml/l). But when number of live stages (weevils, grubs and pupae/plant) was considered, T4 (Stem trap swabbed with *Beauveria bassiana*) and T5 (Stem trap swabbed with *Heterorhabditis* sp.) proved to be on par with treated check (T6) in their efficacy in reducing the various stages of attack.

Highest bunch weights of 10.157 kg, 9.643 kg and 9.447 kg were recorded in T6 (Insecticide check –chlorpyriphos (0.1% (2.5 ml/l), T5 (Stem trap swabbed with *Heterorhabditis* sp. @ $1x10^9$ IJs/ml at 5^{th}, 6^{th} and 7^{th} month after planting) and T1 (Fungus, *Beauveria bassiana* ($1x10^7$ spores/ml) spray at 5^{th}, 6^{th} and 7^{th} month after planting + stem trapping) respectively. T4 (Stem trap swabbed with *Beauveria bassiana*) and T5 (Stem trap swabbed with *Heterorhabditis* sp.) proved to be on par with treated check (T6) in its efficacy in reducing the various stages of the pseudostem borer of banana and its management.

14. Management of banana skipper butterfly-*Erionota torus* *(BRS, Kannara)*

After imposing 2^{nd} round of treatment, significantly least number of leaf rolls (0.837) was recorded in T1 (Foliar application of Chlorantranilipole 18.5 SC). This was on par with the values of T2 (Foliar application of Acephate) and T3 (Foliar application of Quinalphos 25 EC). In 3^{rd} and 4^{th} observations, T1 (Foliar application of Chlorantranilipole 18.5 SC) consistently recorded least number of leaf rolls formed thus proving its efficacy against banana skipper butterfly. Among the biocontrol agents foliar application of Bt solution proved to be better. Highest number of leaf rolls were recorded in untreated control.

When yield was considered, significantly high (8.975 kg) and low (7.790 Kg) bunch weight were recorded in T1 (Foliar application of Chlorantranilipole 18.5 SC) *i.e* 8.975 kg and T6 (Control) respectively. Bunch weight in all the remaining treatments was on par with control (T6).

The treatment T1 (Foliar application of Chlorantranilipole 18.5 SC) effectively reduced the banana skipper butterfly infestation. Among the biological control methods, foliar application of Bt @ 3ml/l ($1x10^{t8}$ cfu) proved better.

15. Diagnosis of banana viruses in germplasm and planting materials used in experiments *(BRS, Kannara)*

The genotypes in germplasm and the planting materials used in experiments were screened for viruses based on symptoms and serologically by ELISA. The results obtained during 2015-16 are : Of the 78 accessions of germplasm, four accessions were infected by BBTV, seven accessions were infected by BBrMV and one accession was infected by BSV. Of the 80 samples of experimental planting materials, two samples were infected by BBTV, five samples were infected by CMV. (v) The indexing of germplasm accessions conducted from

2008-2015 period showed that fourteen accessions of the germplasm were free of BBTV, BBrMV and CMV.

16. **Integrated management of Fusarium wilt disease of banana** *(BRS, Kannara)*
Significant reduction in wilt index and vascular wilt index was recorded in carbendazim applied treatments (T2 and T3). Least wilt index was recorded in T3 (Disease free suckers from disease free field + application of vermicompost @ 250g/plant + dipping in carbendazim (0.2%) for 30 min. followed by carbendazim drenching 0.2% solution and carbendazim injection @ 3 ml of 2 % solution (3^{rd} , 5^{th} and 7^{th} month after planting) followed by T2 (dipping in carbendazim (0.2% for 45 min). Least vascular wilt index was recorded in T2 followed by T3 and they were on par. There was no significant difference in growth parameters like height, girth and number of leaves among treatments. Organic treatments, T6 (Soil application of *T. viridae* + *P. fluorescence* @ 50g/plant two times) and T5 (Application of *P. fluorescence*@ 50g/sucker three times) were on par and were more effective than T4 (Soil application of *T. viridae* @ 50g/sucker three times).

17. **Management of sigatoka or prevalent leaf spot disease with oil based formulations** *(BRS, Kannara)*
The lowest disease index (PDI) was recorded for T2 (Propiconazole 0.05 % + mineral oil 1% - 3 sprays at 25 days interval) followed by T3 (Chemicals + Mineral oil). Youngest leaf spotted also recorded the same trend with highest value in T2 followed by T3. There was no significant difference in vegetative characters except plant girth. Significant difference was also recorded in bunch weight; maximum recorded in T 3 (6.33 kg). The conclusions drawn are T2 is the best treatment for management of Emmusae leaf spot.

18. **Survey of fungal, bacterial and viral diseases of banana** *(BRS, Kannara)*
No new diseases were recorded in the period of survey. Increasing incidence of BBrMV was observed compared to previous year.

19. **Management of post harvest disease** *(BRS, Kannara)*
The bio agent *Psuedomonas viridiflava* is the best for reducing anthracnose severity and crown rot severity.

20. **Screening of banana germplasm** *(BRS, Kannara)*
Emmusae Leaf spot : Of the 78 accessions screened against Emmusae leaf spot, two accessions recorded PDI zero. Ten accessions showed PDI 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 18 accessions screened against Fusarium wilt, 12 accessions recorded vascular wilt index (VW1) 1 – 20. Two accessions showed VWI in the range of 21 -30, Four accessions showed VWI more than 30.

21. Collection, characterization, conservation, evaluation and utilization of jack fruit germplasm *(BRS, Kannara)*

Exploration was carried out in Thsissur, Ernakulam, Palakkad and Idukki districts. The traits targeted was earliness, extended cropping period and suitability for chips, fruits, cooking purpose and processing. Twenty accessions identified were characterized using IPGRI jackfruit descriptor and evaluated *in situ*. The accessions include 13 dessert types, 6 cooking types and 1 all purpose type. Out of the cooking types two were suited for chips.

22. Varietal trial on jackfruit

Muttom varikka and Pechiparai-1 are vigorous growing than other varieties. Vegetative growth was significantly superior in Pechiparai-1 and MuttomVarikka.

23. Survey and incidence of disease in Jack Fruit

Survey was conducted in different locations of Thrissur and Palakkad district and the diseases observed are given in table.

Sl.No	Disease	Causal organism	Symptom
1	Leaf spot	*Colletotrichum* sp	Brown coloured irregular spots on leaves
2	Leaf spot	*Curvularia* sp	Dark brown spots small in size and numerous in number
3	Leaf blight	*Alternaria* sp	Leaf blight with zonations at the tip of leaf
4	Leaf blight	*Pestalotia* sp	Grey coloured blight at the leaf margins
5	Leaf blight	*Rhizoctonia* sp.	Irregular greyish brown spots with thick margin
6	Algal rust	*Cephaleuros* sp.	Brown coloured raised spots appear on leaves
7	Twig blight	*Diplodia* sp.	Blighting of slender twigs
8	Pink disease	*Corticium salmonicolor*	Symptom appears at the junction of branches or between branch and trunk. Drying of infected branches and appearance of reddish exudates.
9	Fruit rot	*Rhizopus* sp.	Dark brown to black spots on immature fruits, fruits get covered with fungal mycelium, cause pre mature fruit drop
10	Fruit rot	*Sclerotium*	Infect fruit in all stages of growth. Infected area get cover with white fungal mycelium. Infection cause fruit rot
11	Fruit rot	*Botridiplodia* sp	Dark brown circular spots develop on fruits. Infected areas rot

24. Survey and surveillance of pests of Jackfruit

Roving survey

The spittle bug, *Clovia lineaticollis* is a mild but regular pest whenever new shoots are formed, and observed from all the surveyed areas. Defoliation by grass hopper and leaf caterpillar was of regular occurrence. Infestation by the tingid bug was wide spread but of mild nature. The incidence of leaf eating cerambycid beetles (*Olenecamptus bilobus)* was observed during the months of April- June, September –December. All the pests were of minor nature only.

Glenea multiguttata, a cerambycid beetle was observed to cause damage to Jack leaves, especially by severing the veins of jack leaves, leading to drying of leaves and young shoots. Similarly Jackfruit bud weevil (*Ochyromera artocarpi)* was observed to feed heavily on young and tender jack fruits. These cerembycid beetles were reported from Thriruvananthapuram, Pathanamthitta, Thrissur, Ernakulam, Idukki, Wayanadu, Palakkad, Alleppy Districts. Jack fruit aphid (*Greenidia artocarpii)* a sucking pest that causes crinkling of leaves was also observed in young shoots. Incidence of *Oberea artocarpi* was recorded from Central zone (Thrissur and Palakkad districts) repeatedly mostly from trees less than 5 years old.

Fixed plot surveys

Gregarious infestation of Leaf beetle (*Olenocamptus bilobus*), closely followed by infestation of Leaf caterpillar (*Margaronia bivitralis*) and Breadfruit mealy bug (*Icerya aegyptica*) was seen in fixed plot in Thrissur District. Incidence of *Oberea artocarpi* was regularly observed. Grubs of jack shoot borer, *Oberea artocarpi* was lab reared and bioecology under Kerala condition is being recorded. Incidence of *Epepeotes uncinatus*, the newly reported jack defoliator, which was reported for the first time in the previous year, was repeatedly noticed in the fixed plots. *Batocera rufomaculata* incidence was noticed on a damaged branch

25. Breeding new varieties of pineapple (PRC, Vellanikkara)

The F1 hybrid progenies (58 No's) developed through crossing of Kew and Mauritius were evaluated. The hybrids showed characters of Kew and Mauritius as well as mixed characters. Yield and organoleptic evaluation was done. Hybrids with average fruit weight above 1.00 kg, TSS more than 10^0 B and good taste were selected for further evaluation. 14 hybrids were selected.

26. Collection and evaluation of pineapple germplasm for various traits (PRC, Vellanikkara)

Twenty four varieties collected and evaluated are being maintained. The hybrid MD-2 has been added to the germplasm.

27. Demonstration of the potential of high yielding varieties of pineapple and popularisation of TC pineapple (PRC, Vellanikkara)

Amritha, Mauritius and MD-2 varieties performed well under Vellanikkara conditions. The mean fruit weight of Amritha was 1.170 kg and that of Mauritius variety was 1.370 kg. In Amritha and Mauritius there was no difference in yield, when PoP recommendation of fertilizers was compared with 50% additional fertilizers under fertigation.

In another study the performance of TC plants of MD-2 was compared with suckers and crowns of TC MD-2 plants – Suckers as well as crowns of TC plants of MD2 under drip and mulch performed better compared to TC plants of MD2 (under drip and mulch) or suckers of MD2 (without drip and mulch) with respect to fruit weight and fruit circumference. The average fruit weight of crowns of TC plants of MD2 (under drip and mulch) was 1.86 kg and that of suckers of TC plants of MD2 (under drip and mulch) was 1.71 kg and on par. The crop duration was also significantly less in both the cases. All the treatments produced high

quality fruits in terms of TSS, sugars and acidity. The fruits were very attractive with cylindrical shape and golden yellow flesh colour in all treatments. Large scale planting of MD2 hybrid has been undertaken for producing sufficient suckers for distribution.

28. **Post harvest handling, storage and value addition in banana and pineapple for domestic and export market.** (PRC, Vellanikkara)

The objective of this project was to standardize the maturity indices for domestic market and export market in pineapple and also to study the suitability of pineapple varieties for product preparation and value addition. The best stage of harvest for domestic market for Mauritius pineapple variety was standardised. For immediate consumption fruits have to be harvested at 51-100% eyes changed to yellow. For distant market fruits have to be harvested at fully mature green stage.

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. Regarding pickle preparation the variety Kew was most suitable for pickle making. For fresh pulp and juice maximum score with regard to colour and texture 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.

29. **Organic versus inorganic nutrient management of pineapple varieties for safe and sustainable production**

The initial observations till nine months of planting indicated that the pineapple variety Amritha came to flower in 265 days, followed by Mauritius in 272 days and MD-2 in 307 days from the date of planting. The variety Amritha came to flower in 23 days followed by Mauritius in 30 days and MD-2 in 38 days from the date of ethephon application. At nine months after planting MD-2 (81.49 cm) was the tallest followed by Mauritius (81.47 cm) and Amritha (76.58 cm). At nine months after planting all the treatment effects were statistically significant for number of leaves. The maximum number of leaves was produced in MD-2 (27) followed by Amritha (26) and Mauritius (23) at six months after planting. The canopy spread varied significantly with varieties after three months of planting. The maximum spread was for Mauritius (84.39 cm) followed by MD-2 (80.95 cm) and Amritha (77.53 cm).

Concluded PG Projects

1. **Morpho –molecular characterization of jackfruit (*Artocarpus heterophyllus* Lam.) accessions**

Twenty types/ accessions of jack fruit maintained at the College orchard and in the Pineapple Research Centre, Vellanikkara along with MuttomVarikka, Sindhoor and Thamarachakka were used for the study. All the accessions/ varieties showed variability in tree characters, fruit characters and fruit quality. Grouping of accessions done based on tree characters, which

resulted in six overlapping clusters and based on inflorescence characters five non overlapping clusters were obtained. Molecular characterization of the selected accessions were carried out using standard procedure and subjected to IISR technique.

2. **Identification and characterization of jack fruit types in Kasaragod district.**
   Out of the thirty jack fruit types selected for the study, KJ180, KJ182, KJ183,KJ185,KJ186,KJ356 and KJ397 were found to be the best dessert types. KJ173 (flake less) was ideal for tender jack purpose. KJ121 showed fruiting more than thrice in a year.

3. **Evaluation of papaya types**
   A preliminary survey was conducted in the homesteads of Thrissur, Palakkad and Ernakulum districts. Twenty five accessions were selected for field evaluation based on morphological characters with special reference to flowering and fruiting characters. Tolerance to important pest and diseases were also considered for selection. Twenty five accessions along with five released varieties namely Arka Prabath, CO 8, CO 7, CO 2 and Pusa Nanha were evaluated in the field. In the field evaluation Pusa Nanha recorded the lowest plant height throughout the observation period. Acc. 15 and Acc.13 were comparatively short in nature. Highest fruit weight (1830 g), fruit length (29 cm) and fruit volume (2060 ml) was recorded in Acc.15. Accession 25 produced highest numbers of fruits per plant (35.11) followed by Acc. 1 (32.66), Acc. 5 (32.33) and Acc. 6 (30.11). Highest per cent of reducing sugar was recorded by Acc.11 (10.49 %) followed by Acc. 14 (10.36%). As a result of survey, collection and evaluation 8 accessions and Pusa Nanha were selected. These included Acc. 1, Acc. 6, Acc. 8, Acc. 11, Acc. 13, Acc. 14, Acc. 15, Acc. 25 and Pusa Nanha.

Ongoing PG Projects

1. **Production dynamics of strawberry (*Fragaria x ananassa* Duch.) in Kerala**
2. **Ecophysiology and screening for climate change resilience in mango (*Mangifera indica*) genotypes**
3. **Precision farming in banana (*Musa* AAB Nendran) for productivity enhancement.**
4. **Standardization of *in vitro* male bud culture in banana Musa (AA) 'Kadali'**
5. **Evaluation of clonal variation in banana *Musa spp* (AAB group) 'Rasthali'**
6. **Standardization of macro propagation technique in banana *Musa* (AAB) 'Nendran'**
7. **Salinity stress tolerance in rootstock mango (*Mangifera indica* L.)**
8. **Vegetative propagation of promising jack fruit (*Artocarpus heterophyllus* Lam) types.**
9. **Performance evaluation of ecotypes of banana (*Musa* AAB Plantain subgroup**

Name of the Project Coordination Group (5)

Field Crops – Cereals (other than rice), millets, Pulses, oil seeds, fodder crops and green manure crops

Project Coordinator: Dr. Mercy George

Concluded Projects: 29 Nos
Ongoing Projects: 2 Nos

Concluded PG Projects: 2 Nos
Ongoing PG Projects: 7 Nos

Concluded Projects

1. **Management of cowpea aphid - AINP on Arid Legumes, RARS, Pattambi**
   Among the nine treatments tested against cowpea aphid, the treatment T_7(Dinotefuran @ 0.4g/litre spray) was found to be the best in managing the cowpea aphid. This was followed by T_5 (Ethiprole + Imidacloprid @ 0.3g/litre spray).The next best treatment was T_2 (Neem leaf extract 40% spray). The treatments *viz*., T_4 (Tag folder @ 4ml/litre spray), T_3 (Azadirachtin 10000 ppm@ 2.5ml /litre spray) and T_1 (Neem leaf extract 30% spray) were found on par in managing the cowpea aphid.

2. **Evaluation of cowpea entries for pests- AINP on Arid Legumes, RARS, Pattambi**
   The cowpea entries *viz*., CPP-3, CPP-4, CPP-12, CPP-17, CPP-18 and CPP-19 were recorded with no incidence of aphid.

3. **Survey of pests occurring in cowpea (Palakkad and Malappuram) districts - AINP on Arid Legumes, RARS, Pattambi**
   The survey on DC-15 cowpea fields showed that the variety is resistant to aphids and pod borers.

4. **Management of seed mycoflora of cowpea- AINP on Arid Legumes, RARS, Pattambi**
   Among the six treatments tested, the treatment T_2 (Carbendazim + Mancozeb seed treatment @ 2g/kg of seed) was found to be the best in increasing the germination and reducing the dry root rot of cowpea variety Kanakamony. The treatments *viz*., T_1 (Carbendazim seed treatment @ 2g/kg of seed) and T_3 (Mancozeb @ 3g/kg of seed) were found on par in increasing the germination and reducing the dry root rot. With regard to yield T_2 recorded the highest yield of 1029.06 kg/ha this was followed by T_1 with 1029 kg/ha where as T_3 recorded 936.56 kg/ha.

5. **Efficacy of different rhizobium cultures on cowpea- AINP on Arid Legumes, RARS, Pattambi**
   Among the five treatments tested, the treatments *viz*., T_1 (RCW 33b seed treatment@ 10 g/kg of seed) T_2 (RCW 33c seed treatment @10 g/kg of seed) and T_3(CP3 seed treatment @10 g/kg of seed) were found on par in increasing the yield of cowpea. They recorded the yield of 1402.30, 1374.55 and 1363.45 kg respectively.

6. **Evaluation of cowpea entries for diseases- AINP on Arid Legumes, RARS, Pattambi**
   Out of twenty three entries tested against collar rot of cowpea, sixteen entries *viz.*, CPP-1, CPP-2, CPP-3, CPP-5, CPP-9, CPP-10, CPP-11, CPP-12, CPP-13, CPP-14, CPP-15, CPP-16, CPP-17, CPP-19, CPP-20 and CPP-21 were showed resistant reaction to collar rot disease.

7. **Evaluation of horse gram entries for diseases- AINP on Arid Legumes, RARS, Pattambi**
   Out of nine entries tested, two horse gram entries *viz*., HGP -8 and HGP-9 recorded the maximum dry root rot incidence (66 per cent) and the rest seven showed resistant reaction.

8. **Evaluation of guar entries for diseases- AINP on Arid Legumes, RARS, Pattambi**
   No disease was observed in all the eight entries.

9. **Survey of diseases occurring in Cowpea (Palakkad and Malappuram) districts - AINP on Arid Legumes, RARS, Pattambi**
   The survey showed that the variety Dc-15 was resistant to diseases.

10. **Management of bacterial leaf blight of rice (Observation trial)**
    In order to manage the kresek phase of bacterial leaf blight of rice seven treatments *viz*., T_1. Mancozeb 0.1%, T_2. Mancozeb 0.2%, T_3.Mancozeb 0.3%, T_4. Cow dung extract 2% + Vermi compost extract 2%, T_5. Cow dung extract 2%, T_6. Streptocycline 250 ppm and T_7.Control were tried in completely randomized block design with three replications during rabi 2015. Among them, T_3 (Mancozeb 0.3%) and T_6 (Streptocycline 250 ppm) were found the best in managing the kresek phase of BLB. This was followed by T_2 (Mancozeb 0.2%) and T_4 (Cow dung extract 2% + Vermi compost extract 2%). The treatments *viz*., T_1 (Mancozeb 0.1%) and T_5(Cow dung extract 2%) were found on par in managing the disease.

11. **Farm trial on management of cowpea aphid through seed treatment**
    Farm trials were conducted at different places of Anakara, Thrithala and Polpullypanchayats.

12. **FLD on horse gram variety CRHG-19**
    Frontline demonstrations on horse gram variety CRHG-19 was conducted at different places of Palakkad district during rabi season. The result showed that the variety performed well and could yield an average yield of 1838kg/ha.

13. **FLD on cowpea variety DC-15**
    Frontline demonstrations on cowpea variety DC-15 was conducted different places of Palakkad district.

14. **FLD on black gram varieties *viz*.,LGG-460, TM-96-2 and Co-8**
    Frontline demonstrations on black gram varieties *viz*.,LGG-460, TM-96-2 and Co-8 were conducted at different places of Palakkad district.

15. **FLD on green gram varieties *viz*., ADT-3. Vamban-3, Vamban-6, LBG-752 and Co-6**
    Frontline demonstrations on green gram varieties *viz.*,ADT-3. Vamban-3, Vamban-6, LBG-752 and Co-6 were conducted at different places of Palakkad district.

16. Nutrient management on different varieties of cowpea

Pooled mean over three years showed that all the three different levels of fertilizer applications *viz*., RDF 100 %, 75 % RDF + Bio fertilizers (*Rhizobium*+ PSB), 50 % RDF + N equivalent through FYM/compost were found on par in increasing the yield of cowpea varieties *viz*., Kanakamony and DCS 47-1.

17. AVT on cowpea

Among the sixteen entries tested, the entry CP-7 recorded the highest yield of 1353.58 kg/ha and it was followed by the entry CP- 10 with the yield of 1281.43 kg/ha and they were found on par. These were followed by CP-1 and CP-15 with the yield of 1184.62kg/ha and 1093.97 kg/ha respectively. The entry CP-7 was of short duration type (64 days to maturity) and CP-10 (84 days to maturity) was of long duration type. Both entries CP-7 and CP-10 were resistant to dry root rot disease.

18. IVT on cowpea

Among the eleven entries tested, the entry CP-29 recorded the highest yield of 1916.64 kg/ha and it was followed by the entries *viz*., CP-28, CP-23 and CP-24with the yield of 979.73,798.01 and 761.62kg/ha respectively. The entry CP-29 could mature in 71 days where as CP-28 could mature in 75 days. Both entries CP -29 and CP- 28 were resistant to dry root rot.

19. IVT on horse gram

Among the eleven entries tested, only six entries were found with pod setting. Among them, entry HG- 13 showed maximum yield of 1143.92 kg/ha and it was followed by the entry HG-8 with the yield of 1026.75/kg/ha. The entry HG-13 could mature in 75 days where as HG-8 could mature in 73 days.

20. AVT + IVT on guar

Among the sixteen entries tested, the entry GR-2 recorded highest yield of 939.80 kg/ha and it is followed by the entries *viz*., GR-16 and GR-1 with the yield of 802.90 and 780 kg/ha respectively.

21. Hybrids developed at RARS, Pattambi

Among the eleven hybrids developed at RARS, Pattambi, the three years pooled data showed that nine were showing higher yield over the check variety Kanakamony.

22. Crosses attempted at RARS, Pattambi

Seven crosses were attempted during 2015 -16 and the progeny seeds were stored for further work.

23. IVT – Initial varietal Trial Oat (SC) --AICRP ON FORAGE CROPS & UTILIZATION, VELLAYANI

Among nine varieties, IVTO-SC-4 recorded highest green fodder yield of 204 q/ha.

24. IVTC- Initial Varietal trial in Forage Cowpea (NEW)

Among 10 varieties, IVTC-6 and IVTC-6 recorded highest green fodder yield of 295 q/ha.

25. IVTRB- Initial Varietal trial in Forage Rice bean

Among seven varieties, IVTRB-5 recorded highest green fodder yield (165q/ha).

26. Evaluation of Bajra Napier Hybrids for Yield and Forage Quality

Significantly higher green fodder yield was recorded by the culture NB-08-11 (T_1).

27. Evaluation of Guinea grass cultures for Yield and Forage quality

Significantly higher green fodder yield was recorded by the culture GG-08-04 (235.93 q ha^{-1}).

28. Studies on the effect of additives on silage quality of different grasses

Both BN hybrid and guinea grass were found to be equally suitable and remunerative for silage preparation. Addition of tapioca flour@1% on the fresh weight basis is recommended for quality organic silage preparation from cultivated perennial grasses.

29. Impact of Magnesium and Boron on nutrient uptake, quality and yield of Hybrid Napier

Application of 80kg $MgSO_4$ along with RDF (200:50:50kg NPK and 25t/ha of FYM) to bajra napier hybrid is recommended for higher fodder yield and better quality fodder. The technology resulted in production of upto 2100 q green fodder with higher crude protein content and net returns of upto Rs. 94,000, B:C ratio of 2.35.

Ongoing projects

1. 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. F1 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 raised in the field.

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

Comparative Yield Trial-II was carried out with the selected lines and ASS-11,ASS-10 and ASS-7 recorded significantly higher yield than the check variety Thilak.

Concluded PG Projects

1. **Combination breeding for high protein cowpea (*Vigna unguiculata* L.Walp)**

The study was undertaken at COH, Vellanikkara as three experiments. I). Evaluation of cowpea genotypes. 2) Hybridisation of the selected genotypes in Line x Tester design. 3) Evaluation of F1 hybrids. Results of evaluation of cowpea genotypes revealed that there is wide variability for all the traits except branches per plant among bushy and semi trailing types of cowpea. In trailing type , variability was observed for plant height, number of pods per plant, pod weight grain yield per plant and seed protein content. Among the twenty two genotypes evaluated ten genotypes with more than 25 per cent protein content were selected for hybridization programme. The selected genotypes (Vellayani Jyothika, Bhagyalakshmi, Anaswara, Kanakamony, Lola, Vyjayanthi, AV-5, PKB-3, PKB-4 and Sharika) were crossed in line x tester (6 x4) design.

Evaluation of parents and hybrids revealed that there was higher magnitude of phenotypic and genotypic coefficient of variation, heritability and genetic advance for plant height, grain yield per plant and length of pods suggesting scope for genetic improvement of these traits through selection. Seeds per pod and protein content showed low PCV and GCV but high heritability and low genetic gain, indicating that these traits are governed by non-additive gene action therefore selection is not appropriate for improvement of these traits.

Based on mean value , *sca* effects and three types of heterosis for days to flowering, pods per plant, seeds per pod ,test weight , grain yield per plant and protein content the hybrids were ranked . Based on total of these ranks four hybrids with lowest scores were selected. These were H2 (Vellayani Jyothika x PKB-3) , H10 (Anaswara x PKB-3) , H11(Anaswara x PKB-3) and H12 (Anaswara x PKB-3). These hybrids can be advanced to segregating generations to identify transgressive segregants with high yield and protein content .

2. **Baby corn (*Zea mays* L.) as a dual purpose crop in summer rice fallows.**

A field experiment entitled "Baby corn (*Zea mays* L.) as a dual purpose crop in summer rice fallows" was conducted at the Department of Agronomy, College of Horticulture, Kerala Agricultural University, Thrissur, Kerala, India during the period from February to April 2015, to study the effect of different maize varieties under different plant densities 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.

Ongoing PG Projects

1. **Production package for palisade grass**
2. **Cutting intervals and additives for quality silage production**
3. **Evaluation of sesame genotypes for tolerance to water logging**
4. **Induced mutagenesis for delayed flowering and high tillering in guinea grass**
5. **VTBN-2015 Varietal Trial in Bajra Napier Hybrid (Perennial)**
6. **Intensive production through Agase based cropping system under protective irrigation**
7. **Studies on carbon sequestration in perennial grass based cropping system.**

Name of the Project Coordination Group (06)

Floriculture

Project Co-ordinator: Dr. Sudha Devi. P.K

Concluded Projects: 2 Nos

Concluded PG Projects: 7 Nos

Concluded Projects

1. **Maintenance of area landscaped in and around KAU, Headquarters and College of Horticulture, Vellanikkara**

   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 interior scaping also. Maintained the medians by planting new flowering plants.

2. **Network project on seed and nursery programme-Planting material production**

   The funds were released in December 2016. This was utilized for the purchase of 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*), sweet lime (*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.

Concluded PG Projects

1. **Evaluation of African Marigold (*Tagetes erecta* L.) hybrids/varieties for yield and resistance to bacterial wilt**

   All genotypes showed considerable variation with respect to yield and resistance to bacterial wilt. The genotype P-4 was found to be promising with high yield, large sized flowers and moderate susceptibility to bacterial wilt. The genotype M-1 was 100 per cent resistant to bacterial wilt while the genotype Sakura 031 was found to be 100 per cent susceptible. The genotype M-1 can be used as rootstock for grafting susceptible genotypes. Grafting the susceptible genotypes on resistant rootstock found to be an effective tool to combat the bacterial wilt. Grafting significantly increased the yield in susceptible genotypes without affecting the flower quality attributes.

2. **Evaluation of sewage sludge as a growth medium for ornamentals**

The pot culture experiment results indicated that the growth and yield of marigold was significantly higher in the treatment receiving potting mixture and sewage sludge in the ratio 9:1. The content of heavy metals (Cd, Cr, Ni, Pb) in shoot and root of marigold were found to be above the permissible limit in treatments containing sewage sludge indicating significant bioaccumulation of heavy metal from sewage sludge by marigold.

3. **Refinement of nutrient management practices in *Dendrobium* orchids**

Dendrobium variety Yellow Splash was used for the study. Bioinoculants + benzyl adenine (along with POP recommendation) gave best results in both vegetative and floral parameters. Dominance in vegetative characters observed in *Azospirillum* inoculated plants and AMF followed PGPR Mix – 1 in combination with 100 – 150 ppm BA. With respect to Floral characters, best results was obtained from AMF inoculated plants followed by *Azospirillum* and PGPR Mix -1 inoculation along with BA (100 – 150 ppm). POP + AMF + 150 ppm BA.

4. **Evaluation of fragrant vandaceous orchids for ornamental traits**

Twenty five vandaceous orchids were evaluated for commercial exploitation as value added plants.

Vascostylis Crownfox Red Gem recorded maximum plant height, spread, intermodal length and leaf length.*V.* Pranerm Prai x *V. tessellata* showed maximum shoot girth, leaf area, leaf number and root length.

Among floral characters, Number of spikes produced was maximum (11.50) in *Neostylis* Lou Sneary and was significantly superior to all other varieties and was followed by *Ascda* Sirichai Fragrance (6.43) and *Vascostylis* Crownfox Red Gem (4.54).

Aerides quinque Vulnera Rhy. Coelestis recorded the maximum spike lenth (33.17 cm) and was significantly superior to all other varieties except *Vascostylis* Crownfox Red Gem (32.73 cm). *Aerides quinque Vulnera Rhy. Coelestis* recorded the maximum (22.23 cm) rachis length followed by *Ascda*. Udomchai (20.43cm), *Vascostylis* Crownfox Red Gem (19.80cm) and *Vasco* Blue Bay Blue (19.33cm). Maximum number of florets was noticed in *Vasco* Blue Bay Pink (44.33) followed by *Vasco* Blue Bay White (40.33) and *Vasco* Blue Bay Blue (39.67).Minimum number of florets was recorded in *V.* Pranerm Prai x V. *tessellata* (4.83). Maximum flower size (83.23 cm^2) was recorded in *V.* Rothschildiana followed by *Ascda.* Suksamran Sunlight Yellow (78.27 cm^2) and *V.* Pranerm Prai x V. *tessellata* (72.00 cm^2).Fragrance was observed in all varieties except *V.* Rothschildiana. While considering the blooming periods more number of varieties were flowered during the months of May to July whereas flower production was minimum during February to March. Plant quality rated on the basis of fullness, growth and visual appearance, flower colour and pigmentation, spike longevity, shape and arrangement of foliage during the growth period. *Vasco* Blue Bay Pink had highest mean total score (44.8), followed by *Vascostylis* Crownfox Red Gem (44.7), *Vasco* Blue Bay Blue (44.6) and *Rhynchorides* Bangkok Sunset (44.5). *Neostylis* Lou Sneary,*Rhynchorides*Bangkok Sunset,*Vasco* Blue Bay Blue,*Vasco* Blue Bay White,*Vasco* Blue Bay Pink,*Ascda* Sirichai Fragrance,*Vascostylis* Crownfox Red Gem,*Ascda* Peggy Foo *x Rhyn. coelestis*Blue,*Ascda.* Udomchai, *Aerides quinque Vulnera Rhy. Coelestis* were found to

be suitable for cut flower purpose and these can be recommended for cut flower purpose. *Neostylis* Lou Sneary and*Vasco* Blue Bay White can be recommended for fragrant garden and moon garden. *Rhynchorides* Bangkok Sunset, *Neostylis* Lou Sneary, *Vasco* Blue Bay Blue and *Vasco* Blue Bay Pink are excellent pot plants. While taken the overall qualitative and quantitative attributes, *Vascostylis* Crownfox Red Gem, *Vasco* Blue Bay Blue, *Rhynchorides* Bangkok Sunset, *V.* Mimi Palmer, *V.* JVB X *Ascocenda* Yip Sum Wah and *Vasco* Blue Bay Pink were excellent for both cut flower as well as pot plants. Fragrance was observed in all varieties except *V.* Rothschildiana. Fragrance were categorized based on different notes such as floral, fruity, spicy, green, sweet and miscellaneous.

5. Characterisation and conservation of promising genotypes of orchids from Central Western Ghats

The preliminary survey indicates higher diversity of orchidsin natural forests, which includes rare, endangered species such as Bulbophyllum mysorense, Aerids cripa, A maculosa, Dendrobium crepidatum, Cymbidium bicolor, Rhyncostylis retusa etc. With respect to the species diversity four genera had more number of species compared to other genus, viz., Dendrobium, Bulbphyllum, Hebanaria and Oberonia and maximum number of orchid species were recorded in the genus Dendrobium followed by Bulbophyllum. A total of 46 accessions belonging to14 genera were rescued and established in the orchidarium of which 26 were native to Central Western Ghats. Ideal period for general growth of the plants under Padanakkad condition is January-February while the sprouting was more during June. Genera like Acampe, Bulbophyllum, Coelogyne, Cymbidium, Dendrobium etc showed faster growth in the orchidarium compared to the rest. Six of the accessions flowered in the orchidarium among which one was a wild collection from Brahmagiri. It is a promising genotype which can be used for breeding purposes as it has the longest flower duration (26 days), bright colour, large petals (45.7mm) & sepals (35.6mm) and it flowered two times within 10 months. Morphological and molecular data revealed that there is no duplication in the collection, even within the same genus.

6. In vitro micro propagation protocol for Vanda hybrids with clonal fidelity analysis

Treating the explants with 0.1 per cent carbendazim for 20 minutes, followed by 70 per cent ethanol for 5 minutes and 0.1 per cent mercuric chloride for 5 min effectively reduced the microbial contamination with highest percentage of explant survival. showed positive results for inflorescence segments inoculated on to 1/2 MS + 10 mg l-1 BA+ 2 mg l-1 TDZ+30 g l-1 sucrose+7.5 g l-1agar + 250 mg l-1 cefotaxime as observed as direct shooting of the dormant buds. About 80 per cent and 60 per cent culture establishment was brought about in Dr. Anek and Sansai Blue respectively in 9 weeks. The established cultures successfully produced multiple shoots on MS+4.5 ml l-1BA +30 g l-1 sucrose + 7.5 g l-1 agar + 250 mg l-1 cefotaxime both when inoculated with and without the stalk in about 100 days of inoculation of explant. The micro-shoots from cultures without stalk were further transferred to hormone free basal MS media for elongation. Elongated shoots of about 4 cm were transferred to rooting media with a composition of MS + 0.5 mg l-1 NAA + 1 mg l-1 IAA +30 g l-1 sucrose +7.5 g l-1agar + 250 mg l-1 cefotaxime for better rooting of the regenerants. The percentage of rooting was observed to be 72.41 per cent for Dr. Anek and 70.37 per cent in Sansai Blue.

The rooted plantlets with ample number of healthy roots were planted outm in small earthen pots with charcoal, coconut husk and brick pieces. These were successfully hardened in net house of 50 per cent shade and showed a hundred percent plantlet survival.

7. Induction of genetic variability in phalaenopsis orchids through hybridization and embryo culture

Among the morphological characters studied Phalaenopsis parents varied significantly with respect to total number of leaves, leaf area, and shoot height. Statistical analysis showed that varieties varied significantly for floral characters i.e number of days from first flower opening to last flower opening, days for wilting of the first flower, days for wilting of the last flower, flower size, spike length. Flower size was observed to be biggest in Winter Spot and smallest in Elegant Yellow. Flowers of six selected varieties bloomed between the month of March to November. All varieties bloomed once in a year except Winter Spot which came to flowering twice in a year. Dendrogram generated based on phenotypic characters grouped the selected varieties into different clusters between similarity coefficient of 0.10 to 1.00. At 20 per cent similarity coefficient bifurcation occurred which showed that all the varieties were distinctly variable from each other and shared only 20 per cent similarity. Anthesis time of the flowers ranged from 5:00 am to 2:00 pm among the varieties. Elegant Yellow opened earliest of all (5:00 am -8:00 am) whereas Violet was observed to open from 11:00 am - 2:00 pm. Maximum number of days for stigma receptivity was observed in Winter Spot (3-12 days) and Violet had minimum (1-5 days). Palynology results of parents revealed that there were no significant difference between varieties for pollen fertility percentage, length of pollen tube and pollen production per pollinium. Whereas significant difference was observed in pollen germination percentage and pollen diameter. Pollen germination percentage was maximum (100 %) in Elegant Yellow and minimum in Elegant Purple (47.2%). Pollen diameter was maximum in Winter Spot (107.68 μ) and minimum in Pink (84.58 μ). Out of 13 ISSR primers screened, seven primers gave maximum number of clear and reproducible bands. 100 per cent polymorphism was obtained by UBC 841. Dendrogram generated based on molecular data clustering had similarity coefficient between 0.56-0.78. Three different clusters were observed in which Elegant Purple and Pink were most closely (78 %) related to each other. Inter varietal crosses made in all possible cross combinations between the selected varieties resulted in pod set of six crosses. They were Winter Spot X Elegant Purple, Winter Spot X Pink, Elegant Purple X Pink, Pink X Winter Spot, Pink X Elegant Purple and Violet X Elegant Purple. Pod set percentage ranged between 0 – 66.6 per cent among the varieties. Embryo culture was done with seeds from successful crosses in MS and Knudson-C basal media with and without growth regulators. Seeds from the crosses Winter Spot X Pink, Elegant Purple X Pink and Pink X Elegant Purple germinated maximum (50 %) in half MS medium supplemented with 1 mg l-1 BA, 0.1 mg l-1 NAA and 0.5 per cent activated charcoal and in Knudson-C (40 %) basal medium supplemented with BA 3 mg l-1 and NAA 0.3 mg l-1.Germinated seeds developed into protocorms in the crosses between Pink × Elegant Purple and Elegant Purple × Pink. Protocorms when sub cultured to half MS basal medium supplemented with 1 mg l-1 each of BA and NAA exhibited leaf differentiation from the cross Pink × Elegant Purple. Therefore, plantlets emerging from these crosses have to be further grown for assessing the genetic and phenotypic variability generated.

Name of the Project Coordination Group (7)

Aromatic& Medicinal Plants

Project Coordinator: Dr. Mini Raj. N

Concluded Projects: 6 Nos

Ongoing Projects: 10 Nos

Concluded PG Projects: 1 No

Concluded Projects

1. **Standardization of Agrotechniques for Nursery and Organic Farming Techniques in Noni (*Morinda citrifolia)* in a Multicropping System**

Soaking noni seeds and seeds stored for one month in 70 per cent cow dung slurry for 24 hours registered better performance than untreated control with respect to germination percentage, intensity of dormancy, days to achieve 50 per cent germination as well as maximum speed of release of dormancy. Hydration treatments, (soaking in cold for 24 and 48 hours) exhibited moderate performance with respect to parameters for assessing dormancy behaviour. Fresh seeds subjected to overnight soaking in cow dung slurry was superior with respect to seed quality parameters like shoot and root length of seedlings, seedling dry weight, vigour indices, as well as electrical conductivity of seed leachate. Considering the superior performance with respect to parameters influencing dormancy and germination, as well as seed quality parmeters, overnight soaking of noni seeds in 70 per cent cow during slurry can be recommended as a promising technique for invigorating noni seeds. Noni seeds are not amenable to storage beyond one month, since their germination percentage after stoarge for two, three and four months was 10 percent or less. Storage beyond one month resulted in comparatively high EC values indicative of deterioration in membrane stability during prolonged storage.

Hydration treatments of noni seeds followed by soaking in 70 cent cow dung slurry for 24 hours proved to be the best invigoration treatments for breaking dormancy as well as registering high germination percentage and superior seed quality parameters in invigorated stored seeds. A drastic reduction in germination percentage was noticed invigorated stored seeds at 4 MAS indicting that invigoration treatments were not effective beyond 3 MAS.

Five noded semi hardwood cuttings and 2-3 nodded hollow stem cuttings registered superior performance as vegetative propagating materials. Basal dip in cow dung slurry or charcoal slurry proved superior with respect to sprouting percentage as well as shoot and root parameters. Tender coconut water and noni juice were also promising organic growth promoters. Supplementing *Azospirillum* and PGPR to standard potting mixture, proved to be superior with respect to the parameters studied. Positive effect of AMF was evident only in combination with PGPR, confirming the beneficial effect of synergistic microbial associations.

Application of poultry manure, 20 kg/ plant along with vermicompost, 4 kg/plant and neem cake, 2 kg/plant, enriched with PGPR I, was standardized as the most effective treatment for raising noni under organic resource mangement for ensuring optimum vegetative growth and yield parameters like number of fruits, mean fruit weight and total fruit yield. Compared to farm yard manure based organic manures, application of poultry manure registered enhanced contents of available phosphorus and available potassium in noni soils. Farm yard manure based treatments recorded comparable values with that of poultry manure based treatments with respects to fungal and bacterial population in the soil.

Intercropping in noni revealed that cowpea among vegetables bush cowpea, amaranthus and bhindi could be raised as profitable intercrops in noni garden during rabi, summer and khariff seasons respectively, since they enriched soil microbial population and soil nutrient status,

maintaining reasonably good yield of the main crop. Annual spices like ginger and turmeric and the zingiberaceous medicinal plant, kacholam can also be recommended as suitable intercrops in noni gardens during khariff season considering both the profit generated.

2. Exsitu Conservation of RET Medicinal Plants

This project funded by ICAR (100 crore project) was carried out at the Department of Plantation Crops & Spices, College of Horticulture, under the leadership of Dr.N.MiniRaj.

Scientific progress of work

RET species selected

1. *Benincasa hispida* (Vaidyakumbalam).
2. *Coscinium fenestratum* Gaertl. (Maramanjal).
3. *Embilia ribes* (Vizhal).
4. *Myristica malabarica* L. (Kattu jathi).
5. *Nervilia aragoana* Goud. (Orilathamara).
6. *Nothapodytes nimmoniana*Graham. (Peenari).
7. *Pterocarpus santalinus* L. (Rakthachandanam).
8. *Pterospermum rubiginosum* Hyne. (Elluooty).
9. *Rauvolfia serpentina* (Sarpagandhi)
10. *Salacia reticulata* Wight (Ekanayakam).
11. *Symplocos racemosa* Roxb. (Pachotti).
12. *Trichosanthus cucumerina* (Kaipan padavalam).

In the first year (2012-13) of the project no technical work could be done as the fund was released in the month of March. Only the non Recurring expenditure could be booked during the year. Progress of work carried out during 2013-14 is presented below.

A. ***Collection of secondary data*** **:** Published flora of Kerala forests were scanned to locate the natural habitats of the select species. Discussions were held with taxonomists of Kerala Forest Research Institute (Peechi), Tropical Botanical Garden and Research Institute (Palode, Trivandrum), Centre for Medicinal Plant Research (Kottakkal), Malabar Botanical Garden (Kozhikode), M.S.Swaminadhan Research Fountation (Wayanad), State Medicinal Plant Board (Thrissur) and National Bureau of Plant Genetic Resources (Vellanikkara) to get information on the availability and distribution of the species and about the herb gathers at various forest areas.

B. ***Permission from PCCF, Trivandrum*** **:** Application for collection of specimens was submitted to the Kerala Forest Department. After two rounds of discussion and clarification, Principal Chief Conservator of Forest, Foest Headquarters, Trivandrum granted permission to collect minimum specimens from the protected areas and Reserve forests of Kerala on strict conditions. (Copy of permission letter attatched as Annexure -1).

C. ***Arranging propagation chamber, shade net houses, concrete pots, otherinputsand chemicals for propagation studies*** **:** Shade net house, propagation chamber, concrete pots and other propagation devices were repaired and made ready for project. Herbarium sheets and other inputs were procured for the study.

D. ***Forest exploration*** **:** Five forest explorations were carried to the following sites with the help of forest officialsin each region.

1. Malakkappara – Sholayar forests
2. Vazhachal forest
3. Kulathupuzha forest
4. Thamarassery and Wayanad forests

5. Peechi – Vazhani Wild Life Sanctuary.

Details of species collected from forest areas.

SI No.	Area	Species collected	Habit	Propagule collected
1.	Kulathupuzha forest	*Myristica malabarica* *Myristica beddomei* *Gymnacranthira ferquihariana* *Knema attenuata*	Tree Tree Tree Tree	Seeds Seedlings Seedlings seedlings
2.	Peechi forest	*Trichosanthus cucumerina* *Nervilia aragoana* *Rauvolfia serpentina*	Herbaceous climber Terrestrial orchid Herb	Seeds Tubers Root suckers
3.	Thamarassery pass (Wayanad)	*Embelia ribes* *Myristica malabarica* *Pterospermum rubiginosum* *Nervilia infundibulifolia*	Woody climber Tree Tree Terrestrial orchid	Seedlings Seedlings Seedlings Tubers
4.	Tirunelli forest	*Pterospermum rubiginosum* *Nervilia plicta*	Tree Terrestrial orchid	Seedlings Tubers
5.	Vazhachal forest	*Myristica beddomei* *Nervilia plicata*	Tree Terrestrial orchid	Seedlings Tubers

E. Propagation studies

Propagation studies were carried out in the following species

1. *Coscinium fenestratum*

a. Seed propagation

100 seeds were brought from the seed bank of TBGRI, Trivandrum and kept for germination with the following treatments;

T1 – GA 1500ppm
T2 – GA 2000ppm
T3 – GA 2500ppm
T4 – GA 3000ppm
T5 – Control

15 seeds were kept in the treatments ineach treatment in plastic trays. Germination has not started.

b. Layering in *Coscinium fenestratum*

Ground layering as well as air layering was done in *Coscinum fenestratum* plant available in the herbel garden on semi hardwood branches. None of these have been successful.

2. *Pterospermum rubiginosum*

Two voucher trees are maintained at LRS, Thiruvizhamkunnu. Cuttings of the following categories were brought and used for propagation studies.

T1 – Hard wood
T2 – Semi hard wood
T3 – Terminal cuttings

3. Growth regulators

IAA – 50, 100, 200, 400 ppm

IBA – 50, 100, 200, 400 ppm

F. Voucher plants and trees

Voucher specimens were taken from all the select species collected and herbariums made. Plants were identified using the checklist (CD) of flowering plants of Kerala, published by KFRI, Peechi with clarification from the plant taxonomists where ever required.

Voucher trees of selected species were located as given below

1. *Pterospermum rubiginosum* – LRS, Thiruvizhamkunnu.
2. *Coscinium fenestratum* – Sholayar forests.
3. *Embelia ribes* – Thamarassery pass (8/9th hairpin bent).
4. *Myristica malabarica* – Thamarassery pass.
5. *Myristica beddomei* – Thamarassery pass.
6. *Pterospermum rubiginosum* – Thamarassery pass, Manikkunnu mala.
7. *Nothopodytes nimmoniana* – Lakkidi, private estate.
8. *Nervilia infundibulifoha* – Muthanga Wild Life Sanctuary, Tirunelli forests.
9. *Salacia reticulata* – Not located.
10. *Symplocos recemosa* – Not located.
11. *Pterocarpus santalinus* – Not located.
12. *Rauvolfia serpentina* – Peechi.
13. All *Myristica species* – *Myristica* swamps in Kulathuppuzha forests.

3. Exploitation of bisexual variants for developing high yiekding varieties in *Piper longum* L –Phase II

In an experiment to study the effect of growth regulators on bisexual flower production, it was observed that with three repeated sprays of BA 500mgl^{-1}, ratio of male to bisexual flowers changed from 79:1 to 26:1.

In the hybridization studies, it was observed that seed set was maximum during July and September with bisexual type 1 as male parent and spike set was maximum in September with bisexual type 2 as male parent.

Hybrids with high percentage of bisexual flowers (Acc. 97 and 53) developed during Part I of the project was back crossed to male and female parents. There was no seed set in any of the crosses. However, on back crossing fully female hybrids (15 accessions) with bisexual parents, 54 hybrid seeds were obtained. Even though six back cross seeds germinated, the seedlings did not flower even after two years.

A total of 169 seeds were obtained in the crosses made, only 32 germinated (18.9%). 0ut of the 32 seedlings, 11 were lost due to seedling rot and five due to albinism. There was very high variability in most of the characters studied among the seedlings.

From the seedling population produced in the first and second part of the project 10 female accessions were selected for evaluation in pots under two shade levels, viz., 25% and 50% shade. Monthly observations were made on growth in length of plant, number of leaves, branches, number of laterals, spike production and yield. In general, plants showed good vegetative growth at 50% shade. However, reproductive characters improved with reducing shade levels.

Of the ten hybrid accessions evaluated Acc. 9, 63, 140 and 141 were better performers in terms of yield. These were selected for further evaluation in the field. These four accessions were planted for field evaluation along with female parent and released variety Viswam as standard check. The design was RBD with three replications and six plants per replication. Observations were made on plant length, number of leaves, no. of branches, number of laterals, number of fruits per plant and fresh yield of spikes. Even though female parent showed maximum plant length' Acc. 9, Viswam and Acc. 63 were superior in terms of number of branches, laterals and yield per plant. Spike characters and quality were also evaluated. The experiment in being continued for confirmation of results.

Molecular characterization of the four selected accessions of Piper longum was made along with parents and released variety Viswam. Forty three decamer primers were screened, of which eleven primers showed difference between genotypes. Three primers viz., OPM 20, OPB01 and OPAU03 showed polymorphism between the male and female types. Among hybrids, Acc. 140 was most distinct from the rest. For the remaining hybrids 2-3primers showed polymorphism.

Screening of selected accessions in shade

Promising accessions (Acc 9 and 63)

4. **Ensuring Livelihood Security of Tribals Through On - Farm Bioinput Production and Medicinal Plant Cultivation**

This participatory project was carried out at Pokalappara tribal settlement in Vazhachal forest division, Thrissur. The project period was 2013-2016. The beneficiaries were from the Kadar Tribal community.

Socio-economic profile of the tribal community was assessed. Physical and chemical properties including status of macro and micro nutrients of the forest soil was analysed. Microflora of the forest soil was assessed. Four morphotypes of *Azospirillum* and *Pseudomonas fluorescens* were identified from the forest soil. The *Azospirillum* sp. recorded IAA production in the range of 25.32 µg/ml to 179.91 µg / ml. In the qualitative screening of Phosphate Solubilizing Microorganisms (PSM) for phosphate solubilization, the solubilization efficiency (SE %) of different isolates ranged from 12.5 to 56.52 %. The different isolates of *Pseudomonas fluorescens* recorded IAA production in the range of 5.10 µg/ml to 35.66 µg / ml. The most efficient isolates of *Pseudomonas fluorescens*, phosphate solubilising bacteria and *Azospirillum* were screened for their efficiency in enhancing the growth of tomato plants under pot culture conditions. Among them the isolates VFR-9 (*Pseudomonas fluoresens*), VTC-1 (PSB) and VTC-9 (*Azospirillum*) performed best in improving the growth of tomato plants at 45 days after inoculation.

A vermicompost unit was established and vermi compost produced on large scale. On-farm multiplication of *Trichoderma viride* and *Pseudomonas fluoresens* was also carried out.

Natural habitat analysis was carried out in select species of medicinal plants. A medicinal plant garden of select species was established in the tribal settlement. A medicinal plant nursery was started by the tribal women. Black pepper, ginger, turmeric and medicinal solanum were grown on a wider scale, were primary processed and sold. Value added products from NWFP and spices were made. A sales outlet was started as part of the project through which the nursery plants, bio inputs and other value added products made were sold out. 15 hands on trainings on various aspects of bioinput production and medicinal plant cultivation were imparted to the beneficiaries. A residential training programme (10 days) on farm mechanization was conducted for the tribal youth.

The project ended on February 28th 2016 after successfully completing the targeted objectives. The tribal beneficiaries in the Vazhachal forest division were empowered in Nursery production and cultivation of medicinal plants, value addition of NWFP, bioinput production and farm mechanization. They were capacitized in the good agricultural practices (GAP) and good manufacturing practices (GMP) in medicinal plant sector. A tie up with Oushadhi, the pharmaceutical co-operation of Kerala was made for the sale of crude drugs produced by the tribal people.

5. **Studies on adaptability of ashwagandha (*Withania somnifera*) to Kerala situations**

1. Harvesting time : - Tubers are to be harvested at 6 months stage; delay in harvest cause shriveling of the tubers

2. Evaluation of accessions : - Accessions collected from different sources were planted in

growbags during June 2014. Observations recorded at 4 MAP and 6 MAP are given below.

Acc. no	4 MAP			6 MAP		
	Fresh wt.of shoot/plant (g)	Fresh wt. of tuber/plant (g)	Dry wt.of tuber/plant (g)	Fresh wt.of shoot/plant (g)	Fresh wt. of tuber/plant (g)	Dry wt.of tuber/plant (g)
1	17	8.1	2.2	2.8	1.2	0.7
2	48	4.5	1.1	8.9	3.3	0.9
3	107	16.5	3.9	Dried	Dried	Dried
4	84.5	12.2	2.6	8.8	6.9	2.8
5	55	6.8	0.9	2.9	0.9	0.4
6	47	3.7	0.8	8.4	6.1	1.7
7	28.2	34.6	0.4	3.3	1.6	0.8
8	76	9.4	1.7	28.4	15.7	4.6
9	64	10.2	2.9	31.5	18	6.7
10	87	11	2.9	8.6	5.3	3.3
11	54	4.9	3.2	22.8	10.6	2.4
12	26	3.5	2.2	Dried	Dried	Dried
13	16	2.1	0.7	Dried	Dried	Dried
14	34	5.7	1.2	13	6	4.5
15	72	37	11.3	26.2	80.7	16.3

Acc. 15 produced comparatively higher tuber yield; however, the tuber production in grow bag was poor compared to field planting during previous year.

3. Evaluation of Antihelminthic activity in *Withania somnifera*

Methanolic extract of *Withania somnifera* tubers were evaluated for antihelmenthic activity. All the worms were alive even after 5 hours, which indicates that tubers have no effect on worms.

Total Phenolic Content (absorbance value taken for 0.05mg/ml) in the tuber estimated by Folin-Ciocalteu method was 57.24 mg/g.

6. Standardization of sustainable harvesting techniques in asokam (*Saraca asoca*)

a. Effect of growth regulators on percentage of bark regeneration

Application of GA 100 ppm to 200 ppm, IBA 1000 ppm and Kinetin 100 ppm are found effective for faster regeneration of bark. A fine layer of bark is formed at 2nd month which was then damaged by coccinellidae beetles. Hence a separate trial was conducted in which effect of Kaolin paste smearing at 2-3 weeks of bark extraction was studied to control the beetle attack.

b. Effect of kaolin smearing on bark regeneration

Smearing Kaolin paste after 2-3 weeks was effective to check insect attack.

c. Effect of time of extraction on bark regeneration

July –August period is found ideal for better bark regeneration.

d. Quality of crude drug

Various plant parts were analysed for phenolic content. Phenolic content is highest in stem bark, whereas side branch had lower values. Cytotoxicity of stem bark and branches were evaluated. Methanolic extracts of stem bark of *Saraca asoca* showed moderate activity whereas branches and leaves showed no cytotoxicity (in Brine shrimp assay method). Similar observations were noted in anthelmintic activity also (using earthworms). The study is concluded.

Ongoing Projects

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

a. Screening varieties of mango for polyphenol content and antioxidant power

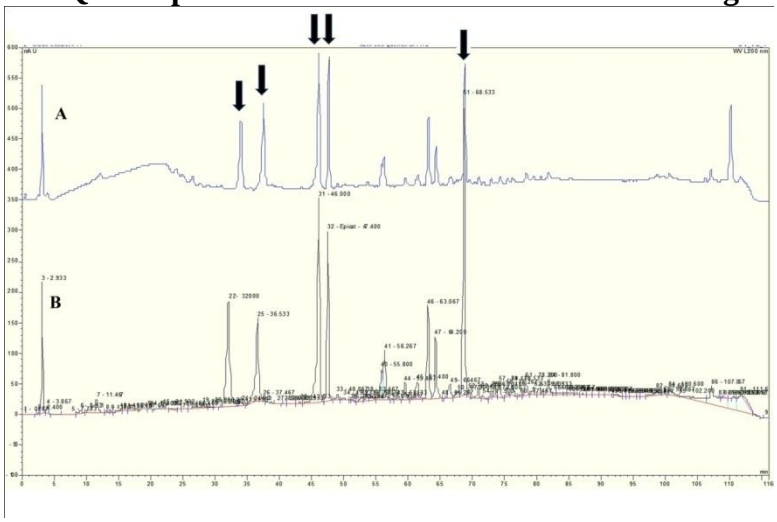
The mature leavesfrom Mango variety 'Moovandan' were collected during September and dried, powdered and extracted sequentiallywith selected solvents in the order of increasing polarity toextract the polyphenols. The yield of polyphenols in the product was assessed vis-à-vis it's*in vitro* antioxidant capacity. Chloroform, ethyl acetate, methanol, water were used as extractants. Refluxing sonication and Soxhlet's methods were attempted.

HPLC profiling of phenolic compounds in methanol extractives were done and accurate masses of major peaks in the extractives were determined in LC Q TOF and a few compounds were tentatively identified based on accurate mass and MS/MS fragmentation and also in comparison to earlier reports on mango leaf extract constituents. Highest yield of chloroform extractives were obtained by sonication but its total phenolic Contents was found to be negligible. Among different solvents used, methanol gave maximum yield and higher phenolic content and gave a direct correlation with its antioxidant activity. Among the methods of extraction, refluxing with methanol was found to be satisfactory in terms of ease of extraction, yield, total phenolic content and its antioxidant potential. Sequential methanol extraction by refluxing for 1.5 hrs were found to be the best in terms of extractives yield, antioxidant power and phenol content.

b. Detection of $FeCl_3$ quenched antioxidant peaks in the HPLC profile of methanol extractives

The methanol extract was subjected to HPLC separation in an analytical HPLC under the following conditions and peaks quenching by FeCl3 were identified under the same HPLC conditions,

LC Q TOF profile of methanolic extractives showing identified peaks

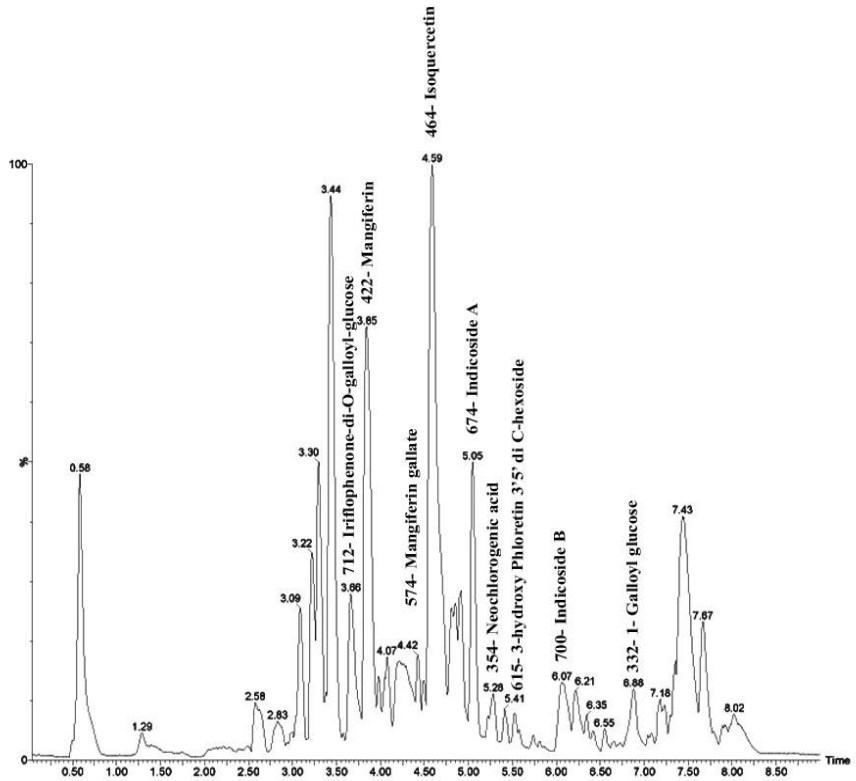


A. HPLC profile of methanol extractives

B. HPLC profile in $FeCl_3$ quenched methanolic extractives

Note – Arrows show FeCl3 quenched peaks in the HPLC profile

Many peaks in HPLC profile of methanol extractives showed antioxidant activity when quenched in vitro with $FeCl_3$



Some major Compounds major compounds in the methanol extract of Mango tentatively identified based on HRMS and MSMSby LC Q TOF

Compound number	Rt(min) (-ve)	$[M-H]^-$	Other MS-MS ions(m/z)	Tentative identification
1	4.6	183	168, 124	Methyl gallate
2	4.9	407	317, 287, 245	iriflophenone 3-C-β-D-glucoside
3	10.2	421	403, 331, 301, 271, 259	Mangiferin
4	12.5	433	301	Quercetin-3-O-Pentose
5	11.4	463	300, 271, 178, 151	Isoquercitrin
6		469	169	Valoneic acid bilactone
7	10.6	527	407, 389, 311, 287, 269	Iriflophenone 3-C-(2-O-galloyl)-β-D-glucoside
8	5.9	559	439, 407, 389, 317, 287, 269, 245, 169	Catechin
9	16.3	573		isomangiferingallate
10	9.8	711	559, 541, 465, 271, 169	Iriflophenone di-o-galloyl-glucoside
11	10.6	787	635, 617, 465, 295, 169	Tetra-o-galloyl glucose

*Leaf from Mango variety 'Moovandan' is used for HRMS

Total phenol content and antioxidant activity was higher in methanol extraction by refluxing method. Phenol content gives a direct correlation with its antioxidant activity

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

Processing of raw drugs

Plant parts traditionally used in Ayurvedic and folklore medicine system were harvested from AMPRS farm at maturity, washed, chopped, dehydrated and ground into a fine powder for solvent extraction and storage. Authentic material purchased from raw drug stores were also used for the studies wherever plant could not e raised in the farm

Preparation of methanolic extract:

Sieved dry fine powder (10 grams) of selected plant part was soaked in 100 mL of 90 % methanol in glass bottle and kept in a room temperature for seven days with occasional stirring. Methanol extractives thus obtained was filtered, centrifuged and the supernatant concentrated and solvent removed in a rotary evaporator and dry weight of extractives recorded and then stored at 4 ^{0}C

Brine shrimp Lethality Assay

Medicinal plant extractives were subjected to cytotoxicity studies in test organism Brine shrimp (*Artemiasalina*), a genus of aquatic crustaceans.It is an invertebrate component fauna of saline aquatic and marine eco system. It can be used in a laboratory bioassay in order to determine the toxicity by the estimation of lethality concentrations.

Medicinal plant extractives were screenedfor cytotoxicity in laboratory cultured one day old brine shrimp (Meyer et al; 1982) at 500 ppm concentration on dry weight basis with podophyllotoxin(Sigma P4405) as positive control in four replications in each replication. For those plant parts which showed moderate and high toxicity in methanolic extractives assay, LC_{50} was determined along with negative and positive control.

Hatching and rearing brineshrips: Filled a glass bowl with artificial sea water (4 L), which was prepared by dissolving 30g/L Sodium chloride (NaCl).Airstones were Immersed air pump was into the glass bowl. Vigorously aerated the water for about 10 min.Then added 1g *Artemia*eggs/ cysts after halting aeration. Aeration was continued after releasing brine shrimp eggs in the bowl. A light source was provided to facilitate hatching of cysts, kept the set up undisturbed for 24 hours. After 24 hours, the hatched nauplii (larvae of artemia) were removed with the help of a siphon. All unhatched eggs floating on top of bowl were also removed. The highly motile phototropic nauplii were transferred to fresh brine solution. Fed the artemia by adding a drop of yeast, protein or marine algae (Nualgi) into the brine solution. On the third day, harvested shrimps were used for toxicity studies.

Determination of LD50

50 mg of extract was dissolved in 100 µl DMSO and made upto 50 ml 3% saline solution, to get a concentration of 1000µg/ml (stock solution). The stock solution was appropriately diluted with saline solution to prepare test solutions of 1000µg/ml, 500 µg/ml, 100 µg/ml and 10µg/ml concentrations.

Stock Solution

50mg of methanolic extract of selected plant parts was dissolved in 50ml of saline solution with 0.5 % DMSO

Test solutions

1. 1000 ppm From Stock Solution I, 20 ml is taken (1000 µg/ml)
2. 500 ppm 10 ml + 10 ml saline solution with 0.5 %DMSO (500 µg/ml)
3. 100 ppm 2ml + 18 ml saline solution with 0.5 %DMSO (100 µg/ml)
4. 10 ppm 200µl + 19.8 ml saline solution with 0.5 %DMSO (10 µg/ml)

Control Solution

20 ml Brine solution + 100 µl of DMSO

20 ml of all four test concentrations (1000 µg/ml, 500 µg/ml, 100 µg/ml, 10 µg/ml) were prepared and 5 ml solution was transferred to each petriplates. Nauplii (10 numbers) were transferred to each petriplates. 10 µg/ml protein was added as food to all plates kept for incubation for 24 hrs. After 24 hrs, number of dead shrimps in each plate was counted and LD50 was determined.

Antifungal Assay

Test organisms

1. *Phytophthora capsici*
2. *Fusarium oxysporum*
3. *Rhizoctonia solani*

Source- Dept. of Plant Pathology, Kerala Kerala Agricultural University, Vellanikkara.

500 ppm methanolic extracts were tested by poison food technique in PDA medium

Assay by food poison technique

200 ml Potato dextrose agar medium was autoclaved at 121^{o}C for 15 minutes and 1000 µl of stock extract was added and mixed thoroughly to get final concentration of 500ppm of extract in PDA medium. The medium was poured into sterile petri plates. Mycelia disc of 6mm diameter from 3 day old actively growing culture of *Rhizoctonia solani* and 7 day old cultures *of Phytophthora capsici* and *Fusarium oxysporum* were transferred to the centre of the solidified surface of the medium in individual plate. Control plates were also maintained where the culture discs were grown under same conditions on PDA without extracts but with 1000 µl methanol as solvent in 200 ml medium. The petri plates were incubated at 25 ± 1^{0}C. Each treatment was replicated thrice. Observations were taken when fungi grown in control plates covered entire surface. The percent inhibition in mycelial growth in treated plates over control plates was calculated.

Antioxidant and phenol assay

Methanolic extractives of 50 plant spp. were tested against brine shrimps, and also against three phytopathogenic fungi namely *Phytophthoracapsici*, *Fusariumoxysporum*, *Rhizoctoniasolani* by poison food technique.Antioxidant activity was assayed and phenol content determined. LD 50 against brine shrimps was determined for active extractives.

A few methanolic extractives with broad spectrum antifungal activity has been identified which can be further fractionated to increase specific activity towards selected fungi. A few extractives which could serve as a good source of antioxidant principles also identified.

- *A few plant extracts showed significant activity against phytopathogenic fungi.*
- *Plants like Curcuma zedoaria showed activity against all the three fungi tested*
- *Extracts that showed general toxicity towards brine shrimps were further tested in an insect*

Brine shrimp toxicity assay

Methanolic extractives of 50 plants (78 plant parts) were tested against brine shrimp of which, 19 extractives were highly active resulting 100 % death in 24 hours at a dose of 1000 ppm and 13 extractives were moderately active. 14 Plants showed LD 50 below 160 ppm

Antifungal assay

Methanolic extractives of 50 plants (70 plant parts) were tested against phytopathogenic fungi of which, 7 extractives showed high activity and 6 extractives showed moderate activity *at 500 ppm* against *Rhizectoniasolani*, only one extractive showed high activity and two showed moderate activity against *Fusarium oxysporum* and only two extractives showed moderate activity against *Phytophthora capsici*at 500 ppm concentration.

3. Toxic heavy metal load of crude drugs and herbal medicines in kerala market

Monitoring the level of toxic heavy metals (lead, chromium, mercury, arsenic) in selected crude drugs in market in Kerala. Samples of the following 33 crude drugs were collected from the market during the period and analysed for levels of heavy metals (lead, chromium, mercury, arsenic).

Sl. No.	Name of plant	Plant part	Content in microgram per kg, (ppb)			
			Lead	Chromium	Mercury	Arsenic
1	*Acacia catechu* (Karingali)	Heart wood	0.5789	23.0138	5.9856	1816.6739
2	*Adhatoda beddomei* (Adalodakam)	Leaves	0.0000	1.4569	2.6746	2346.7385
3	*Aegle marmelos* (Koovalam)	Root	12.3841	28.5649	8.6748	239.6837
4	*Andrographis paniculata* (Kalmegh)	Leaves	36.5428	35.5739	18.5438	28.5636
5	*Asparagus racemosus* (Satavari)	Rhizome	18.3672	32.4528	2.3636	998.3522
6	*Azadira chtaindica* (Neem)	Bark	3.1252	2.5632	1.5477	121.3251
7	*Bacopa monnieri* (Brahmi)	Tops	102.3328	52.4552	22.4455	910.3563
8	*Boerhaavia diffusa* (Punarnava)	Root	39.3552	29.0332	28.4532	29.4533
9	*Caesalpinia sappan* (Sappan tree)	Heart wood	0.0000	1.3456	1.2653	0.0000
10	*Celastrus paniculatus* (Jyothishmathi)	Seeds	0.0000	0.0324	1.6385	0.0000
11	*Centella asiatica* (Kudangal)	Leaves	0.0000	2.3553	3.5634	23.4287
12	*Cinnamomum zeylanicus* (cinnamon)	Bark, leaves	2.8823	33.4572	18.4433	0.0000
13	*Kaempferia galanga* (Kacholam)	Rhizome	3.4272	23.4528	1,9438	345.5632
14	*Clitorea ternatea* (Sankupushpi)	root	23.4539	22.4522	32.4532	32.4545
15	*Ficus benghalensis* (Peraal)	Bark	0.0000	1.3443	2.3564	113.4563
16	*Ficus microcarpa* (Ithy)	Bark	0.0000	2.5434	0.9875	114.5221
17	*Ficus racemosa* (Athi)	Bark	0.8846	3.4329	1.9113	127.3528
18	*Ficusreligiosa* (Arayal)	bark	3.1200	3.4325	1.2556	134.3452
19	*Kaempferia rotunda* (Chengazhineerkizhangu)	Rhizome	4.2341	21.3247	07634	290.5645
20	*Mangifera indica* (Mango)	Leaves	3.4332	5.4533	4.4561	18.3425
21	*Mimosa pudica* (Touch-me-not)	root	19.3434	20.5993	29.1028	33.5673
22	*Moringa oleifera* (Moringa)	Leaves	45.4562	32.4551	20.2231	32.4561
23	*Mucuna pruriens* (Kapikachu)	Seeds	0.0000	0.3452	2.4521	0.3998
24	*Ipomoea mauritiana* (Paalmuthukku)	Rhizome	6.3244	17.4348	1.3433	205.9445

25	*Premna serratifolia* (Munja)	Root	15.3429	32.5632	10.0034	195.3891
26	*Psidium guajava* (Pera)	Leaves	3.4332	5.4533	4.4561	18.3425
27	*Pterocarpus marsupium* (Venga)	Heart wood	6.5679	2.3562	2.2323	14.4532
28	*Punica granatum* (Pomegranate)	Fruit rind	20.3423	20.3432	23.5666	33.3221
29	*Salacia reticulata* (Ponkoranti)	Root	12.3449	3.2366	3.8632	67.3452
30	*Saraca asoca* (Asokam)	Bark	1.1235	3.4234	2.5632	98.4532
31	*Sida rhombifolia* (Kurunthotty)	Root	23.2413	32.3210	19.3428	23.4991
32	*Tribulus terrestris* (Njerinjil)	Fruit	0.0000	4.4289	13.3421	20.0023
33	*Zizygium jambolana* (Njavel)	Seeds	2.3434	1.1934	1.6459	0.0000

4. Collection, Maintenance and Evaluation of Germplasm of Medicinal and Aromatic Plants

The existing valuable collection of aromatic germplasm and medicinal plant species maintained in microplots, pots and fields were maintained by replanting/ proper cultural operations. The vast area under medicinal tree collection was conserved properly by undergrowth clearing, need-based pruning and training; manuring and plant protection measures.The programme on enrichment of the collection by adding newer species of rare and endangered plants was continued.

This served as a demonstration for a large number of visitors including students, researchers, farmers and general public. Seeds and planting materials as well as crude drugs were made available from this source. Generated information on seed germination, dormancy, viability, vegetative propagation methods of a number of medicinal and aromatic plants.

5. Evaluation of Vetiver (*Vetiveria zizanioides*) Accessions FOR Superior Genotypes

a. Evaluation of 29 accessions of vetiver in the station farm

29 accessions of vetiver are being evaluated for identification of superior genotypes. The accessions showed variation with respect to flowering habit and growth parameters.

Acc. 7 was identified as nonflowering in nature and has comparatively high tiller production and root growth. This accession is specifically suitable for soil conservation by hedge planting and hence recommended for release.

Evaluation of the accessions is continued to identify types to suit various other requirements.

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

Eight accessions with better adaptability, non flowering nature, high tillering, favourable root characters (higher yield, longer and soft textured roots having better aromatic smell) were selected for further trial during 2015-16.

Non-flowering types with higher tiller count and root yield are preferred by farmers. Flowering leads to faster degradation of the tillers and thus the number of healthy slips available as planting material for the succeeding crop is considerably reduced.

Hence the accessions 2,10 and 11 which showed profuse flowering were not preferred by the farmers. Acc. 7 and 33 were nonflowering in nature; besides, tiller production and root yield were significantly higher compared to the local type, though oil content was slightly lower than the local type. These were closely followed by Acc. 24 and 27.

No pest or disease incidence were noticed in any of the evaluated accessions, whereas the local type was infested with mealy bug and grasshopper attack in the early stages.

The farmers are satisfied with the vigorous growth and better root yield of the accessions and accordingly four accessions viz. Acc. 7, 24, 27 and 33 were identified as superior to the local type.

Since the local variety is being cultivated by the entire farmers of the area for more than 50 years, adaptability, acceptability and pest incidences should be evaluated further before reaching a final conclusion. Hence it is proposed to continue the demonstration for 2-3 years with the selected four accessions viz. Acc. 7, 24, 27 and 33 to select the promising type.

6. 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 and for this 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.

Coscinium fenestratum, a member of the Menispermaceae family is a dioecious perennial tree climber growing up to 10 m height. Study on plant growth characters of the liana revealed the colour of young and mature shoot as brown with spiral phyllotaxy with the shoots being yellow internally. It was observed that the branchlets were brown and tomentose at the young stage, later becoming glabrous with disciform petiole-scars. The quantitative characters of stem of the male and female plants showed no significant difference. Anatomical studies revealed that the epidermis is single layered with certain ridges at regular intervals and covered with uniseriate multicellular hairs. It was observed that cortex consists of rectangular and polyhedral, thin walled, collenchymatous cells consisting of very prominent bands of hard stone cells with crystals inside. Usually, the number of vascular bundles was found to vary in the male stem (21) and female stem (22). Just above each vascular bundle, arches of 15-18 layered sclerenchymatous cells with lysigenous cavities were seen opposite to the phloem in definite patches. In between the arches, 2-4 layers of chlorenchymatous tissue

were present. The 1-2 layered interfascicular cambium originated in between the bundles, in line with the fascicular cambium, resulting in a ring of 2-6 layered cambium.

With regard to the characters of leaf in both the male and female plants, petiole was noticed as tomentose with pulvinus. The ovate leaf lamina was seen as dark green on the glabrous adaxial surface and light green on the minutely tomentose abaxial surface. It was observed that the lamina had acuminate tip and slightly cordate base with a reticulate-multicosate divergent type venation. The length of leaf petiole and lamina were found to be significantly different in the male plant (10.28 cm and 21.13 cm, respectively) and female plant (12.02 cm and 17.95 cm, respectively). The lamina breadth and life-span of leaf showed no significant difference. Anatomical studies of leaf revealed epidermis as single layered with lower region possessing large number of multicellular and uniseriate trichomes. It was seen that mesophyll consists of 1-2 layered, thick walled, highly chlorophyllous palisade tissue and 2-4 layered, thin walled and spongy tissue with abundant intercellular spaces. Vascular bundle was seen encircled by a wavy ring of 2-10 layers of sclerenchymatous tissue and collenchyma and parenchyma cells present.

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 flower heads on the long peduncles were seen arising in an acropetal fashion. The peduncle colour was noticed as brown in female and light yellow brown in male inflorescence and softly hairy in texture.

The female inflorescence (11.13 cm) was observed to be longer than the male inflorescence (7.15 cm) showing a significant difference. The number of flower heads in a male inflorescence was recorded as 8.2 and 7.9 in a female inflorescence which showed no significant difference. The number of florets in a flower head was observed as eleven on an average. The diameter of the male floret was measured as 0.22 cm and that of a female floret was 0.32 cm showing significant difference. It was recorded that the life-span of male flower head was 33 days and that of female flower head was 34.5 days and differed significantly. The duration of opening of flower head in male inflorescence was noted as 7.1 days whereas in female flower head, as 8.7 days differing significantly. The number of days required by the male flower head to reach 50% flowering recorded, was two days lesser (3.7 days) than the female flower head (5.7 days) and had significant difference.

The zygomorphic male floret was observed as globose, sessile and whitish yellow in colour. The tepals were seen as densely hairy on the outer surface and glabrous on the inner surface. The tepals in the innermost and middle whorls appeared slightly fused whereas those in the outermost whorl were noticed as free. It was found that the anthers were small, oval in shape and adnate. The male floret was found to be having nine tepals in three whorls with varying sizes in each whorl. In the male floret, three out of the six stamens were found connate to the middle and the others remain free. The outer anthers were observed as single celled and the inner ones two-celled. The length of anther-lobe was measured as 0.42 mm while that of filament was measured as 0.74 mm. The floral formula of male floret was thus derived as % $\male P_{3+(3)+(3)} A_{3+3} G_{zero}$.

The female floret was noticed similar to the male floret in shape and colour with the tepals having dense hairs on the outside and glabrous surface on the inside. It was noticed that the floret lacked a distinct style, and the branched stigma being attached directly to the densely

hairy superior ovary. The type of placentation was observed as axile, with the ovules attached to the trilocular ovary.

It was observed that the female floret consists of nine tepals in three whorls surrounding the pistil differing in length and breadth in each whorl. The floral formula of female floret was thus derived as % ♀ $P_{3+(3)+(3)} A_{zero} G_{(3)}$.

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.

The tomentellous fruit was found to be a one-seeded drupe, globular in shape and dark brown in colour. The fruit weight, length and breadth were recorded as 8.53 g, 2.36 cm, and 2.36 cm respectively. With a high fruit set of 93.00%, the per cent of fruits carried to maturity was noted as 27.33% only. It was observed that the number of days taken for fruit maturity from the day of flower opening was 150 days.

Kidney shaped seed of greenish brown colour was seen surrounded by the dark brown pulp inside the fruit. The seed weight, length and breadth were noted as 1.7 g, 1.52 cm, and 1.14 cm respectively. The germination percentage of fresh seeds with a moisture content of 21.13% was recorded as 50%. Developmental study of carpels and fruits revealed that the condyle (distinctive feature corresponding to the placentary region) identified was of Menispermum type. Additionally, endocarp ornamentation observed in this study is a common feature in many Menispermaceae species. The bright yellow coloured embryo was located on a region nearby the hilum. Seeds displayed good viability during tetrazolium test.

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 + Cior 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.

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

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	

8. Crop improvement (Entries for MLT, Varieties released and others) - AICRP on Medicinal plants

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 .

SWATHI

Plant height : 95.09 cm

No. of branches/ plant : 19

Root length: 61.09 cm

Root girth: 3.94 cm

No. of roots/ plant: 33

Root weight (fresh)/plant :165.80g

Root weight (dry)/plant:72.20g

Plumbagin content : 0.51%

MULTI LOCATIONAL TRIALS - AICRP on Medicinal plants

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 number of 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

9. Crop production - AICRP on Medicinal plants

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 were 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

10. Phytochemistry- AICRP on Medicinal plants

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

Results: Three different *Tinospora* species are commonly found in Kerala namely *Tinospora cordifolia, Tinospora malabarica and Tinospora crispa.* Theye were collected and grown in oue 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 were 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, phenol and crude fibre content in three species of *Tinospora*

	Total antioxidant activity (mg AA /g)	**Total phenol content (mg TA/g)**	**Crude fibre content (%)**	**Berberine content (%)**
T. cordifolia	7.86	45 .20	24	0.19
T. malabarica	5.78	35.33	22	0.22
T. crispa	12.78	59.71	20	Not detected

Heavy metal content in three species of *Tinospora* (ppm)

	As	**Cd**	**Co**	**Pb**	**Ni**	**Cr**	**Fe**
T. cordifolia	ND	ND	ND	0.008	0.014	0.010	1.666
T. malabarica	ND	ND	ND	0.015	0.025	0.013	5.724
T. crispa	ND	ND	ND	0.008	0.020	0.010	2.500

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

Results: 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 60$\mathbf{F_{254}}$,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.

Concluded Projects PG

1. **Rhizosphere management for higher root production in ashwagandha (*Withania somnifera* L. DUNAL)**

Treatments

T_{1}- HDP in trenches mulched with polythene and filled with enriched growing medium

T_{2}- T_1 + Recommended dose of NPK

T_{3}- T_1 + Liquid organic manures

T_{4} - T_2 + Azospirillum

T_{5} - T_3 + Azospirillum

T_{6} - T_4 + B and Mg

T_{7} - T_5 + B and Mg

T_{8} - T_6 + Summer irrigation at 15 mm CPE

T_{9} - T_7 + Summer irrigation at 15 mm CPE

T_{10} - T_6 + Summer irrigation at 30 mm CPE

T_{11} - T_7 + Summer irrigation at 30 mm CPE

T_{12} - HDP in trenches filled with enriched growing Medium.

T_{13} - NRP in trenches filled with enriched growing Medium.

T_{14} - Broadcasting in trenches filled with enriched growing medium.

Results obtained

Treatments significantly influenced plant height at all stages of growth.

- The treatment T4 (HDP in trenches mulched with polythene and filled with enriched growing medium + Recommended dose of NPK + Azospirillum) recorded significantly higher plant height at 45 DAT. T6 (HDP in trenches mulched with polythene and filled with enriched growing medium + Recommended dose of NPK + Azospirillum + B and Mg) registered higher plant height at all other stages of crop growth.
- Similar to plant height, significant effect of treatments on functional leaf number was observed throughout the period of crop growth. The treatment T1 (HDP in trenches mulched with polythene and filled with enriched growing medium) registered highest functional leaf number at 45 DAT. The treatments T3, T4, T9 and T1 showed higher values at 60, 75 and 90 DAT respectively. T6 at both the stages 105 and 120 DAT recorded higher functional leaf number.
- INM practices and summer irrigation were found to influence the leaf area significantly throughout the period of crop growth. T1 at 45 DAT; T3 at 60 DAT; T4 on par with T13 at 75 DAT; T1 at 90 DAT; T6 at 105 DAT and T6 at 120 DAT recorded significantly higher values.
- The treatments did not exert any significant effect on primary, secondary and tertiary branches at any of the growth stage. However higher number of primary branches were recorded by T7
- The treatments had no significant on primary root number during early stages of growth (45 DAT and 60 DAT). However the treatments T2, T4 and T6 and T2 and T6 recorded highest values of 2.75 and 3.75 at 45 DAT and 60 DAT respectively. The effect of treatments was evident from 75 DAT onwards. T10 at 75 DAT; T9 at 90 DAT; and T8, at 105 DAT and 120 DAT recorded higher primary root number.
- Root length was found to be significantly influenced by treatments at all growth stages of crop. T6 recorded significantly higher value at 45 DAT. At 60, 75 and 90 DAT the longer root was showed by T10. At 105 and 120 DAT, the treatment T8 and T10 registered the greatest length.
- Significant influence of treatment on root spread was observed at all growth stages. The treatment T6 at 45 DAT and 60 DAT recorded higher values. The performance of the treatment T11 was found to be significantly superior at 75 DAT, 90 DAT and 120 DAT.
- Effect of treatments on root volume was found to be remarkable at all stages of growth. T3 showed greater value of 3.3 cm^3 and 7.7 cm^3 at 45 and 75 DAT respectively. At 75 DAT the performance of the treatment T11 was found superior. T10 registered highest root volume at 90, 105 and 120 DAT.
- Significant influence of treatment on fresh root weight was observed at all stages of growth. T3 at 75 DAT registered the highest fresh root weight per plant. From 90 DAT onwards T10 showed remarkable influence on fresh root weight per plant.
- Dry root weight per plant also showed significant difference due to treatment effects and it followed a similar trend as that of fresh root weight per plant.
- The remarkable influence of treatment on fresh and dry root production per hectare was observed at 120 DAT. T10 recorded the highest fresh and dry rot yield of 1377 and 688.8 kg per hectare respectively. The lowest fresh and dry root yield of 600 and 295.2 kg ha^{-1} were recorded by T13.

- Treatments had significant effect on seed yield per plant and T6 recorded the highest seed yield of 6.75 g seed per plant which was 66.67 per cent higher compared to T14.
- Seed yield per hectare was also found to be significantly influenced by treatment effects. The treatment T6 recorded the highest seed yield per hectare.
- The treatments had no significant effect on relative leaf water content at any of the growth stages.
- Similar to relative leaf water content, treatments had no significant effect on leaf temperature at any of the crop growth stage.
- The treatment effect was remarkable at 90 DAT and the treatments T8 recorded the highest stomatal conductance of 180.50 mmol m^{-2} s^{-1}.
- The treatment effect on SCMR was insignificant at 45 DAT, 75 DAT, 90 DAT and 105 DAT. However, it was significant at 60 and 120 DAT and T7 showed the highest values.
- Dry matter production showed significant difference at all stages of growth except at 45 DAT due to treatment effect. At 60 DAT, highest dry matter production of 2.214 t ha^{-1} was recorded by T7. From 90 DAT onwards the treatment T10 showed higher values. The highest dry matter production of 3.13, 3.92 and 3.949 t ha^{-1} was registered by T10 at 3, 3.5 and 120 DAT respectively.
- T6, T11, T10, T6 and T10 recorded higher leaf, stem, root, berries and total dry matter production at the time of harvest. Dry matter production of 4.32 g, 28.47 g, 8.61 g and 8.75 g were recorded by leaf, stem, root and berries respectively. Total dry matter production was 49.36 which on par with T11 and T6. It was 73.81 per cent higher compared to T14.
- Profound influence of treatment was observed on per cent distribution of dry matter into leaf, stem, root and berries. T1 showed the highest distribution of dry matter for root production and it differed significantly from all other treatment. Distribution of dry matter for root production ranged from 12.33 to 22.79 per cent. Contribution of total dry matter production to berries varied from 16.89 to 32.86 per cent.
- Significant effect of treatments on root shoot ratio was found at all stages of growth. T4 at 60 DAT showed the higher root shoot ratio. At 90 DAT root shoot ratio of 0.246 was recorded by T10. T1 at later stages of growth that is 105 and 120 DAT registered higher values.
- T1 at 45 DAT and 90 DAT; T14 at 60 DAT; T4 at 75 DAT and T6 at 105 DAT and 120 DAT showed higher values of LAI of 0.577, 0.833, 1.061, 1.484, 0.597 and 0.461 respectively.
- Treatments did not exert any significant effect on leaf area ratio at 45 DAT. From 60 DAT onwards the effects of treatments were evident on leaf area ratio. T14 at 2 and 75 DAT, T1 at 90 DAT, T14 at 105 DAT and T1 at 120 DAT recorded significantly higher leaf area ratios. The highest leaf area ratio of 122.43 cm2 g-1 was observed at 60 DAT. From 60 DAT onwards there was gradual decline in leaf area ratio.
- The treatments exerted profound influence on absolute growth rate at 60 DAT and 75 DAT. Absolute growth rate at 45 to 60 DAT ranged from 0.42 to 1.24 cm day^{-1} and T10 recorded the highest AGR of 1.24 cm day^{-1}. At 60 to 75 DAT, T13 was significantly different from all other treatments. From 90 DAT onwards, absolute growth rate was insignificant due to treatment effect.
- At 45 to 60 DAT crop growth rate ranged from 2.83 to 12.15 g m^{-2} day^{-1} and the highest value was recorded by T7. At 75 to 90 DAT, T2 registered the highest crop growth rate of

10.62 g m^{-2} day^{-1}. At 90 to 105 DAT, T9 recorded the highest crop growth rate of 5.21 g m^{-2} day^{-1}.

- Total crude alkaloid content ranged from 6.5 % to 10.4 %. The highest crude alkaloid content of 10.54 % was registered by T7. Other biochemical parameters namely total sugar and total amino acid content were not at all influenced by treatment effects.
- Azospirillum population ranged from 11.5 x 105 to 64 x 105 per gram dry soil. The highest population of 64 x 105 per gram dry soil was registered by the treatments T8.
- Before irrigation, soil moisture content ranged from 10.3 to 13.35 % indicating the highest moisture content in T9. However, treatment had no significant effect on moisture content after irrigation. Seasonal consumptive use and mean daily consumptive use were found to be significantly influenced by treatment effect. Seasonal consumptive use and mean daily consumptive use ranged from 145.73 mm to 250.80 mm and 1.22 to 2.09 mm respectively and T14 registered the higher values.
- The highest crop water use efficiency of 474.78 g m^{-3} was recorded by T10. Field water use efficiency varied from 84.46 to 222.31 g m^{-3} and the highest value was recorded by T6. The treatment which recorded highest value of field water use efficiency also registered the highest water productivity of 1313.467 g m^{-3} and it differed significantly from all other treatments.
- Nitrogen content ranged from 1.3 to 2.75 %. The highest nitrogen content was recorded by T6. Phosphorus content also varied from 0.26 to 0.31 % and the highest content was registered by T8. Potassium content was highest in T9 and ranged from 1.49 to 2.77 %. Magnesium content ranged from 0.11 to 0.12 %. Boron concentration varied from 5.09 to 10.44 mg L-1 and the highest content was registered by T10.
- INM practices and summer irrigation remarkably influenced the total uptake of all the nutrients (N, P, K, B and Mg). Total uptake of nitrogen ranged from 26.85 to 106.07 kg ha-1 and the highest uptake was registered by T6. Phosphorus uptake varied from 4.94 to 11.85 kg ha-1 and the highest uptake was registered by T10. The highest total uptake of potassium, boron and magnesium was registered by T10.
- INM practices and summer irrigation had remarkable influence on N, P, K, B and Mg status of soil after the experiment. Soil nitrogen ranged from 163.07 to 275.97 kg ha-1. The highest nitrogen content was recorded by T2. Soil phosphorus ranged from 56.56 to 103.04 kg ha-1 and T4 registered the highest value. Potassium content ranged from 130.20 to 387.80 kg ha-1 and T8 recorded the highest value. T11 registered the highest boron content of 6.910 g ha-1. Like other elements, magnesium content also varied significantly. T7 recorded the highest value.
- T9 recorded the highest cost of cultivation of 58844 □ and T14 recorded the lowest. Gross income ranged from 124544 to 263296 □ and T10 registered the highest value. Net income also showed a similar trend and it ranged from 47938 to 170088 □. Benefit cost ratio varied from 1.63 to 2.83. T10 registered the highest benefit cost ratio of 2.83.
- The treatment, T10 was found worthwhile for popularization with respect to higher fresh and dry root yield per plant and root production per hectare, dry matter production, crop water use efficiency, gross income, net income and BCR.

Name of the Project Coordination Group (8)

Biotechnology, Biochemistry, Plant Physiology

Project Coordinator: Dr. M.R Shylaja

Concluded Projects: 4 Nos
Ongoing Projects: 4 Nos

Concluded PG Projects: 33 Nos
Ongoing PG Projects: 49 Nos

Concluded Projects

1. **In vitro regeneration and conservation of Chittamruthu**

   Objectives of the study were standardization of a protocol for axillary shoot proliferation of *Tinospora cordifolia* from nodal explants, production of artificial seeds using axillary buds from axenic cultures and evaluation of their regeneration potential in the recovery medium, evaluation of short-term storage of artificial seeds and direct plantlet regeneration under non-aseptic conditions. *In vitro* regeneration protocol for *Tinospora cordifolia* was developed. A simple protocol with MS (Half strength macronutrients) supplemented with 2 mg L^{-1}BA and 2.5 g L^{-1} $CaCl_2$ could be used for establishment and multiplication cultures. E*x vitro* rooting with pulsing 300 mg L^{-1} NAA for 5 minutes could give efficient rooting. An encapsulation technology for synthesis of artificial seeds of *T. cordifolia* was developed with liquid MS medium (devoid of Ca Cl_2) supplemented with 3.5 per cent sodium alginate complexed with 75 mM Ca Cl_2 with 100 per cent regeneration. Artificial seeds could be stored for 4 weeks at 4^{o}C and 25 ^{o}C with 50 per cent regeneration.

2. **Molecular characterization of spike branching trait in black pepper (*Piper nigrum* L.)**

   The objectives of the project 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 was undertaken.

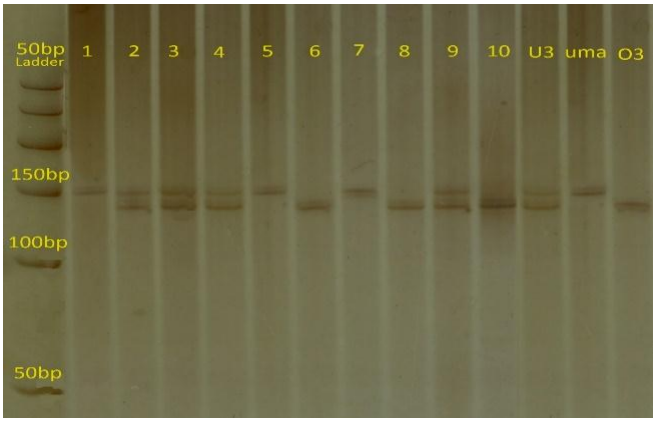
3. **Advanced Centre for Integrated Biotechnology for Research and Development**

   The objectives were to establish an Advanced Centre for Integrated Biotechnology for research, education and development at the College of Agriculture, Vellayani and to take up research programmes in identification of genes governing agriculturally important traits, improvement of crops using R-DNA technology, production of industrial enzymes and bioenergy production from agricultural waste

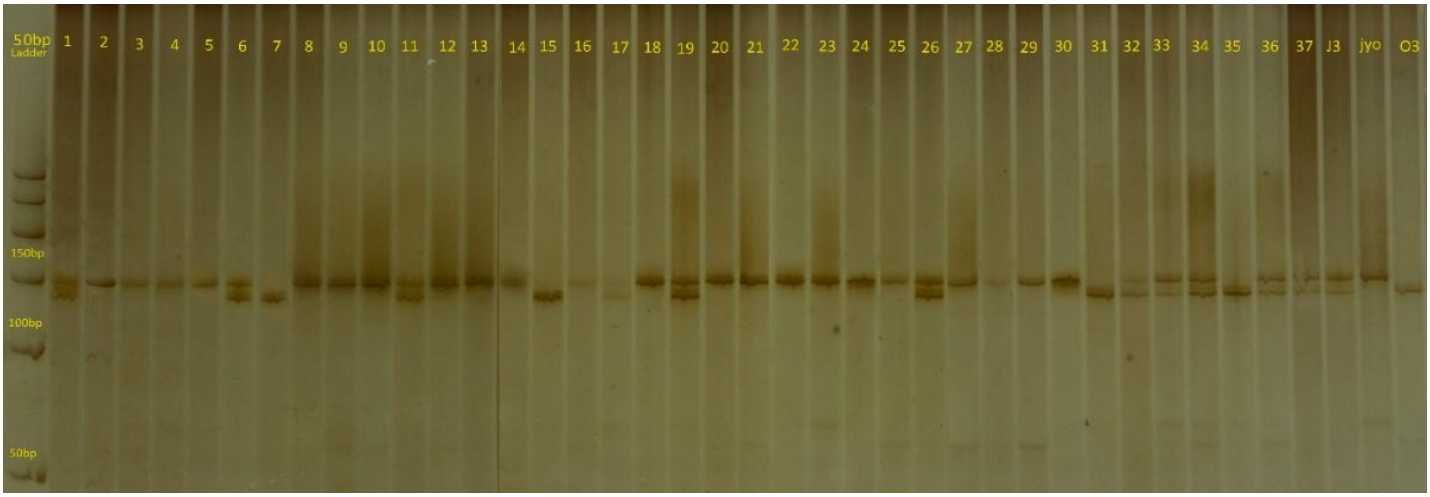
   Laboratory facility of 1384 sq. m constructed on the existing Integrated Biotechnology block and the equipments purchased are utilized for the conduct of thesis project work and practicals of biotechnology students. Fragment of AP1 gene involved in flowering of black pepper was isolated. Expression of AP1 in pepper was confirmed using Real time PCR. Nine promising bacteria with cellulolytic property were isolated. Three micro algal strains were isolated and the best medium for algal biomass was standardized. Characterization of different agricultural wastes in terms of carbohydrates, sugars, lignin etc. was carried out for testing the suitability for bioethanol production. Pineapple, banana and watermelon biomass showed potential for alcohol production and was confirmed by submerged fermentation. *Saccharomyces cereviseae* was found effective in production of alcohol compared to *Zymomonas mobilis*. Raw peel of banana, fruit waste of pineapple and rind of watermelon were identified as potential feedstock for bioethanol production.

4. Marker assisted introgression of thermo sensitive genic male sterile gene to red rice background for stable sterility for hybrid seed production

The study was undertaken to develop a red rice line with multiple *tms* genes through three way cross, to develop a stable marker associated with the TGMS genes, to analyze the molecular mechanism associated with the thermo sensitivity. An SSR marker was identified for selecting male sterile plants. RM5897 were identified as polymorphic marker which differentiates TGMS from non TGMS. Urea PAGE was performed and the banding patterns showed that, RM5897 was effective for selecting progenies. The primer produced polymorphic bands with ~141bp length.



Amplified product on urea page (1-10(F_2 progenies of Uma X EC720903), U3 (F_1 progenies of Uma X EC720903), Uma, EC720903) with the marker RM5897.



Amplified product on urea page (1-37(F_2 progenies of Jyothi X EC720903), J3 (F_1 progenies of Jyothi X EC720903), Jyo (Jyothi), EC720903) with the marker RM5897.

Ongoing Projects

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

The objective of the study was to transfer the anthracnose resistance available in semi-trailing vegetable cowpea to trailing type vegetable cowpea through 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. Using the F_3 population of Sharika X Kanakamony, through BSA, markers for anthracnose resistance were identified. RAPD primer OPA02 has yielded marker at 850 bp in susceptible genome, whereas, ISSR primers UBC810 and UBC811 have yielded markers at 1.4 kb and 1.5 kb, respectively in resistant genomes. These markers were reproducible and their linkage with resistance and suitability in MAS were confirmed through co-segregation analysis in F_3 population. UBC811 marker was eluted, cloned on pGEM-T and sequenced. The sequence had shown that this marker is 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 used in backcrossing with recurrent parent Sharika. A total of 5 crosses were performed. BC_1 population from all the 5 crosses were raised in adjacent plots and subjected for field screening.

2. 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. Various experiments were initiated during 2015-16. The project is in progress.

3. Metabolome analysis in ginger and product development using gingerol

The project on PPP mode was officially launched at KAU on 18th August 2014 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. Compared gingerol content in KAU samples with the raw materials procured by the company. Standardised dry ginger extract with high level of gingerol. Standardized the temperature, pH and storage conditions for stability of gingerols. Screening of somaclones for gingerol content was completed with dry ginger samples of 2013-14, 2014 -15 and 2015-16 harvests. Screening could locate ten high

gingerol yielding somaclones from Maran group and twelve clones from Rio –de-Janeiro group. The project is in progress.

4. **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.

Network project on Commercial micropropagation is in progress at nine network centres and quality evaluation of TC plants in progress at two centres. A separate commercial unit for micropropagation was established at CPBMB, College of Horticulture. Demonstration farms of TC derived plants were established at various centres. Training programmes on techniques in plant tissue culture were conducted at different centres. Optimised protocols for large scale production of NeduNendran, Attu Nendran and Chengalikkodan. Developed protocols for direct and indirect organogenesis of gerbera. Plantlets produced at different centres confirm the standards of NCS-TCP.

Concluded PG Projects

1. **Validation of micropropagation protocols of pineapple (*Ananas comosus L.*) with clonal fidelity analysis**

Objective of the study was to regenerate tissue culture plants of pineapple through viable protocols and examine suitability of the protocol for micropropagation with clonal fidelity analysis using ISSR markers. Commercial variety of Kerala, Mauritius, was used for the study. Four micropropagation protocols were selected to regenerate plants. Micropropagation protocol of pineapple by Jose (1996) was found efficient for culture establishment and shoot multiplication. Clonal fidelity analysis with ISSR markers showed that the protocol by Jose (1996) had the highest similarity coefficient between regenerants and parent.

2. **Molecular characterization of black pepper (*Piper nigrum* L.) genotypes for drought tolerance**.

The study was aimed to identify the differentially expressed genes and signal transduction pathways operating in black pepper during water stress condition. Drought tolerance of ten black pepper genotypes were screened. The genotype PRS-64 was identified as the most drought tolerant and PRS-44 as the susceptible genotype. Differential gene expression involved in drought resistance of PRS-64 was analysed by DDRT-PCR. The transcript derived fragments from different treatments by DD-RT-PCR technique were cloned into pGEMT vector and sequenced. The annotation of sequences revealed good homology to the genes in signal transduction pathways under stress conditions. The genes identified and characterized were copper amine oxidases, NADH dehydrogenase, ribosomal RNA gene, calcium dependent protein kinase and heat shock proteins.

3. **Development of molecular markers for anthracnose resistance in vegetable cowpea [*Vigna unguiculata* (L.) Walp]**

The objective of the study was to identify an ISSR or RAPD molecular marker linked to anthracnose disease resistance in vegetable cowpea, using bulked segregant analysis to enable marker assisted selection. The dual purpose semi-trailing cultivar Kanakamony, which was reported as immune to anthracnose and the high yielding trailing vegetable type cultivar Sharika, which was susceptible, were used for the development of the mapping population for BSA to identify the marker. Reciprocal crosses were made to develop F_1s and subsequently selfed to develop F_2 population. Totally 163 F_2 population were pot raised inside the greenhouse and screened with artificial inoculation of *Colletotrichum lindemuthianum*. Inoculation was carried out in 10 days old seed lings and was repeated twice at an interval of 15 days. Each plant was inoculated with 20 ml inoculum at a spore conc. of 10^6 ml^{-1}. Good quality DNA from both the parents were extracted and screened initially with 47 RAPD and 43 ISSR primers respectively. Twelve RAPD and 10 ISSR primers yielded polymorphic bands were subjected for BSA. Two ISSR primers (UBC810, UBC 811) linked to anthracnose resistance and one RAPD primer (OPA02) linked to anthracnose susceptibility were identified in vegetable cowpea using Bulk segregant analysis .

4. **Development of molecular marker linked to yellow vein mosaic virus resistance in okra [*Abelmoschus esculentus* (L.) Moench]**

The project aimed to identify an ISSR or RAPD marker linked with the gene governing resistance to the yellow vein mosaic virus disease in okra through bulked segregant analysis to enable marker assisted selection. Two varieties of okra Parbhani Kranthi and Salkeerthi which showed resistance/ susceptible disease reaction respectively were taken for the study. Crosses were made to develop F_1s and subsequently selfed to develop F_2 population. Totally 200 F_2 population were field screened. No artificial inoculation methods were followed. Good quality

DNA from both the parents were extracted and screened initially with 84 RAPD 82 ISSR primers respectively. Out of these, 39 RAPD and 24 ISSR primers were subjected for BSA based on the number of bands and nature of amplification. Phenotypically resistant and susceptible F_2 plants were screened out; DNA was isolated and bulked them separately as resistant and susceptible bulks. Two ISSR (ISSR8, UBC 873) and two RAPD markers (OPB11, OPB18) linked to Yellow vein mosaic virus (YVMV) resistance in okra were identified and one ISSR marker (ISSR 22) linked to YVMV susceptibility was identified.

5. DNA barcoding of spider mites (Prostigmata: Tetranichidae) in vegetables crops

The project aimed to generate DNA barcodes for different species of spider mites of vegetable crops and to study the intra and inter species genetic relationship. DNA barcoding of three species of spider mites (*T.truncatus, T.macfarlanei* and *T.oknawanus*) were done using *ITS2* and *COI* loci markers. BLAST results revealed *ITS2* and *COI* loci were powerful to yield up to 99.25% and 98.45% efficiency respectively to differentiate the species and genus level with 100% efficiency. Phylogenetic analysis revealed that *T. truncates* and *T. okinawanus* were closely related species. Specimen details along with images were submitted to Barcode of Life Data (BOLD) and barcodes were generated subsequently by BOLD database.

6. Development of small interfering RNA (siRNA) mediated resistance in banana against banana bract mosaic virus

The objective of the study was to develop siRNA mediated technology for the development of banana plants resistant to *Banana bract mosaic virus.* A rapid protocol for somatic embryogenesis from immature male inflorescence was standardized. The study was successful in developing an ihpRNA construct against replicase gene of BBrMV. Transgenics carrying ihpRNA constructs were developed by the transformation of embryogenic calli. Six plants were confirmed to harbor the ihpRNA construct.

7. Identification and characterisation of traditional rice genotypes for drought tolerance through proteomic approach

Traditional rice varieties of Kerala were screened for drought tolerance. Proteome analysis of a drought tolerant genotype (Chuvanna Modan) was compared to a susceptible genotype (Parambuvattan) by 2D PAGE and identified two up regulated and two differentially expressed proteins.

8. Screening ginger (*Zingiber officinale* Rosc.) somaclones for gingerol content and validation of anticancerous properties of gingerol -

The objectives of the study were to screen ginger somaclones for gingerol content, to identify cancer targets for gingerols and shogoal using *in silico* tools and to validate anticancerous properties of gingerol. Fifty somaclones of ginger derived from the cultivar Maran regenerated

through direct /indirect methods of regeneration and *in vitro* mutagenesis were used for screening for gingerol content. The content of pungent principles in fifty ginger somaclones were estimated using High Performance Liquid Chromatography. Accelry Discovery studio 4.0 software was used for molecular docking of four ginger ligands viz. 6-gingerol, 8-gingerol, 10-gingerol and 6–shogaol and other approved drugs with the selected targets for cancer.

Ginger somaclones showed variability in recovery of dry ginger, oleoresin and content of pungency principles like 6-ginerol, 8-gingerol, 10-gingerol and 6-shogaol. Somaclones regenerated after *in vitro* mutagenesis recorded higher content of gingerol. Results of molecular docking and ADME/toxicity analyses showed that 6-gingerol was superior to other ginger ligands and eleven approved drugs studied for cancer. In cell culture studies, the phytocompound 6-gingerol was found cytotoxic to the three cancer cells lines studied HCT15 (colon cancer), Raw 264.7 (mouse leukaemic monocyte macrophage cell) and L929 (murine fibro sarcoma cell) and the cytotoxcity increased with increase in concentration of 6-gingerol. The potential of 6-gingerol as a promising anticancerous phytocompound is confirmed from the present investigations.

9. Immunomolecular detection and characterization of Poty viruses infecting Cowpea (*Vigna unguiculata* (L.) Walp) and Papaya (*Carica papaya* L.)

The objectives were to study the symptomatology and transmission of *Poty* viruses infecting Cowpea *(Cowpea aphid borne mosaic virus & Blackeye cowpea mosaic virus*) and Papaya (*Papaya ring spot virus)*, along with its biological, immunological, molecular diagnosis and characterisation.

Symptoms caused by *Blackeye cowpea mosaic virus* (BlCMV) in cowpea include mosaic and vein banding and that of *Papaya ringspot virus* (PRSV) in papaya showed mosaic and shoe string on leaves and ringspot on fruits and leaves.

BlCMV and PRSV were mechanically transmitted (80 and 100 per cent respectively). Seed transmission (48.5 per cent) was recorded for BlCMV in cowpea. PRSV was not transmitted through seeds. BlCMV was transmitted by *Aphis craccivora* Kochand *Aphis gossypii* Glover (30 per cent respectively).Papaya mealy bug(*Paracoccus marginatus* Williams and Garnara de Willink)(80 per cent) was the most efficient vector of PRSV followed by *Aphis gosssypii* Glover (40 per cent) and *Aphis craccivora* Koch (30 per cent).

Host pathogen interaction studies in resistant and susceptible genotypes of the cowpea (CO6 and Vellayani Jyothika) and papaya (Pusa Nanha and local variety) indicated a significant reduction in total carbohydrates and chlorophyll contents in susceptible genotypes on inoculation with *Potyviruses*, whereas resistant genotypes showed no significant difference. However, phenol, protein and defense related enzymes showed a significant increase in resistant genotypes on inoculation, compared to the susceptible genotypes.

Sodium dodecyl sulphate-Polyacrylamide gel electrophoresis (SDS-PAGE) and native-PAGE were conducted for the comparison of proteins and isozymes respectively, in resistant and susceptible genotypes. Eleven novel proteins were induced in CO6 whereas ten new proteins were observed in Vellayani Jyothika. Nine and eight induced proteins were identified in Pusa Nanha and local variety of papaya respectively.

Three isoperoxidases with Relative mobility (Rm) values of 0.13, 0.20 and 0.27 were unique for CO6. There was no unique isozyme on inoculation in Vellayani Jyothika. Isoperoxidases with Rm values of 0.08 and 0.23 were unique for Pusa Nanha. However no specific isozyme was observed in local variety of papaya.

Chenopodium amaranticolor and *Chenopodium quinoa* were identified as indicator plants for the biological detection of BlCMV and PRSV. Immunological studies using Direct antigen coating-Enzyme linked immunosorbent assay (DAC-ELISA) and Dot immunobinding assay (DIBA) and molecular detection *viz.* Reverse transcription-Polymerase chain reaction (RT-PCR) identified the *Potyviruses* as Bean common mosaic virus (BCMV) strain Blackeyeand PRSV respectively. Comparative aminoacid sequence alignment revealed a 95 and 100 per cent homology with coat proteins of BCMV and PRSV respectively.

The transmission studies revealed that *Potyviruses* were transmitted mechanically and by insects. Present study also revealed that BlCMV was transmitted through seeds while, PRSV was not seed transmitted. The host pathogen interaction studies identified phenol, protein and defense related enzymes along with induced proteins and isoforms of peroxidase could be used as biochemical markers to identify resistance and susceptibility in plants. The molecular study confirmed that BlCMV infecting cowpea was closely related to BCMV, a strain of Blackeye. PRSV in the present investigation was found related to PRSV isolates reported from other parts of India. Comparative sequence analysis of BlCMV and PRSV *Potyviruses* showed that the sequences were entirely different and showed only a 51.12 per cent similarity at nucleotide levels. Serological and sequence studies thus suggest that BlCMV caused the mosaic disease in cowpea and PRSV, the ring spot disease in papaya.

10. Molecular detection and characterization of phytoplasma infecting brinjal (*Solanum melongena* L.)

A Phytoplasma infecting brinjal and catahranthus were characterised and their relationships with other phytoplasma diseases of crop plants were compared. The presence of phytoplasma in tissue culture plants developed from inoculated plants was confirmed using nested PCR. The present study revealed that the culture of phytoplasma could be maintained *in-vitro* using tissue culture technique.

11. Identification and characterization of viruses in sweet potato (*Ipomoea batatas* (L.)Lam.)

The objective of the study was to diagnose, clone and characterize viruses implicated in mixed infections of sweet potato. Sweet potato samples with various virus infection symptoms were collected from the germplasm repository of CTCRI , TVM and field samples from Bhubaneswar and screened for SPFMV, SPMMV, SPLCV, SPCSV, SPVG, SPVC and SPV2 using both genus and virus specific primers. Out of 32, 29 samples showed SPFMV infection. Mixed infection by SPFMV and SPLCV was found in 15 samples. One sample was infected with SPVG along with SPFMV and SPLCV. After identification, one sample each for SPFMV, SPLCV and the only sample positive for SPVG were cloned and sequenced.

12. *In vitro* propagation and identification of molecular markers linked to dwarfness in white yam (*Dioscorea routundata* Poir.)

The objective of the project was to standardize *in vitro* protocol for the rapid propagation of dwarf/bushy white yam and to identify molecular markers linked to dwarfness. The protocol for *in vitro* propagation was standardized. Fifteen ISSR, 10 SSR & 8 RAPD primers with high polymorphism were selected for the molecular characterisation. Number of polymorphic bands were higher for ISSR and RAPD, the average polymorphism information content was lesser for SSR as compared to RAPD and ISSR. Dendrogram showed the partition of most of the dwarf and tall genotypes into 2 different clusters. The present study helped to identify a high yielding, highly divergent white yam genotype, DR17 that could be used for the genetic improvement of white yam in future

13. Identification and characterization of protease encoding genes from metagenomic library of dairy effluent

The objective of the study was to construct and characterize metagenomic library for esterase producing microbes from dairy sludge. Metagenomic library was constructed in pEZ BAC vector. Functional screening of the library on skim milk agar showed a clone having protease activity which was confirmed to have a metagenome insert of size approx. 9kb. The crude cell extract of this clone at 24^{th} h of growth showed protease activity of 166.99U/ml (111.32U/mg protein). The protease obtained was found to be alkaline and had maximum activity at 40^0C and pH 9.0.

14. Molecular marker development of cassava mosaic disease resistance using bioinformatics tools

The objective of the study included development and evaluation of various SNP and SSR prediction pipelines, verification of SNP and SSR markers for cassava mosaic disease (CMD) resistant and susceptible breeding lines. The SNP prediction tool Quality SNP was found to be a better tool compared to Auto SNP. Quality SNP had better SNP prediction algorithm and ability

for classification of the identified SNP into various categories. The SSR prediction tool MISA was found to be better compared to SSRIT. One SNP (SNP 896) and one SSR (SSR 2063) primer was able to clearly differentiate between the resistant and susceptible varieties. This is the first report of SNPs and SSRs computationally identified and verified in the wet lab.

15. Genetic diversity analysis and identification of molecular markers associated with leaf blight resistance in taro (*Colocasia esculenta* (L.) Schott)

The study aimed to analyse the genetic variation existing in Kerala landraces of taro using molecular markers and to identify molecular markers associated with taro leaf blight resistance from the germplasm. Thirty accessions from Kerala and twelve genotypes comprising six susceptible and six resistant genotypes were analysed in the study. PCR with ten SSR markers divided the genotypes into three clusters.

16. Oxidative stress and protein profiling in cassava (*Manihot esculenta* Crantz) under abiotic stresses

The study aims to assess the oxidative stress and changes in the protein profile in cassava under abiotic stresses such as water deficit stress (WDS) and high temperature stress (HTS) in contrasting genotypes (short and long duration varieties) of cassava. The antioxidant activity, protein profiling, growth and yield parameters of four genotypes of cassava under irrigated, high temperature stress and water deficit stress conditions were studied. Results indicated that Glutathione Reductase (GR) activity can be used as a biochemical marker for developing WDS tolerant varieties. APX activity can be used as a marker for identifying HTS tolerant varieties

17. Oxidative stress and protein profiling in sweet potato (*Ipomoea batatas* (L.) Lam.) under abiotic stresses

The study aimed to assess the oxidative stress and changes in the protein profile in sweet potato under abiotic stresses such as water deficit stress (WDS) and high temperature stress (HTS) in contrasting genotypes of sweet potato. The antioxidative enzyme activity, protein profiling and growth and yield parameters of five varieties/genotype of sweet potato under irrigated, high temperature stress and water deficit stress conditions were studied. Under HTS condition SOD activity increased in Sree Arun and S-1466 where as other varieties /genotype had increased SOD activity under WDS. The study suggested that SOD activity can be utilized as a biochemical marker for developing HTS tolerant varieties as it showed consistent changes under both WDS and HTS

18. Development of biodegradable films from enzymatically modified cassava starch

The study aimed at the enzymatic modification and characterization of cassava starch and the development and characterization of biodegradable film from it. The physico-mechanial, hygroscopic and functional properties of films made from cassava starch modified with

liquefying and debranching enzyme were analysed. Starch used in this study was extracted from cassava variety CMR 256 by wet processing method. Cassava starch was modified using alpha amylase and pullulanase, which is a debranching enzyme. Pullulanase treated films showed good rheological properties like 2060 Pa storage modulus ,37.9 Pas complex viscosity showing its more solid nature and visco elasic properties. Alpha amylase showed better colour properties when compared to pullulanase treated films, where as pullulanase treated films showed highest thickness when compared to Alpha amylase treated films.

19. Identification and characterization of viruses infecting lesser yam (*Dioscorea esculenta* (Lour.) Burkill)

The study was taken up to detect the presence of different viruses infecting lesser yam (*Dioscorea esculenta*), to identify the viruses, to characterize the viruses and to design virus specific primers for detection. Out of 25 sample collected for study, 88%, 36% and 40% sample showed positive to YMMV, Yam macluravirus and Yam badna virus respectively. The current study indicated that YMMV is the most common virus infecting lesser yam plant.

20. Molecular characterization of cassava mosaic disease (CMD) resistant varieties and wild relatives of cassava (*Manihot esculenta* Crantz) using SSR and SNP markers

The objective of the study was to analyse the extent of genetic variations, population structure and phylogenetic relationship among CMD resistant and wild relatives of cassava using SSR and SNP markers.

Genetic diversity of 25 CMD resistant, 16 susceptible and seven wild relatives of cassava was analysed using 14 SSR and two SNP markers. The polymorphism analysis of SSRs and SNPs generated a total of 53 alleles across the 48 cassava accessions, the NS 198 was found highly polymorphic with 6alleles followed by NS169, SSR 36 and SSR 39. The similarity index values obtained for each pairwise comparison among the 48 samples of cassava based on the combined SSR and SNP marker showed two resistant varieties TME3 and TME4 which were closely related with a similarity index of 0.98.

21. Molecular characterization of sweet potato *(Ipomoea batatas* (l.) Lam) accessions and wild relatives using SSR markers

The study aimed to analyse the genetic variation, population structure and phylogenetic variation among selected accessions of sweet potato and wild relatives using simple sequence repeats (SSR) markers. With twelve SSR primers used, the similarity coefficient values of 45 genotypes ranged from 0.37- 0.96. Lowest similarity index (0.37) was observed between sweet potato variety Sankar and *Merremia dissecta*, the highest was observed between two *I. carnea* species . In PCA scatter plot, the 20 cultivars were clustered separately from the wild species. The PIC values for 12 SSR primers ranged from 0.26 to 0.85 with an average of 0.67.

22. Development of efficient transformation and regeneration protocols in elite clones of cassava (*Manihot esculenta* Crantz) genotypes

The objectives of the study were screening of cassava mosaic disease (CMD) resistant clones for regeneration efficiency and standardization of an efficient protocol for *Agrobacterium* mediated transformation in cassava. The study was carried out using 13 cassava genotype including seven released varieties and CMD resistant pre-release clones. Agrobacterium mediated transformation was carried out using the strains viz. LBA4404, EHA105 and AGL-1 with a co cultivation duration of 12hrs, 24hrs and 48 hrs. Transformation was obtained only when LBA4404 was used with a co cultivation time of 48hrs. As compared to callus, the cotyledonary explants recorded higher transformation efficiency.

23. Proteome analysis of organically grown yardlong bean [*Vigna unguiculata* sub sp. *sesquipedalis* (L.) Verdcourt]

The study aimed to understand the basis of the expected quality enhancement in organically grown yardlong bean in terms of protein and amino acid expression through 2-dimensional proteome analysis. Initial soil nutrient status was analysed and it was found that the nutrient status was same in two plots. Yardlong bean variety 'Sharika' was cultivated organically and inorganically in two plots each of $40m^2$area. The nutrient analysis of the yardlong bean suggested that pods from the last harvest showed higher levels of micronutrients compared to the first harvest pods. Organoleptic analysis showed no significant difference in color, taste, flavor, stringiness and general appeal between the produce. SDS-PAGE revealed no differential bands. 11 spots were eluted from 2DE gels for MALDI-Tof/MS. No significant differences were seen between organically grown and inorganically grown produce either on organoleptic analysis or proteome analysis.

24. Cloning and characterization of Fusarium wilt resistance gene analogs in banana (*Musa* spp.)

The objective of the study was to amplify genomic DNA of *Fusarium* wilt resistant banana genotype with primers specific to 'R' genes of TIR-NBS-LRR class for cloning and characterization of resistant gene analogs. Two months old plants of resistant Palayankodan and susceptible Poovan varieties were inoculated with the spore suspension of *F. oxysporum* f. Sp. *cubense* by root feeding method and resistance/susceptibility of respective varieties were confirmed. PCR amplification of DNA samples from both resistant and susceptible varieties were done with 25 forward and reverse primer combinations related to 'R' genes of TIR-NBS-LRR class. R gene analogs of the TIR-NBS-LRR class providing resistance against *Fusarium* wilt in Banana were cloned and characterized and observed similarity with resistant gene.

25. Molecular docking and validation of medicinal effects of coconut (*Cocos nucifera* L.).

The study aimed to analyze the medicinal effects of important metabolites in coconut through *in silico* analysis and its validation through wet lab studies. Effect of various components to inhibit or activate the targets involved in cardiovascular disorders, cancer, alzheimers, diabetics were analyzed through molecular docking. Medium chain fattyacids like lauric, capric, caprylic and myristic acids and polyphenols like gallic and caffeic acid in coconut oil were selected as ligands. Seven protein targets for carcinoma were docked with selected ligands. Thymidylate synthase (TS) was found most effective target for carcinoma. Lauric acid recorded better dock scores with the targets for cancer and Alzheimer's. *In vivo* animal studies and *in vitro* cell line studies highlighted the potential hypolipidemic, anti-diabetic and anti-cancerous properties of lauric acid. Results provided a scientific explanations for the hypolipidemic, anti-diabetic and anti-cancerous properties of coconut through its phyto compounds

26. Detection of novel metabolites in garlic (*Allium sativum* L.) through *in silico* analysis and its validation.

The objective of the study was to identify novel metabolites in garlic by molecular docking studies and perform wet lab analysis with selected phytocompounds to confirm their appropriate benefits. Forty eight phyto-compounds from garlic were docked with thirty two targets involved in lifestyle diseases such as cancer, diabetes, arthritis, blood pressure and cholesterol. Seventeen phyto-compounds in garlic inhibited all the protein targets involved in the disorder. Maximum inhibition was observed with DNA Topoisomerase, EGFR, P13Kγ and Thymidilate synthase of cancer, Glucokinase, DPP4 and Aldose reductase of diabetes, Angiotensin converting enzyme (ACE) of blood pressure, HMG CoA reductase of cholesterol, CoX2, iNOS and TNFα of arthritis and inflammation. Phyto-compounds like alliin, s-allyl l-cysteine, s-allyl d-cysteine, s allyl mercapto cysteine, l-γ-glutamyl- s-allyl-l-cysteine, apigenl. Phloroglucinol, p-coumaric acid, kaempferol, ferulic acid, quercetin and myricetin inhibited maximum no. of targets in all the disease. ADME/T analysis revealed s-allyl mercapto cysteine and p-coumaric acid as highly acceptable and the other compounds as acceptable for developing drugs. Based on *in silico* analysis phyto-compounds such as s-allyl-l-cysteine, alliin, ferulic acid and p-coumaric acid were used for wetlab validation. All the 4 compounds in garlic were cytotoxic to cancer cells of HCT 15, Raw 264.7 and L929 at an IC_{50} value ranging from 70-250µg/ml, determind by MTT assay. MTT analysis of four selected phyto-compounds as well as real time quantitative analysis of EGFR oncogene validated these compounds for further development as potential drugs.

27. Development of an *in vitro* regeneration system and validation of genetic stability in *Phalaenopsis* hybrid Winter Spot with molecular marker

The study aimed to develop a commercially viable micropropagation protocol for *Phalaenopsis* hybrid Winter Spot. Among the explants studied, inflorescence node was the best with respect to culture response. For induction of multiple shoots, MS medium supplemented with 4.5mgl^{-1} BA resulted in the highest average number of multiple shoot (4.1). The percentage of multiple shoot induction was observed maximum 86.6% in MS + 4.5 mgl^{-1} BA followed by MS + 4.5 mgl^{-1} BA +0.1mgl^{-1} IAA with 80 per cent. The number of days taken for multiple shoot induction ranged from 40 to 45 days. For elongation and rooting, MS medium supplemented with BA 4.5 mgl^{-1} + IAA 1mgl^{-1}, 80% rooting was observed. An *in vitro* regeneration system using inflorescence node as explants was developed for *Phalaenopsis* hybrid Winter Spot. Genetic stability in clones was tested using RAPD markers.

28. Photosynthetic efficiency and productivity of gynoecious parthenocarpic cucumber in naturally ventilated poly house.

The study aimed to evaluate the physiological basis of growth, photo morphogenesis, photosynthetic productivity and quality of gynoecious parthenocarpic F_1 cucumber grown in naturally ventilated poly house. The experiment was conducted in a farmer's poly house commercially producing gynoecious parthenocarpic F_1 cucumber at Thannyam in Thrissur district. The variety used was ZECO F_1. Comparison of climatic parameters in open and poly house environment, morphological, physiological, biochemical, yield and quality parameters of the plant under two environmental situations were studied in the project. The study suggested that the diffused light and equal distribution of radiation over the crop canopy favoured morphological characters of poly house grown crop. This in turn helped the crop to maintain high photosynthetic rate and carboxylation efficiency even at later stages of the crop which resulted in increased number of harvest in poly house.

29. Growth and physiology of *Isachne miliacea* Roth. in different soil types and its sensitivity to common herbicides

The project aimed to understand the phenology, growth habits and propagation of *Isachne miliacea* and to test the sensitivity of the weed to the herbicides commonly used in the state. Propagation of *I.miliacea* was affected by factors such as light, temperature, moisture and depth of burial. Growth of the weed was highest in open condition compared to shaded condition. Herbicide sensitivity studies using bioassay techniques revealed that among the pre-emergence herbicides tested, higher weed suppresasion was observed in butachlor and oxyfluorfen. Among the post emergence herbicides, best control was obtained for azimsulfuron followed by cyhalofop butyl and fenoxaprop p- ethyl.

30. Marker assisted transfer of thermosensitive genic male sterility to high yielding red kernelled varieties of rice (*Oryza sativa* L.).

The main objectives were to develop molecular markers associated with TGMS gene and to transfer TGMS character to red rice background. Two TGMS lines were imported from International Rice Research Institute (IRRI) namely, TGMS1 and TGMS2 which are from two different TGMS sources ID24 and IR32364 respectively. Microsatellite analysis was done to find out the SSR markers polymorphic to the *tms* gene. DNA was isolated from the 50 F_2 plants and performed PCR using 45 SSR markers. Capillarity electrophoresis was done for the allele sizing of PCR products. Among 45 SSR markers used, three primers RM 3351, RM 23 and RM31 could differentiate Uma, Jyothi and TGMS1, TGMS2. A set of twenty one primers were able to distinguish TGMS1 and Uma. The F_2 plants sterile as per the TGMS markers were found sterile under sterility inducing condition. Under low temperature their fertility was transformed indicating the presence of *tms* gene. From the study, the sterility *tms* gene got successfully transferred into 14 sterile F_2 plants and RM31, RM23, RM3351, RM212, RM244 and RM258 can be used for the evaluation of TGMS1 x UMA hybrids and their F_2s.

31. Physiological, phytochemical and molecular studies on abiotic stress mediated antioxidant accumulation in *Amaranthus spinosus* Linn.

The objectives of the study were to elicit information on the physiological, biochemical and molecular attributes associated to the antioxidant accumulation due to abiotic stress factors viz. light stress and water deficit stress and CO_2 enrichment in *Amaranthus spinosus* Linn. Plants under CO_2 enrichment and 50 per cent FC showed maximum catalase activity (0.169 units). CO_2 treatment did not show a significant variation with respect to antioxidants. Expression level study of the gene CHS (*Chalcone synthase*) revealed over expression of the gene under abiotic stress, especially under moderate shade stress. The plant can be exploited for its therapeutic value and can be cultivated as an intercrop in plantations.

32. Physiological and molecular analyses of growth responses in black pepper (*Piper nigrum* L.) under elevated carbon dioxide environments

The objectives were to study the physiological, molecular and biochemical basis of growth responses in black pepper under elevated CO_2 conditions. The study conducted inside the Open Top Chamber revealed that elevated CO_2 environment had a positive influence on growth and development of black pepper. Panniyur 1 was the best performing bush pepper. Pepper plants of the variety Karimunda had the best root characters, high mesophyll efficiency and low transpiration rate under elevated CO_2 environment which made it suitable for water limited situations with higher water use efficiency.

33. Evaluation of selectively fertilized coconut hybrids (*Cocosnucifera* L.) for water use efficiency through stable isotope discrimination

The objectives were to evaluate the selectively fertilized coconut hybrids for water use efficiency, to study the mechanism of water stress tolerance in coconuts, and to estimate genetic variability in coconut for water use efficiency through stable isotope discrimination. Among the coconut genotypes evaluated for WUE, hybrid Kerasree was found the most water use efficient genotype under water deficit treatment, which coincides with its lost value for C^{13} discrimination. Hence the study revealed that stable isotope discrimination can be used as an alternative for gravimetric method to screen out water use efficient genotypes. Moreover, efficacy of stress tolerance screening technique like selective fertilization is once again proved, which offers great prospects for drought tolerance breeding in perennials.

Ongoing PG Projects

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

The objectives of the study were 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. Facultative apomixis was confirmed in Panniyur- 1 and Panniyur-2 varieties of black pepper. ISSR and SSR markers polymorphic for apomixis were observed in black pepper. Transcriptome analysis revealed few differentially expressed genes putatively involved in apomixis. Studies were conducted on bush pepper plants of the selected varieties viz., Panniyur-1 and Panniyur-2 and floral biology was studied. In Panniyur-1 and Panniyur-2 the active female and male phase is separated by 10 and 8 days, respectively. Attempts were made to confirm apomixes by allowing berry development in controlled condition by bagging of spike initials. Berry development occurred under bagged condition. In this study, 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 supplemented with hormones. *Ex vitro* germination of seedlings were carried out. The project is in progress

2. 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. Metabolite profiling of selected somaclones was completed and gene expression analysis for gingerol production is in progress. 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 of five months after planting. Total volatile oil components separated from fresh and dry ginger rhizomes were 148 and 104 respectively. The project is in progress

3. **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

4. **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

5. **Differential expression of pathogenesis related genes by plant growth promoting rhizobacteria in controlling taro leaf blight**

   To 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

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

   ISSR markers UBC 811, UBC 815, UBC 826, UBC 857, UBC 866 and SSR marker mTcCIR42 were screened with twenty resistant and four susceptible genotypes of cocoa. ISSR analysis had shown that all the primers are capable to differentiate resistant and susceptible genotypes. The SSR assay has also differentiated the resistant and susceptible genotypes. The project is in progress.

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

   The objective of the study was validation of the molecular markers for bacterial wilt resistance in chilli for Marker Assisted Selection. F_2 segregating generation for bacterial wilt incidence was developed by crossing Anugraha X Pusa Jwala. Parent genotypes, Ujwala and F_2 generations were genotyped for bacterial wilt incidence through artificial screening. Validation studies were done using reported RAPD, SCAR, AFLP and SSR primers for bacterial wilt incidence with BSA. The project is in progress.

8. 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. The 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 was found least. The project is in progress.

9. 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. The project is in progress

10. *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 project is in progress.

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

Objectives were standardization of a protocol for short term conservation of *P. rosea* using encapsulation technique, long term conservation of *P. rosea* using vitrification techniques of cryopreservation *viz*., simple vitrification and encapsulation vitrification, and assessment of genetic fidelity of recovered and regenerated plantlets from storage, using molecular markers.
In short term conservation studies, maximum regeneration responses were obtained with mannitol 10 per cent in encapsulation matrix and liquid MS as storage medium at 25˚C after 30 days of storage. 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 project is in progress

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

The study aimed to develop an *in vitro* regeneration protocol for micropropagation in *Vanda* hybrids using suitable explants and to perform clonal fidelity test using ISSR markers

Among the various explants selected for initiating *in vitro* regeneration of two selected *Vanda* hybrids namely Dr. Anek and Sansai Blue, inflorescence segments responded positively whereas the leaf, root and stem segments failed to respond under the various media combinations tested. Culture initiation in *Vanda* hybrids using inflorescence segments was good 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 project is in progress.

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

The study aimed to develop serological and PCR based methods for identification and characterization of *Katte mosaic virus* of cardamom (*Elettaria cardamomum* Maton). Six infected and 2 healthy samples were collected from Wayanad and Idukki district of Kerala and maintained in the insect proof net house which 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 project is in progress

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

Objective was to develop antibody based nano biosensor for quick detection of *banana bract mosaic virus*. For the development of nanobiosensor, gold nanorods (GNRs) at an aspect ratio of 3.03nm synthesized and characteristic features of Gold nanorods were observed by UV-Vis spectrophotometer and transmission electron microscope (TEM). The project is in progress

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

Objective was to develop a nanobiosensor for easy and quick detection of banana bunchy top virus. Gold nanorods (GNRs) were synthesized using seed mediated growth method and characterization of synthasised GNRs 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. The project is in progress.

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

Objective was to develop molecular clones of coat protein (CP) gene of BBrMV and to characterize it. 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. The project is in progress.

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

The objective was to understand the molecular mechanisms behind different levels of pungency in different species of *Capsicum*. Ten *Capsicum* accessions with different levels of pungency were employed in the study, These include five pungent genotypes and five non-pungent genotypes. SCAR molecular markers specific to pungency character in chilli were used to characterize all the ten 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. The project is in progress.

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

The objective was to check antiviral property of *Glycosmis pentaphylla* (Retz.) Correa, locally known as 'panal', a widely used plant in Ayurveda, for cough, rheumatism, anaemia and jaundice. 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. Molecular docking of 23 compounds from leaves and 14 from stem and roots is in progress with Discovery Studio 4.0.

19. 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 seen solely as well as combined with SLCMV (mixed infection) in 9 districts namely Thiruvananthapuram, Kollam, Alappuzha, Kottayam, Idukki, Ernakulam, Palakkad, Malappuram and Kasargod. The project is in progress.

20. 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 project is in progress.

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

Mining of resistance genes associated with anthracnose infection in greater yam is in progress.

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

The objective of the study was to analyse the genetic variation in elephant foot yam based on morphological and molecular characteristics. Twenty- eight accessions of elephant foot yam from all over the country were selected for characterization. The project is in progress.

23. 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 in this line. Five PPD resistant and twenty-three PPD susceptible cassava lines were utilized in the study. The project is in progress.

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

The study focused on four varieties/genotypes of cassava *viz.,* Sree Vijaya, H165, Sree Athulya, H226 in a field trial with three replications, each replication with 25 plants. The present study revealed that cassava varieties had 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. The project is in progress.

25. 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 project is in progress.

26. Genetic diversity analysis of wild yams of Western Ghats.

27. The research work was 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. ISSR data revealed that among the wild yams *Dioscorea vexans* found in Andaman's was the highly divergent one. The project is in progress

28. 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 4 different controlled pollinations. *i.e.* Komadan x WCT, WCT x Komadan, Komadan x CGD, Komadan x Komadan. Population genetic analysis of

RAPD markers revealed that the genetic diversity among the 4 populations. The project is in progress.

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

The study was focused on four varieties of Sweet potato *viz*., Sree Kanaka, Sree Arun, ST-13 and Kanhangad in a field trail with three replications. Observation was made for morphological parameter study and photosynthetic rate.Sucrose and starch content was higher in the variety ST-13 and Sree Arun variety 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. The project is in progress

30. 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. 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 project is in progress.

31. *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 of taro, consequent to application of *P. indica.* The project is in progress.

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

33. The main objective of the study was to standardize the method for *in vitro* propagation of thermosensitive genic male sterile rice. The project is in progress

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

Objective of the study was to scientifically evaluate antiinflammatory, antinociceptive, and antioxidant potential of leaves of an ethno medicinal plant *Pterospermum rubiginosum* B, Heyne ex G. Don and to carry out its pharmacognostic studies. The project is in progress.

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

The main objective of the study was to evaluate the anti-inflammatory, analgesic and antioxidant potential of the ethanolic extract of the root of the ethnomedicinal plant *Dracaena terniflora* Roxb. and to carry out its pharmacognostic studies. The project is in progress

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

The objective was to combine morphological and molecular data for greater understanding of the distribution and extent of genetic dissimilarity present within the *Dioscorea alata* accessions collected from different regions of Kerala. The project is in progress

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

The Objective was to isolate and sequence of 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. The project is in progress.

38. 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 project is in progress

39. 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. The project is in progress

40. 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'. The project is in progress

41. Analysis of capsanthin- capsorubin synthase gene in Byadagi chilli (*Capsicum annuum* L.) and elucidation of carotinoid metabolic pathway

The objectives of the study were analysis of *Capsanthin capsorubin synthase* gene in Byadagi chilli and elucidation of carotenoid metabolic pathway for production of capsanthin and capsorubin. Seven genetically distinct chilli varieties i.e. 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. The project is in progress

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

Objective was to characterize eight promising cocoa varieties released from KAU, using SSR and ISSR markers to develop DNA fingerprints. DNA isolation was done using modified protocol. Genomic DNA from each variety amplified with 10 and 11 selected ISSR and SSR markers respectively. The project is in progress

43. 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. The project is in progress.

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

The study aimed to understand the photo protective potential of ecofriendly stress mitigating chemical sonphotoinhibition in photochemistry and photosynthesis of rice (*Oryza sativa* L.) under solar ultraviolet-B radiation. The project is in progress

45. Physiological characterization of thermosensitive genic male sterility in rice (*Oryza sativa* L.)

The main objectives of the study were to develop thermo-sensitive genic male sterile line in red rice background and its physiological and phonological characterization. The study revealed that CSP of the TGMS line under study is 26.1^0C. It can be used as a reliable female parent in rice breeding programme. The project is in progress

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

The main objective was to study 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. Spectral modifications through shade nets altered morphological and physiological responses of salad cucumber, yardlong bean, capsicum and tomato. The project is in progress

47. Carbondioxide enrichment mediated plant- microbe interaction in cowpea *(Vigna unguiculata L.)* under water stress

The objectives of the study were to assess 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 project is in progress.

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

The objectives were 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 had a role in improving the stress tolerance and recovery responses in the case of tomato and amaranthus. The project is in progress.

49. 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.

Name of the Project Coordination Group (09)

Soil Health and Organic Farming

Project Coordinator: Dr. Ushakumari. K

Concluded Projects: 8 Nos

Ongoing Projects: 2 Nos

Concluded PG Projects: 8 Nos

Concluded Projects

1. **Network Project on Characterzation 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 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	500 to 850		5	15

the southern parts of Thiruvananthapuram district up to Kazhakoottam panchayat				
9/ Laterite soils extending from Northern parts of Thiruvananthapuram district (from Kazhakoottam panchayat) to Ernakulam district including both	500 to 850 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 (Thiruvanantha puram 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	

2. 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, registering a pH above 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.

Two field demonstrations were conducted in the panchayath, one at Vilappil and another at Cherukode with the objective of convincing the farmers about the effectiveness of different agronomic and nutrient management practices in enhancing nutrient use efficiency and soil and water productivity under coconut based cropping systems.

With the co-operation of the Vilappil Krishibhavan, three Training programs were conducted as part of the project in order to impart knowledge among the farmers on the importance of soil health and balanced nutrition for increasing productivity of crops without affecting environmental quality.

3. **Farmer participatory approach to assess the impact of IPNS on soil health and crop yield in a typical laterite soils of Western Ghats**

The experiment was conducted to understand the effect of integrated use of inorganic fertilizers and organic sources such as bio fertilizers, manures on soil chemical and biological characters and to assess the effect of IPNS on the growth, yield and yield attributes of vegetable crops in a laterite environment. From the study it is concluded that the inorganic nutrients can be substituted in the form of enriched compost by judiciously combining bioinoculants such as *Freutaria aurantia*, *Phosphobacterins*, *Azosprillum*, VAM and organic amendments such as neem cake, bone meal etc. Enrichment of vermicompost @ 2 % with *Freutaria aurantia* was found to be effective with respect to soil chemical and biological characters. Thus the application of enriched vermicompost @2% with *Freutaria aurantia* along with inorganic sources such as 100% NP and 50% NP in the form of urea and single super phosphate can be recommended to the laterite soils of the Western Ghats region. This improves the soil chemical and biological attributes thus sustaining soil health and plant yield.

4. **Rejuvenation and Conservation of Vellayani Lake- GoK Plan Project**

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.

Vellayani lake is the sole drinking water source of Kovalam, Vizhinjam, Pachalloor, Vellayani and adjoining areas. The indiscriminate anthropogenic interventions caused great threat to the quality of water and to water spread areas. A one day seminar was conducted on 27.03.2015 by participating the local people (150 numbers) of Kalliyoor and Venganoor Panchayath for creating awareness on conservation and rejuvenation of Vellayani lake.

5. **Micro nutrient management for sustenance of soil health under intensive cultivaton 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”. This mixture was formulated 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.

6. **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), *muntakan* (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 *muntakan* 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.

7. **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 redloam 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 redloam soils, the organically treated plots showed a distinctively higher values than the conventional plots. In general redloam 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 activites 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.

8. 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 Tk. 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 farmers plots. The experiments were laid out using bitter gourd as test crop. The soil of the experimental site was a typical laterite type with a pH of 5.3. Electrical conductivity of 0.01 d Sm^{-1}, available N 217.6 Kg ha^{-1}, available $P_2O_5$20.58 kg ha^{-1} and available K_2O165.34 kg ha^{-1}.

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. However the organic amendments imposed a similar effect on soil pH. With regard to EC treatment involving the application of 100% Nitrogen as enriched vermicompost using neem cake has registered a highest value than the other treatments.

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.

Enzyme activity is essential in both mineralization and transformation of organic C and plant nutrients. 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.

It is also inferred that all the biological and biochemical parameters revealed similar trends over time in response to the addition of organic matter amendment had an effect on soil microbial community size and activity resulting in an increase in microbial biomass (C and N), enzyme activities and N mineralization.

Ongoing Projects

1. **Network project on "Characterization and Management of soil fertility with respect to secondary and micronutrients for Agro-ecosystems of Kerala"**
   A total of 272 experiments are being conducted in various parts of the state to determine the critical levels of secondary and micronutrients viz., Ca, Mg, Zn, Cu and B for rice, banana and vegetables (Yard long bean, Snake gourd and Bitter gourd) in soil and in plant. Response to applied doses of lime, magnesium sulphate, copper sulphate, zinc sulphate and borax have been recorded in locations deficient in respective nutrients in terms of increase in yield and quality of produce.

2. **Regional Soil Health Management Under the project -Soil Resource Management and Biological Soil Fertility**
   Changes in soil fertility parameters in geo referenced sampling points in different districts under intensive agriculture over a period of three years were studied. The soil reaction of the representative samples collected from locations under intensive agriculture in **Wayanad,**

Malappuram and **Kollam** districts showed an increase towards strongly to extremely acidic classes.

Concluded PG 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 and revealed the following. Among the 100 samples collected from Thrissur,

Malappuram and Kozhikodu 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. **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.

7. **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.

8. **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. Potential buffering capacity or the

supplying power of soil had significant positive correlation with CEC and exchangeable cations in soil. The adsorption data of both calcium and magnesium at 25ºC and 40 ºC were best explained by Temp 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 (ΔH^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 incubation experiment conducted to study the effect of organic matter on the adsorption of calcium and magnesium revealed a positive influence of organic matter on availability of calcium and magnesium. 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.

Name of the Project Coordination Group (10)

Farming Systems Research and Climate Studies

Project Coordinator: Dr.Jacob John

Concluded Projects: 6 Nos
Ongoing Projects: 4 Nos

Concluded PG Projects: 1 No
Ongoing PG Projects: 39 Nos

Concluded Projects

1. **Development and validation of on- station integrated farming system models - AICRP on Integrated Farming Systems, Karamana**
   The highest net returns per 0.2 hectare (Rs.56922) was obtained from coconut based IFS. This was followed by homestead based (Rs.26895) and banana based (12046) systems. The employment generation per hectare was highest for rice based system followed by banana based. Nutrient generation and recycling was highest in banana based IFS**,** followed by coconut based.

2. **Investigating rice based farming systems involving fish through suitable land modifications vis-à-vis conventional rice based cropping systems - AICRP on Integrated Farming Systems, Karamana**
   The (rice+fish)-(rice+fish)-(culinary melon+fish) system was most profitable (Rs.3,60,714/- per ha) followed by (rice+fish)-(rice+fish)-(amaranthus+fish) (Rs.264984/- per ha) and (rice+fish)-(rice+fish)-(fodder cowpea+fish) (Rs.1,94,082/- per ha). Fish (catla+rohu) when simultaneously cultured with rice, generated a gross income of upto Rs.1061/- from a cent (40 sq.m).

3. **Response of nutrients in rice based cropping on farmer's field - AICRP on IFS, Thiruvalla**
   Mineral nutrition with NPK at 90:45:45 kg/ha along with $ZnSO_4$ at 25 kg/ha gave maximum grain and straw yield. But it was on par with NPK application at recommended dose. The treatments with NP application had recorded comparatively higher grain and straw yield than NK application. The uptake of NP and k was found to be highest in treatments with NPK+Zn and NPK application.

4. **Diversification of existing farming systems under marginal household conditions- AICRP on IFS, Thiruvalla**
   The technical intervention made with crop modules like mineral nutrition of coconut, intercropping with banana or vegetable, replacement of existing variety in rice and weed control using herbicide, correction of soil reaction etc improved the productivity and total net returns of the coconut and rice based farming system. Inclusion of feed supplements like mineral mixture in the feeding schedule had improved the milk quality and productivity of the milch animal. Provision of cow mat has improved the health and sanitation of the animal thereby reducing the incidence of Mastitis and foot and mouth disease.

5. **On Farm evaluation of farming system modules to improve the profitability and livelihood of small and marginal farmers**.
   The nut production and general health of the coconut palms improved on account of technical interventions undertaken during the third year of experiment. The processing and value addition undertaken had improved the quality of the produce and enabled the farmer to fetch higher price. The gross and net returns of the existing coconut based farming system increased with the launching of enterprises like apiary, nutritional kitchen garden, vermicompost production and pisciculture.

6. **Frontline demonstration (FLD) on oilseeds**
   Sesamum variety Tilak gave higher seed yield as compared to check variety.

Ongoing projects

1. **Developing systems recommendations for nutrient, disease and insect pest management in major cropping systems of Kerala (Network)**
2. **Socioeconomic analysis and farmer participatory development of homestead farms of Kerala**
3. **Network project on crop weather analysis**
4. **Network project on crop weather analysis**

Concluded PG Projects

1. **Allelopathic effect of trees grown in homesteads of Kerala on turmeric (*Curcuma longa* Linn.)**
   Leaf leachates and extracts of teak, tamarind and mango are inhibitory and hence, caution should be exercised and measures to alleviate the inhibitory effects through copious irrigation may be adopted while planting turmeric under the canopy of these trees. Coconut leaf leachate stimulated growth of turmeric. The leaf loppings of mango inhibited growth and yield of turmeric and hence, cannot be recommended for mulching in turmeric. Leaf loppings of cashew, jack and teak enhanced yield and hence, can be recommended to farmers for applying as mulch in turmeric @ 15 t ha^{-1} (112.5 g per grow bag of 25 cm height and 30 cm diameter, capable of holding 15 kg potting mixture comprising of soil:sand:cow dung in 1:1:1 ratio) immediately after planting and again after 50 days.

Ongoing PG Projects

1. Allelopathic effect of trees grown in homesteads of Kerala on turmeric (*Curcuma longa* Linn.)
2. Calibration and validation of CERES - Rice crop simulation model
3. Nutrient budgeting in rice based farming system
4. Agrotechniques for container grown yard long bean (*Vigna unguiculata* var. *sesquipedalis*)
5. Crop Productivity and Weed Dynamics in Rice Based Farming Systems
6. Leaf litter recycling in homestead agroforestry systems
7. Organic preparations and biostimulants for moisture stress mitigation in container grown okra (*Abelmoschus esculentus* (L) Moench.)
8. Assessment of rice (*Oryza sativa* L.) production under climate change scenarios
9. Micrometeorological modification with different mulches to enhance the yield in tomato (*Solanum lycopersicum* L.)
10. Effect of growing environment and climate change on physiology of tomato (*Lycopersicon esculentum*Mill)
11. Soil Co_2 emission under different tillage practices in redloam/ laterite, clay and coastal sandy soils of Kerala

12. Modeling soil carbon dynamics of two major ecosystems of humid tropics
13. Spatiotemporal distribution of aquatic invasive plants in Kuttanad wetland ecosystem
14. Impact of climate change on water availability across western ghats
15. Impact of heat and nutritional stress on adaptive capability of bucks
16. Changing global climatic scenario on environmental processes across india: its possible causes and impacts
17. Impact of heat and nutritional stress on rumen fermentation characteristics and metabolic activity in bucks
18. Phenology of medicinal snake gourd (*Trichosanthes cucumerina* l.) under different seasons
19. Impact of climatic parameters on watershed management practices using GIS techniques
20. Carbon storage potential of intensive silvopasture systems in humid tropics of Kerala
21. Impact of heat and nutritional stress on the growth and reproductive performance
22. Modeling the impact of climate change on growth and yield of tomato
23. Tree growth climate relationship in plantation teak (*Tectona grandis* l. f.) grown in Thrissur district, Kerala
24. Over the equatorial trough on Indian summer monsoon activity impact of convection
25. Climate change impact on crop water requirement of rice in Thrissur district
26. Carbon dynamics in teak planted laterite soils of Kerala
27. Assessment of portable biogas plants for their energy production and emission reduction potential
28. Landslide hazard zonation of Nilambur taluk using remote sensing
29. Mulching for soil quality, climate stress mitigation and crop productivity in okra
30. Dendroclimatic analysis of teak (*Tectona grandis* l. f.) from central India to evaluate the potential for climate reconstruction
31. Climate change adaptation through improved water use efficiency in rice (*Oryza sativa* L.)
32. Energy use and emission reduction in dairy farm
33. Impact of climate change variables on young coconut seedlings (*Cocos nucifera* L.)
34. Effect of weather on leaf blast incidence in rice and predicting potential epidemics under various climate change scenarios
35. Effect of weather on sheath blight incidence in rice and predicting potential epidemics under various climate change scenarios
36. Climate change adaptation on rice production
37. Impact of climate change on water resources of Kurumali river basin
38. Simulation of salt water intrusion into the coastal aquifers of Kadalundi river basin in Malappuram district using visual mudflow
39. Impact of climate change on the temporal and spatial distribution of the Indian peafowl (*Pavo cristatus*) in Kerala

Name of the Project Coordination Group (11)

Crop Pests and Beneficial Insects (CPBI)

Project Coordinator: Dr. Ambika Devi. D

Concluded Projects: 1 No
Ongoing: 37 Nos

Concluded PG Projects: 2 Nos
Ongoing PG Projects: 1 No

Concluded Projects

1. **Management of sucking pest complex in vegetable ecosystem using Entomopathogenic fungus*, Lecanicillium lecanii***

Isolated four Entomopathogens from Vellayani ecosystem and deposited three effective isolates at ITCC, IARI and NFCCI, Pune. The most potent isolate *Lecanicillium saksenae* (Accession no: ***Ls.Vs*.1 – 7714)** has been investigated in detail. Entomopathogenicity of *L.saksenae* is reported for the first first time from India. It has been characterised at molecular level, its ideal growth substrate and temperature has been standardised, suitable carrier for formulation was identified, pathogenicity studies were conducted and evaluated under field conditions.

Pathogenicity test revealed that the new isolates were found effective in managing mealy bug, jassids, scales, aphids, mites and whiteflies. *L. saksenae* was also found to be effective in managing cowpea pod bugs and rice bugs. Field evaluation proved its efficacy in managing chilli thrips, cowpea aphid and tomato whitefly.

The isolate is more compatible with new generation insecticides than with older ones. It was found to be compatible with spinosad, flubendiamide and chlorantriniliprole and also with botanicals like *Hyptis, Andrographis*, garlic extract, neem seed kernel extract and neem oil emulsion.

Training programme was imparted to two SHGs enrolled under the SHG group Samrudhy ATMA Vanitha Karshaka Sangam (Reg no: T371/2) and the other associated with Instructional farm, College of Agriculture on techniques related to isolation, mass production and formulation of Entomopathogenic fungi. Conducted three awareness programme to farmers on the potential of entomopathogenic fungi in crop pest management at Balaramapuram Krishi Bhavan, Pallichal Krishi Bhavan and Malayinkeezhu Krishi Bhavan.

Ongoing Projects

1. **Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala. Sub project – 3. Coconut and arecanut**

Recommendations given for the management of pests and diseases are given below

Rhinoceros beetle: Crown cleaning followed by the application of 20g Cartap hydrochloride 4G or Fipronil 0.3G or Carbosulfan 6G mixed with 200g sand in the innermost 2-3 leaf axils. This treatment has to be done thrice during January, May and September.

Leaf rot: Crown cleaning (removal and destruction of affected parts) in coconut palms.Pour 300 ml of the following fungicide solution at the base of spear leaf twice a year (April-May and September-November) Hexaconazole + Potassium phosphonate(Samarth) 3ml/L OR *Pseudomonas fluorescens* 2% (20g/L) OR PGPR mix II 2% (20g/L)

Bud rot: The experiment indicated that removal of affected tissues in the crown followed by application of Hexaconazole + Potassium phosphonate – 3 ml/l in the crown was effective in controlling bud rot. The second effective treatment was PGPR Mix ll-*2%*-20 g/l. However, to obtain consistent data, the experiment has to be repeated during 2016-17 in severe bud rot affected area.

Red palm weevil: Based on the number of adult and larvae present in the treated palms observed at monthly interval for a period of 21 months, it was seen that leaf axil filling with Cartap

hydrochloride 4%G 20g or Carbosulfan 6G 20g or Chlorantraniliprol 0.4GR 25g mixed with 200g sand were equally effective in managing the pest.

Coreid bug: The effect of treatments applied on the 3rd youngest bunch was assessed 5 months after spraying by observing the extent of infestation in the nuts. The percentage of nuts damaged and Mean Intensity Score (MIS) were worked out. Least damage was observed in Buprofezin 25% SC @ 2ml/l treated palms followed by Imidachloprid 17.8 SC. However the MI score revealed the superiority of Imidacloprid 17.8 SC (0.3ml/L). The results indicated that application of Imidacloprid 17.8 SC (0.3ml/L) in coconut bunches was effective in managing the coreid bug.

Mite: The effect of the treatments was assessed 5 months after each spray. The percentage of nuts damaged due to the pests and the Mean Intensity Score (MIS) were worked out. The results indicated that crown cleaning followed by the application of Imidachloprid 17.8 SC @ 0.3 ml/l. was the best treatment. The analysis of MI score also revealed the superiority of Imidachloprid. The next best treatment was *Lecanicilium lecanii* (20 g/l + 5g bar soap) followed by Beauveria *bassiana* (20g/l).

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 brinjal -RKVY**

Among bioagents, nursery of application of *P. lilacinus* @ 25 g/m^2 + main field application @ 5g/m^2 and *B. macerans* nursery application @ 25 g/m^2 + main field application @ 5 g/m^2 are the best treatments for reducing the nematode population and increasing yield of brinjal. So demonstration trials were conducted in farmers fields at three locations in Vellayani, Kalliyoor and Kakkamoola.

Application of the bio agent *Paecilomyces lilacinus* (cfu 2x 10^6) @ 25g/m^2 in nursery bed + mainfiel application of *P. lilacinus* @5g/m^2 suppressed the nematode population (75 per cent reduction over untreated) and increased the yield (72 per cent increase over untreated) in location 1

Application of the bio agent *Paecilomyces lilacinus* (cfu 2x 10^6) @ 25g/m^2 in nursery bed + mainfiel application of *P. lilacinus* @5g/m^2 suppressed the nematode population (79 per cent reduction over untreated) and increased the yield (34 per cent increase over untreated) in location 2

Application of the bio agent *Paecilomyces lilacinus* (cfu 2x 10^6) @ 25g/m^2 in nursery bed + mainfiel application of *P. lilacinus* @5g/m^2 suppressed the nematode population (73 per cent reduction over untreated) and increased the yield (51 per cent increase over untreated) in location 3

For managing root-knot nematode in brinjal, nursery application of *P.lilacinus* @ 25 g/m^2 + mainfield application of *P.lilacinus* @5g/m^2 can be recommended.

3. **Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala.Sub project –the management of nematodes in banana- RKVY**

Trials conducted to test the efficacy of chemicals in suppressing the nematode population in the rhizosphere of banana revealed that application of Carbosulfan @ 16.7 kg/ha was equally effective to the check treatment, paring (P) + Hot water treatment (HWT) + Carbosulfan and P + Hot water treatment + Carbofuran. Regarding root-knot count the lowest was recorded in P + HWT + Carbofuran + Neem cake treatment (10.24 per 5g root). It was found as effective as P +

HWT + Carbosulfan + Neem cake, Carbosulfan, Cartaphydrochloride and Carbofuran giving 79 to 93 percent reduction over untreated. .Results of the farm trials conducted in 4 locations also showed that Carbosulfan application is effective in reducing the nematode population (66.50 to 88.93 percent reduction over untreated) and increasing the yield (62.48 to 87.04 percent increase over untreated) of banana.

In non chemical nematode management, pooled analysis of the data of the trials conducted in three locations revealed that the effect of P + sucker treatment with *P. lilacinus* @ 5g/sucker+ pit application of *P. lilacinus* @ 20g/pit was statistically on par with paring + neem cake, P+ *B. macerans* @ 5g/sucker+ pit application of *B. macerans* @ 20g/pit, P + sucker treatment with *P. fluorescens* @ 5g/sucker+ pit application of *P. fluorescens* @ 20g/pit, P + carbosulfan pit application. The percentage reduction in nematode population in these treatments ranged from 83 to 90 percent. Similar trend was observed in the case of height of the plant and top girth. Highest bunch weight was obtained in *P. lilacinus* sucker treatment @ 5g/sucker + pit application of *P. lilacinus* @ 20g/pit and the effect of these three treatments was statistically on par giving 68 to 74 percent increase over the untreated. Per ha yield in these treatments ranged from 25.48 to 26.33 t/ ha as against 15.20 t/ ha in untreated.

Soil application of Carbosulfan 6G@ 16.7 kg/ka found equally effective to the check treatment, paring+ hotwater treatment + Carbosulfan 0.5g a.i/plant + neem cake @1kg/plant in reducing the nematode population in soil and increasing the yield of banana. Sucker treatment with *P. lilacinus* @ 5g/sucker + pit application @ 20g/pit 45days after planting or sucker treatment with *B. macerans* @ 5g/sucker+ pit application of *B. macerans* @ 20g/pit found to be the best treatments for suppressing the nematode population and increasing the yield of banana

4. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala. Sub project - 3 Evaluation of alternate management technologies against tea mosquito bug *Helopeltis antonii* -RKVY

At 30th day after third spray, damage score on laterals showed that all the treatments including control except pongamia oil (4%), in which the damage was high, were on par among each other. Comparatively high population of red ants in combination of neem and pongamia oil, pongamia oil 2%, azadirachtin and control might have influenced and managed the tea mosquito bug and that may be the reason for low damage in these trees.

At 30th day after second spray, *Metarhizium anisopliae* itself recorded least damage score in panicle and all the other treatments except azadirachtin and control were on par with *Metarhizium anisopliae*.

Data revealed that neem oil 2% + pongamia oil 2% recorded highest nut yield (6. 35kg/ tree), though not significantly superior to other treatments.

In ARS, Anakkayam, at seventh day after first spray, combination of neem and pongamia oil recorded least damage on shoots and was significantly superior to all other treatments. On panicle, combination of neem and pongamia oil and *Beauveria* recorded least damage score at 15th day after first spray and was significantly superior to all other treatments. Same trend was recorded on 30th day after spray.

In the second spray, 2% pongamia oil and azadiractin 1500 ppm recorded significally less damage on shoots followed with *Beauveria, Metarhizium* and combination of neem and pongamia oil. At 15th day, pongamia oil 2% itself was significally superior. On panicle,

combination of neem and pongamia oil recorded significantly less damage at 7th and 30th day after spray.

Variation in red and population was observed among the treatments. There observed high population of red ants in treated trees compared to control, which indicates safety effect of botanicals and bioagents on natural enemies. At 30th day after first spray, all the treatments except combination of neem and pongamia were statically on par with respect to spider population. In the second spray post observations, there was variation in the population among treatments and even high population was observed in treated plots compared to control, which indicates these treatments were safe to natural enemies, but only affects in the migration at the time of spray.

Among the entomopathogenic fungii, *Beauveria bassiana* performed comparatively better to *Metarhizium* and *Lecanicillium lacani* in reducing the tea mosquito bug damage. Combination of neem and pongamia oil (2% each) and pongamia oil 2% performed comparatively better among botanicals. There is scope for utilizing these botanicals in organic cashew cultivation.

5. Development of Technologies Including Alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala. Sub project - management of nematode in pepper

The result of the present investigation showed that treatment with carbosulfan 6% G @16.7 kg/ha was the most effective treatment in increasing the dry weight of pepper (797.25 g). This was on par with cartaphydrochloride 4% G @ 25kg/ha (790 g). The next best treatments were thiamethoxam 25% WG @100g/ha followed chlorantraniliprole 0.4 % G @10 kg/ha. Other treatments were not found to be statistically significant in increasing the yield. The percentage increase in dry weight of pepper was to a tune of 59.45 and 58.00 with carbosulfan 6% G @16.7 kg/ha and cartaphydrochloride 4% G @ 25kg/ha respectively compared to untreated.

All the chemicals were significantly effective in reducing the number of galls and nematode population in soil compared to the untreated. Lowest number of galls was recorded in the carbosulfan treatment (37.00) followed by cartaphydrochloride (40.50) and were on par with each other. Treatment with carbosulfan was found to be statistically superior in decreasing the nematode population in soil (495) followed by cartaphydrochloride (920). The percent reduction in nematode population in soil was to a tune of 89.55with carbosulfan treatment compared to untreated.

From pooled analysis data, Carbosulfan 6 G -16.7kg / ha was found as the best treatment in reducing the population of nematodes in soil (1690.78 J_2 / 200g soil) followed by cartap hydrochloride 4 G -25 kg / ha 915.75 and quinalphos 25 EC 1766.00 J_2 / 200g soil. Carbosulfan 6 G was also effective in suppressing gall production (37.63) followed by cartap hydrochloride 4 G. Both these treatments were found to be at par with each other. Carbsulfan 6 G was the best treatment in increasing the yield of pepper (769.81) followed by cartap hydrochloride 4 G (769.25) and both treatments were found to be par with each other.

6. Development of Technologies Including Alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala Sub project - management of nematode in cardamom

A perusal of data revealed that Cartaphydrochloride 4G @ 1 kg a.i/ha was the most significant treatment in increasing the number of capsules/ panicles (29.50). It was found to be at par with neem seed cake 2 kg/ ha (27). In general all the treatments were effective in increasing the

number of panicles except Chlorantraniliprol 0.4% G 10kg/ha (13.50). Cartaphydrochloride 4G @ 1 kg a.i/ha was the most effective treatment in increasing the number of capsules per panicle (40.75) and dry weight of capsules (0.70g/plant) which was statistically significant to other treatments. The next best treatment was neem seed cake 2 kg/ ha (capsules per panicle; 37.25). Cartaphydrochloride 4G @ 1 kg a.i/ha resulted in an yield of 1.75 t / ha which was much higher than in untreated control (0.50 t/ha). Among the bio agents *Bacillus macerans* ($1x10^7$ cfu 30g/plant) and *Pseudomonas fluorescens* ($1x10^8$ cfu 30g/plant) were equally effective in increasing the dry weight of capsules (0.40 and 0.38 g / plant)

Cartap hydrochloride 4G @ 1 kg a.i/ha was significantly effective in reducing the number of galls (16.75/ 5g root). This was on par with neem seed cake 2 kg/ ha (18.75). The same trend was observed in number of nematodes / 5 g root. Cartap hydrochloride 4G @ 1 kg a.i/ha was significantly effective in reducing the population of nematodes in 200 g soil. (47.25). Among the bio agents *Pseudomonas fluorescens* @$1x10^8$ cfu 30g/plant and *Bacillus macerans* @$1x10^7$ cfu 30g/plant were effective in increasing the weight of capsules which were at par with each other.

Effect of treatments on nematode population infecting cardamom indicated Cartap hydrochloride 4% @ 1 kg a.i/ha as the best treatment in reducing the population of *M.incognita* infecting cardamom ($6.71J_2$/200 g/ soil) (41.7 $5J_2$/ 5g root). This has reflected in increasing yield of cardamom to a tune of 1.75 t/ha. Application of Neem cake @ 2 kg/plant was on par with cartap hydrochloride in reducing the number of nematode population in 5g root galls (28.4), number of nematodes (51.7) and number nematodes in 200g soil (89.5).

Among the biocontrol agents *B .macerans* was the best treatment in increasing the yield (1.25t/ha) followed by *P.lilacinus* and *P. fluorescens.* However all the three biocontrol agents were on par in increasing the yield of cardamom. *B .macerans* was statistically superior to other bioagents in decreasing the population of nematode in soil (91.3 J_2 /200g soil).

7. Evaluation of entomopathogenic fungi against tea mosquito bug (*Helopeltis antonii* Signoret) in cashew

Survey conducted during period yielded certain local isolates which were later identified as *Nomuraea rileyi*. Out of the five entomopathogenic fungi tested, *B. bassiana* and *L. lecanii* were found to be promising under laboratory condition. On further tests, *B. bassiana* was found as the most promising against tea mosquito bug.

8. Research on new molecules of plant protection chemicals Sub Project 1. Screening of new generation insecticides, bio-pesticides and other non chemical insecticides for the management of pests of Cole crops.

For the management of DBM in cabbage grown in hilly tracts, Spinosad (45 SC) and Chlorantraniliprole (18.5 SC) are the most effective treatments based on their efficacy in population reduction and yield. Acetamiprid (20SP was the second best treatment. None of the non chemical measures were effective in managing DBM in hilly areas.

From the experiment conducted in Idukki district (Cheruthoni) during the second year to evaluate different doses of the above selected insectides showed that there was no significant difference among the three tested doses in terms of reduction in population. Hence the lower doses *viz*. Spinosad 0.1 %, Chlorantraniliprole 0. 05% and Flubemndiamide 0.2% can be recommended as the best dose of these three new generation insecticides. Experiments conducted at Trivandrum district (Kalliyoor) also revealed that the three doses tested did not differ in their effect.

Hence the insecticides Spinosad 0.1 %, and Chlorantraniliprole 0. 05% and Flubendiamide 0.2 % (needs label expansion) are best for *Spodoptera litura* management. NPY at 20 g/litre is the best bioagent for *S.litura* at low tempertature, high altitude areas. However its performance was not satisfactory in plains. And for the management of DBM, Spinosad (45 SC) and Chlorantriniliprole (18.5 SC) are the most effective treatments based on their efficacy in population reduction and yield.

9. Research on New Molecules of Plant protection chemicals sub Project 4: Newer and safer chemicals and biopesticides for the management of Pest of mango.

Chlorantraniliprole18.5% SC @0.3g/l and Flubendiamide 0.5g/l could bring out significant reduction in the leaf webber (*Orthaga exvinacea*) count in the trials conducted for the consecutive two years . Among botanicals lowest leaf webber *Orthaga exvinacea* infestation was recorded in the treatment Oxuron @ 5 ml/l. Among biopesticides *Beauveria bassiana @ 20* g /l was also effective.

In the trials conducted for management of mango hoppers Imidacloprid 17.8 % SL.2ml/l, Dimethoate @1.6ml/l, Lambda cyhalothrin @ 1ml/l , Spinosad @ 0.3 ml/ l, Buprofesin @ 0.2 ml/l were found effective and other superior treatment are Thiomethoxam 25 % WG @ 0.3 g/l for the management of mango hoppers in the second consecutive year also. Among botanicals Oxuron @ 5ml/l, and biopesticides *Beauveria bassiana @ 20 g /l.* were found effective.

Standardized newer molecules in Bait application technique (BAT) and Male annihilation technique (MAT) for the management of fruit flies in mango. Spinosad 6: 4: 0.2 (v/v/v) Spinosad 6: 4: 0. 02 (v/v/v)and Imidacloprid 6:4:0.005(v/v/v) were found effective for the management of fruit flies using MAT. The treatment spinosad 6: 4: 0.2 recorded maximum total fly catch of 586.69 flies per trap /fortnight and was identified as the superior treatment compared with other treatments. Spinosad 0.02% was observed to be equally effective as that of malathion 0.1%. in BAT

10. Research on New Molecules of Plant protection chemicals -Sub Project 3: Evaluation of insecticides, for the management of pests of coccinia and tomato

Field trials conducted with four new generation insecticides against the epilachna beetle revealed that on 5^{th} day, 10^{th} day and 15^{th} days after treatment flubendiamide 20% WG 50g ai/ha and Chlorantraniliprole 18.5% SC 30g ai/ha were statistically on par in reducing the number of beetle. On 5^{th} day mean population of epilachna beetle was only 9.56 and 12.69. On 10^{th} day, the mean population of epilachna beetle was 6.50 and 9.82 and on 15^{th} day the mean population of epilachna beetle was only 5.30 and 7.82 respectively in flubendiamide 20% WG 50g ai/ha and Chlorantraniliprole 18.5% SC 30g ai/ha treated plot.

11. AINPVPM - AINP on Agricultural Ornithology

Peafowl and wild boar management in an area wide approach in Poriyani Padasekaram, Mundur, Palakkad had fetched the Kerala State's Highest Krishi Award for the year 2015. The padasekaram had been adapted by AINPAO. Methyl anthranilate based bird repellent protected the rice seeds in nursery for more than 20days. Reflective ribbon and automatic cracker station effectively kept off depredatory birds from aquaculture ponds and the stockings were protected for more than two months. Metagenomic studies on bird fecal pellets have been standardized. Physical barrier with nylon rope and reflective ribbon around the field and Nylon fish net over the seed beds protected the seeds and germinating seedlings from peafowl damage in paddy. Physical barrier with nylon net tied around the field in a particular manner and olfactory

repellent taken in muslin cloth in small pouches and hanged around coleus field at crop level was found to be effective in preventing wild boar intrusion into the field and protecting the crop at tuber formation and maturing stage.

Automatic cracker station and fencing with 2 rows of GI wire along with olfactory repellent were effective in deterring wild boar away from paddy field and preventing crop damage

12. AINPVPM - Rodent Control

Rodent pest of coconut

Two types of damage were recorded in coconut *viz*., damage to the nursery nuts and the other is on the crown of the palm. Indian mole rat, *Bandicoota indica*, Indian tree rat, *Rattus rattus wroughtoni* and coconut rat *R. r. rufescens* caused the damage to the nuts in the nursery and on the crown. In standalone coconut palms, plastic sheet stem banding of 60 cm width, at a height of 2-3m prevented the upward movement of rats from ground to crown. Along with the stem banding, crown cleaning and bromodiolane cake placement on the stem as well as on crown had resulted in significant reduction in nut damage over a period of six weeks.

Rodent pest of cacao

Both rats and squirrels attack cocoa pods. Fully ripened pods were damaged more than the unripened ones. Damage was more in the mixed farms where cacao plants intermixed with arecanut, pepper and rubber. Preliminary observations revealed that the damage was primarily due to three stripped squirrel and house rat.

Rodent pest of rice

Rat damage to rice started in the nursery itself. The sprouted seeds were eaten away by the field mouse, *Mus* booduga, House rat, *Rattus rattus*, lesser bandicoot rat, *Bandicota bengalensis* and larger bandicoot rat, *Bandicota indica* in the upland rice fields in Palakkad district. Tiller cutting was observed in isolated fields.

Rodent pest of cassava

Lesser bandicoot rat, *Bandicota bengalensis* and larger bandicoot rat, *Bandicota indica* extensively damaged the cassava tubers. The mean damage recorded was 28.0 per cent where cassava was grown as intercrop in coconut groves whereas in monocrop, the damage was only 12.0 per cent.

13. Severity of mealybug studies in Kerala

Roving survey conducted through out Kerala from April 2015 to March 2016 and the survey showed that mealybug population was highest in summer season compared to rainy season. Mealybug infestation was recorded on 126 plant species belonging to 43 families; on *Malvaceae, Fabaceae, Asteraceae* and *Euphorbiaceae.*

On various host plants, 36 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 (*Plectranthus rotundifolius* (koorka) on colocasia, cowpea, balsam, okra and coleus apart from banana and pepper.

Trichomes provide a foot hold for mealybugs and trichome-mealybug interaction was studied on 46 plant species. 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.*

14. AICRP on Honey Bees & Pollinators

Identified four plants which provide pollen to stingless bees during the period under report.

Common name	**Scientific name**	**Family**	**Nectar/Pollen**
Aster	*Aster oolentangiensis*	Asteraceae	Pollen
Amaranthus (green)	*Amaranthus* sp.	Amaranthaceae	P
Peace lilly	*Spathiphyllum wallisii*	Araceae	N+P
Flower of souls	*Senecio* sp.	Asteraceae	P

Studies on bee assisted pollination in bitter gourd using Indian bee *Apis cerana indica* Fab. resulted in 24 per cent yield increase. Identified one beetle *Aethina sp*. (familily: Nitidulidae) which caused 100 percent damage to brood cells, pollen and honey pots of stingless bee *Tetragonula* (*Trigona*) *iridipennis* Smith. Identified a predatory spider *(Oxyopes* sp.) attacking adult stingless bee workers.

Host range studies of leaf cutter bee revealed that the following plants were attacked by the leaf cutter bee during the period under report

Common name	**Scientific name**	**Family**
Quick stick	*Gliricidia sepium*	*Fabaceae*
Star gooseberry	*Phyllanthus acidus*	*Phyllanthaceae*
Camel foot tree	*Bauhinia tomentosa*	*Fabaceae*
'Orila'	*Desmodium gangeticum*	*Fabaceae*
Coffee plum	*Flacourtia jangomas*	*Salicaceae*

15. AICRP on BCCP & W

A. Field evaluation of fungal pathogens on gundhi bug, *Leptocorisa oratorius*

Two entomopathogenic fungi, namely, *Beauveria bassiana* and *Metarhizium anisopliae*, identified as superior in the laboratory trials in 2014-15 were evaluated at three different doses each in the field at College of Horticulture, Vellanikkara during the period from December, 2015 to January, 2016. The local isolate of the white muscardine fungus, *Beauveria bassiana* applied at the rate of $2x10^8$ spores/ml was found to be as effective as the insecticide malathion applied at the rate of 500 g a.i ha^{-1}.

B. Field evaluation of *Lecanicillium lecanii* against pineapple mealy bug *Dysmicoccus brevipes*

Field evaluation of *Lecanicillium lecanii* against the pineapple mealy bug *Dysmicoccus brevipes* was carried out at the Pineapple Research Station of Kerala Agricultural University, Vellanikkara during December, 2015. The fungus *L. lecanii* @ 10^9 spores/ml was found to be as effective as Imidacloprid (0.3 ml/l) in reducing the root mealy bug after two rounds of spray.

C. Field evaluation of *Metarhizium anisopliae* formulations against mango hoppers

Three different formulations of *Metarhizium anisopliae* along with chemical and botanical insecticides were evaluated against mango hoppers at the Instructional farm of College of Horticulture, Vellanikkara during January 2016. Spraying with Imidacloprid @0.3ml/l recorded the lowest mean hopper population. Among the different formulations of *M. anisopliae*, the liquid formulation registered the lowest hopper count.

16. AINP on Pesticide Residues

The abstract of the results of trials conducted to develop GAP in following crops.

Sl. No	Crop	Pesticide	Formulation	Dosage (g ai./ha)	Initial conc. (mg kg^{-1})	Days to reach BDL	LOQ (mg kg^{-1})	Half life (days)
1	Bitter gourd	Acephate	Asataf 75SP	560	1.12	10	0.05	1.054
		Profenophos	Curacron 50 EC	500	0.29	5	0.05	0.653
		Chlorpyriphos	Radar 20EC	300	1.16	5	0.05	0.781
		Ethion	Tafethion 50EC	500	0.71	5	0.05	0.508
		Triazophos	Hostathion 40 EC	300	4.12	7	0.05	0.885
		Quinalphos	Ekalux 25 EC	250	0.31	3	0.05	0.173
		Imidacloprid	Confidor 200SL	20	0.72	7	0.05	0.684
		Carbendazim	Bavistin 50 WP	125	0.07	3	0.05	0.307
		Cypermethrin	Cymbush 10 EC	50	0.06	3	0.05	0.342
2	Cucumber	Acephate	Asataf 75SP	560	0.21	7	0.05	1.233
		Profenophos	Curacron 50 EC	500	0.48	7	0.05	1.120
		Chlorpyriphos	Radar 20EC	300	0.26	5	0.05	0.819
		Ethion	Tafethion 50EC	500	0.35	5	0.05	0.704
		Triazophos	Hostathion 40 EC	500	0.47	7	0.05	1.166
		Quinalphos	Ekalux 25 EC	250	0.10	5	0.05	0.799
		Carbendazim	Bavistin 50 WP	125	0.10	1	0.05	0.345
		Cypermethrin	Cymbush 10 EC	In progress				
3	Okra	Cypermethrin	Cymbush 10 EC	50	0.11	3	0.05	0.343
		Imidacloprid	Confidor 200SL	20	0.14	5	0.05	0.754
		Spiromesifen	Oberon 22.9%SC	125	0.23	3	0.05	0.215
4	Chilli	Bifenthrin		50	0.56	20	0.05	2.179
		lamdacyhalothrin	Karate 5 EC	15	0.34	20	0.05	2.520
		Spiromesifen	Oberon 22.9%SC	In progress				
5	Brinjal	Cypermethrin	Cymbush 10 EC	In progress				
		Imidacloprid	Confidor 200SL	In progress				
		Spiromesifen	Oberon 22.9%SC	96	0.27	7	0.05	3.719
6	Tomato	Quinalphos	Ekalux 25 EC	250	1.6	10	0.05	1.146
		Spiromesifen	Oberon 22.9%SC	125	0.14	3	0.05	0.285

17. Supervised field trial sponsored by M/s Bayer Crop Science India Ltd. Bangalore

Supervised field trial on Fluopyram + Tebuconazole on Chilli

The study on dissipation of residues of Fluopyram and Tebuconazole on chilli was carried out at the Vegetable Farm, Kalliyoor, Thiruvananthapuram, Kerala during December-2014 – March 2015. Fluopyram 200 + Tebuconazole 200 – 400 SC was sprayed in chilli plants at two concentrations, *i.e.* 100+100 g a.i./ha (X), and 200+200 g a.i./ha (2X). First spraying was done at the commencement of fruit setting stage followed by the second and third sprays at 10 days interval. Control plots were sprayed with water. The dissipation of residues in chilli was carried out from the date of the third application. Soil samples were analyzed at 20th day after the third application. The mean initial deposit of fluopyram at recommended and double the recommended doses were 0.15 and 0.55 mgkg^{-1}, respectively. The residues dissipated with time and reached below detectable level of 0.05 mg kg^{-1}within 15 days in recommended dose and 20 days in double the recommended dose. The mean initial deposit of tebuconazole at recommended and double the recommended dose were 0.51 and 1.55 mg kg^{-1}, respectively. The residues dissipated with time and reached below detectable level of 0.05 mg kg^{-1}within 25 days in both the doses. The half-life (days) estimated were 8.98, 7.03 days for fluopyram and 14.83, 12.97 days for Tebuconazole in chilli fruits at recommended and double the recommended doses, respectively. The residues of fluopyram and tebuconazole at the time of harvest in red chilli were below detectable level in both the doses.

Supervised field trial on Fluopyram 40 SC on Tomato

Fluopyram 400 SC was applied as soil drenching (twice) in tomato plants at two concentrations, *i.e.* 625 ml/ha (X), and 1250 ml/ha (2X) at the Instructional Farm, Vellayani, Thiruvananthapuram, Kerala during December-2014 – February 2015. First drenching was done on 22.12.2014 and second on 05-01-2015. Control plots were sprayed with water. The dissipation of residues in tomato was carried out from the date of the second application on 05-01-2015. The second crop was also raised at the same Vegetable Field, Vellayani, Thiruvananthapuram, Kerala. Drenching on second crop was carried out on 01-06-2015.Soil samples were analyzed at 15 days after the second application from both the seasons. The mean initial residues of fluopyram at recommended and double the recommended doses were BDL on 0th day itself and on all subsequent days of sampling. Residues detected in soil samples collected on 15th day after drenching of fluopyram were 1.2 and 2.3 µg/g for the first crop and 0.6 and 1.03 µg/g for the second crop, grown on the same field. Even though, the residues were below BDL on all samples of tomato, a half life of one day can be assigned on tomato fruits after drenching with fluopyram at both the doses.

Supervised field trial on Imidacloprid 350 SC on Chilli

Imidacloprid 350 SC was sprayed on chilli plants at two concentrations, *i.e.* 52.50 g. ai./ha (X), and 105 g. ai./ha (2X). First spraying of imidacloprid in chilli was done at fruit setting stage on 29-07-2015 followed by two sprays at 7 days interval at the Vegetable Farm, Shanthivila, Thiruvananthapuram, Kerala during June to August 2015. Control plots were sprayed with water. The study on the dissipation of residues in chilli was carried out from the date of the third application on 12-08-15. Soil samples were analyzed at 20 days after the third application. The mean initial deposit of imidacloprid in chilli at recommended and double the recommended dose were 2.13 and 5.64 mg kg^{-1} respectively. The residues dissipated with time and reached below detectable level of 0.05 mg kg^{-1}within 15 days in recommended and within 20 days in double the recommended dose. The mean residues of imidacloprid were 1.07, 0.88, 0.66, 0.28 and 0.13 mg kg^{-1} after 1, 3, 5, 7 and 10 days of spraying in recommended dose while in double the

recommended dose, the mean residues were 4.93, 2.79, 1.49, 0.87, 0.43 and 0.16 mg kg^{-1} after 1, 3, 5, 7, 10 and 15 days of spraying. The half life values of imidacloprid in chilli at recommended and double the recommended dose were 1.74 and 2.65 days respectively.

Supervised field trial on Spirotetramat 150 OD on Brinjal

The study on dissipation of residues of Spirotetramat in brinjal was carried out at the Vegetable Farm, Kalliyoor, Vellayani, Thiruvananthapuram, Kerala during January-2015 – March 2015. Spirotetramat was sprayed in brinjal plants at two concentrations, *i.e.* 90 g. ai./ha (X), and 180 g. ai./ha (2X). First spraying was done on 5-02-2015 followed by two sprays at ten days interval. Control plots were sprayed with water. The dissipation of residues in brinjal was carried out from the date of the third application on 25-02-15. Soil samples were analyzed at 15 days after the third application. The mean initial deposit of spirotetramat in brinjal fruits at recommended and double the recommended dose were 0.51 and 0.58 mg kg^{-1} respectively. The residues dissipated with time and reached below detectable level of 0.05 mg kg^{-1}within 15 days in both doses. The mean residues of spirotetramat were 0.31, 0.19, 0.16, 0.12 and 0.10 mg kg^{-1} after 1, 3, 5, 7 and 10 days of spraying in recommended dose while in double the recommended dose, the mean residues were 0.32, 0.29, 0.19, 0.14, and 0.10 mg kg^{-1} after 1, 3, 5, 7 and 10 days of spraying. The residues dissipated with time and reached below detectable level of 0.05 mg kg^{-1}within 15 days in both doses. However, the residues of spirotetramat enol was not present in any of the sample. The half life values of spirotetramat in brinjal at recommended and double the recommended dose were 4.53 and 4.25 days respectively. The mean residues of spirotetramat in soil collected at 15^{th} day after third application was below detectable level of 0.05 mg kg^{-1}at the recommended and double the recommended dose.

Supervised field trial on Acephate 50% + Imidacloprid 1.8% SP (Lancer Gold) on Okra

The study on dissipation of residues of Lancer Gold (Acephate and Imidacloprid) on okra was carried out at the Vegetable Farm, Vellayani, Thiruvananthapuram, Kerala during December 2014 to March 2015. Lancer gold was sprayed in okra plants at two different concentrations, *i.e.* 1000 g/ha (500+18 g a.i.) (X dose) and, 2000 g/ha (1000+36 g a.i.) (2X dose). First spraying was done at the onset of fruiting and the second on 10 days after the first application and control plots were sprayed with water. The dissipation of residues in okra was carried out from the day of the second application. Soil samples were analyzed at time of final harvest. The mean initial deposits of Acephate at recommended and double the recommended dose were 0.60 and 1.17 mgkg^{-1}, respectively (at 0 DAA). The residues dissipated with time and reached below detectable level of 0.05 mg kg^{-1} within 5 days in the recommended dose and 7 days in the double the recommended dose. The mean initial deposit of Imidacloprid at recommended and double the recommended dose were 0.07 and 0.12 mg kg^{-1}, respectively (at 0 DAA). The residues dissipated with time and reached below detectable level of 0.05 mg kg^{-1} within 3 days in recommended dose and 5 days in double the recommended dose. The mean initial deposit of Methamidophos (metabolite of Acephate compound) at recommended and double the recommended dose were 0.04 and 0.08 mg kg^{-1} respectively (at 0 DAA). The residues dissipated with time and reached below detectable level of 0.01 mg kg^{-1} within 3 days in recommended dose and 7 days in double the recommended dose. Residues of insecticides and their isomers in soil collected at the time of final harvest are below detectable level. The half-life (days) were Acephate (2.08, 3.78), Imidacloprid (0.307, 2.27) and Methamidophos (0.99, 4.70) in okra at recommended and double the recommended dose respectively.

Supervised field trial on Acephate 50% + Imidacloprid 1.8% SP (Lancer Gold) on Paddy

In order to find out the harvest residue of Acephate and Imidacloprid in Paddy grain, husk, straw & cropped soil, five field trials were conducted at different locations viz. College of Agriuculture, Vellayani, Kerala, G. B. Pant University of Agriculture & Technology, Pantnagar, University of Agricultural Sciences, Raichur, National Institute of Biotic stress Management, Raipur and Odisha Agriculture University, Odisha, based on the agro-climatic zone variation.

Harvest samples of paddy grain, husk, straw & cropped soil were collected from the field where foliar spray was done with three foliar sprays with Acephate 50% + Imidacloprid 1.8% SP (Lancer gold) at two doses, recommended dose T_1= 1000 g /ha (500 + 18.0 g a.i./ha) and double the recommended dose T_2= 2000 g /ha (1000.0 + 36.0 g a.i./ha) along with untreated control (T3) in every location. Samples from all five locations were collected at harvest and received under dry ice condition for analysis. Received samples were analyzed at AINP on Pesticide Residue, Kerala Agricultural University, College of Agriculture, Vellayani, Kerala. No residue was found in paddy grain, straw, husk and cropped soil at harvest from the samples of all five locations.

The study on persistence of Lancergold (Acephate 50% + Imidacloprid 1.8% SP) in/on paddy plant, study was carried out at the Cropping System Research Station, Karamana, Thiruvanathpuram during November 2014- February 2015. Acephate 50% + Imidacloprid 1.8% SP (Lancer gold) was sprayed at two doses, recommended dose T1= 1000 g a. i. /ha (500 + 18.0 g a.i./ha) and double the recommended dose T2= 2000 g a. i. /ha (1000.0 + 36.0 g a.i./ha) along with untreated control (T3) First spraying was done on 06.12.2014 and second on 16.12.2014. Control plots were sprayed with water only. The persistence of residues in paddy was carried out from the day of the second application.

The mean initial deposit of acephate at recommended and double the recommended dose were 0.94 and 1.78 mg kg^{-1}, respectively. The residue dissipated with time and reached below detectable level of 0.07 mg kg^{-1} within 3 days in the recommended dose as well as in double the recommended dose. The mean initial deposit of methamidophos (a metabolite of Acephate) at recommended and double the recommended dose were 0.12 and 0.21 mg kg^{-1}, respectively. The residue dissipated with time and reached below detectable level of 0.01 mg kg^{-1} within 3 days both in the recommended and double the recommended dose. The mean initial deposit of Imidacloprid at recommended and double the recommended dose were 0.09 and 0.19 mg kg^{-1}, respectively. The residue reached below detectable level of 0.05 mg kg^{-1} after first day of spraying in the recommended and after third day in double the recommended dose.

The half life (days) were acephate (0.39, 0.51), imidacloprid (-, 0.54) and methamidophos (0.45, 0.84) at recommended and double the recommended dose, respectively.

Supervised field trial on UPI 1810 on Paddy

In order to find out the multi-location harvest residues of UPI 1810 (Fipronil and Flonicamid) in Paddy grain, husk, straw & cropped soil, five field trials were conducted at different locations viz. College of Agriculture, Vellayani, Kerala, G. B. Pant University of Agriculture & Technology, Pantnagar, University of Agricultural Sciences, Raichur, National Institute of Biotic Stress Management, Raipur and Odisha Agriculture University, Odisha based on the agro-climatic zone variation. Harvest samples of paddy grain, husk, straw & cropped soil were collected from the field where foliar spray was done with UPI 1810 (Flonicamid 15% + Fipronil 15% WDG) at two doses, at recommended dose T1= 400 g/ha (60 + 60 g a.i./ha) and at double the recommended dose T2= 800 g/ha (120.0 + 120.0 g a.i./ha) along with untreated control (T3) in every location and received under dry ice condition for analysis. Received samples were analyzed at AINP on Pesticide Residue, Kerala Agricultural University, College of Agriculture,

Vellayani, Kerala. No residue was found in paddy grain, straw, husk and cropped soil collected at harvest from the samples of all five locations. UPI 1810 was sprayed in paddy plants at two doses, at X dose =400g/ha (60 + 60 g a.i./ha) and at 2X dose = 800g/ha (120.0 + 120.0 g a.i./ha). First spraying was done on 04.12.2014 and second on 19.12.2014 at the Cropping System Research Station, Karamana, Thiruvanathpuram during November 2014- February 2015. Control plots were sprayed with water only. The persistence of residues in paddy was carried out from the day of the second application. The mean initial deposit of flonicamid at recommended and double the recommended dose were 0.39 and 0.82 mg kg^{-1}, respectively. The residue dissipated with time and reached below detectable level of 0.05 mg kg^{-1} within 3 days in the recommended dose and within 5 days in double the recommended dose. The mean initial deposit of fipronil at recommended and double the recommended dose were 2.70 and 3.60 mg kg^{-1}, respectively. The residue dissipated with time and reached below detectable level of 0.01 mg kg^{-1} within 10 days both in the recommended and double the recommended dose. The half life (days) were flonicamid (0.33, 0.81) and fipronil (3.91, 5.19) at recommended and double the recommended dose, respectively.

In order to find out the multi-location harvest time residues of UPH 814 (Pyrazosulfuron Ethyl 0.75% + Pretilachlor 30% WG) in rice grain, husk, straw & cropped soil, field trials were conducted for two seasons (Kharif 2014 and Kharif 2015) at three different locations *viz*. 1. G. B. Pant University of Agriculture & Technology, Pantnagar; 2. Orissa University of Agriculture and Technology, Odisha and 3. National Institute of Biotic Stress Management, Raipur, based on the agro-climatic zone variation. Harvested samples of paddy grain, husk, straw & cropped soil were collected from the field where foliar spray was done with UPH 814 at two doses, at recommended dose T1= 2000 g/ha (15 + 600 g a.i. /ha) and at double the recommended dose T2= 4000 g/ha (30.0 + 1200.0 g a.i. /ha) along with untreated control (T3) in every location and received under dry ice condition for analysis. The samples were analyzed at AINP on Pesticide Residue, Kerala Agricultural University, College of Agriculture, Vellayani, Kerala. UPH 814 residues were found Below Detectable Limit (BDL) irrespective of substrates (paddy grain, straw, husk and cropped soil) and dosage at all three locations in both the seasons.

Supervised field trial on UPH-814 on Paddy

The field study on persistence of Pyrazosulfuron Ethyl and Pretilachlor after application of UPH 814 (Pyrazosulfuron Ethyl 0.75% + Pretilachlor 30% WG) on paddy was carried out at the Cropping System Research Station, Karamana, Thiruvananthapuram, Kerala during December 2015 to February 2016. UPH 814 was sprayed in paddy plants at two doses, at recommended dose T1= 2000 g/ha (15 + 600 g a.i. /ha) and at double the recommended dose T2= 4000 g/ha (30.0 + 1200.0 g a.i. /ha). Spraying was done on 22/01/2016. Control plots were sprayed with water only. The persistence of residues in paddy was carried out from the day of the second application at AINP on Pesticide Residue, Kerala Agricultural University, College of Agriculture, Vellayani, Kerala.

The mean initial deposit of Pyrazosulfuron Ethyl at recommended and double the recommended dose were 0.18 and 0.48 ppm, respectively. The residue dissipated with time and reached below detectable level of 0.01ppm within 3 days in the recommended dose and 4 days in double the recommended dose. The mean initial deposit of Pretilachlor at recommended and double the recommended dose were 8.84 and 15.50 ppm, respectively. The residue dissipated with time and reached below detectable level of 0.05 mg kg^{-1} within 15 days both in the recommended and

double the recommended dose. The half-life (days) were Pyrazosulfuron ethyl (1.293, 1.795) and Pretilachlor (1.877, 1.372) at recommended and double the recommended dose, respectively.

18. Strengthening the NABL Accredited Pesticide residue laboratory to the status of a state referral lab.

Established full-fledged ISO 17025:2005 accredited Pesticide Residue Testing Laboratory to monitor pesticide residues in food & agricultural commodities and Development of Trained personnel for establishing such laboratories throughout the state. Purchased and installed state of art equipments *viz*. LC MS/MS (Triple Quad), GC MS/MS and FT-IR and the laboratory recorded considerable progress during the period in terms of state of art equipments and infrastructure facilities.

19. Production and Marketing of 'Safe to Eat' vegetables, fruits and food products for sale through Govt. outlets-KAU Plan

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, Spencers, Reliance fresh, Niligiris, Chala market, Agricultural wholesale market (Urban and Rural), Eco shops under Krishi Bhavans, organic vegetable shops (Aroma fresh Nandancode, Aroma fresh Kesavadasapuram, Aroma fresh Sasthamangalam, Jaivasree Thycaud, Welgate Kowdiar), and other local markets in Trivandrum, Kasargod, Alappuzha, Pathanamthitta, Idukki, Kollam, Kottayam, Kozhikode, Malappuram, Palakkad and Waynad districts. Total number of 1855 samples were analysed during April 2015 to March 2016 and the results were published in the official web portal of Govt. of Kerala.

Data on the extent of pesticide contamination in vegetables collected from markets and farmgate clearly showed that, out of 1090 vegetable samples 93 samples (8.5%) were contaminated with pesticides in which 21 samples (1.9%) were under unsafe category. Data on the extent of pesticide contamination in fruits collected from markets clearly howed that, out of 192 fruit samples only 8 samples (4.2%) were contaminated with pesticides in which none of them exceeded MRL fixed by FSSA, indicating fruits in general are safe for consumption. Data on the extent of pesticide contamination in spices and condiments collected from markets clearly showed that, out of 466 samples 76 samples (16.3%) were contaminated with pesticides in which 6 samples (1.3%) were under unsafe category, as they exceeded MRLs(FSSAI). Data on the extent of pesticide contamination in dry fruits collected from markets clearly showed that, out of 51 dry fruit samples only 2 samples (3.9%) were contaminated with pesticides in which none of which were under unsafe category. A total of 56 food product samples were collected and analyzed from various markets in Kerala showed no contamination of pesticide residues.

Overall analysis of the data generated during the period under report (April 2015 to March 2016) revealed that out of 1855 samples of food commodities tested, 179 samples (9.6%) were contaminated with pesticides in which 27 samples (1.5%) were under unsafe category. Transfer of technology of Veggie Wash household products to remove insecticide residues from vegetables was continued during the period under report and 45 entrepreneurs were given permission and training.

20. Nematode biodiversity, identification of hotspots and pest free areas for economically important plant parasitic nematodes in the country - All India Co ordinate Research Project on Nematodes in cropping systems

Documentation and occurrence of hot spots for economically important plant parasitic nematodes in the country revealed the following. In Pepper and Cardamom Rajappara and Kailasapara in Idukki District were identified as a new hot spot for *M. incoginta*. Maryoor area in Idukki district is identified as a hot-spot area of infesteation of *M.incognita* in cowpea and carrot while Thirupuram in Trivandrum district is identified as hot-spot area of infestation of root-knot nematode in bitter gourd. In banana the new hot-spot area of infestation of *M.incognita* were identified Aluva, Vlathankara and Marayoor in Ernakulam, Trivandrum and Idukki districts respectively. In Vattavada, *M.incognita* recorded a population of 253 J_2/ 200 cc soil and 135 nematodes / 5 g roots in cabbage. *M. incognita* was the important nematode associated with cauliflower grown in Vattavada area of Idukki district with a population of 235 J_2 / 200 cc soil and 200 nematodes / 5 g roots. Other nematodes were *R. reniformis* with a population of 85 nematodes / 200 cc soil and 32 nematodes / 5 g roots. The nematode species encountered in polyhouses irrespective of crops grown were reniform nematode - *R. reniformis,* root-knot nematode - *M. incognita,* spiral nematode - *Helicotylenchus* sp. and free living nematodes.

21. Impact of economically important nematode population in identified hotspots on crop yield and estimation of avoidable yield loss in experimental plot under different agro –climatic conditions.

The study on impact of economically important nematode population on crop yield from the identified hot-spot areas revealed that the avoidable yield loss due to *M.incognita* was 20.48% and percentage increase in yield was 25.75 in tomato, in cowpea it was 18.78 and 23.14% .In cucumber avoidable yield loss was 23.14% and percentage increase in yield was 30.11. In chilli, the avoidable yield loss was 16.85% and percentage increase in yield was 20.22. In paddy due to *M.graminicola* the avoidable yield loss was estimated 29% as against 56.3% in experimental area.

The methods for the estimation of quantitative loss in paddy due to *M.graminicola* was standardized with respect to phenol content in leaf, starch , protein ,reducing and non reducing sugar content in grain .

Confirmation and evaluation of resistant varieties of rice

Forty three rice cultivars were screened to assess their reaction against rice root knot nematode *Meloidogyne graminicola.* including the highly susceptible check TN1. Among the lines tested A-2-14-27 and GM-14-32 were found highly resistant. A1-14-02, A1-14-04, A1-14-05, A1-14-06, A1-14-13, A1-14-14, A2-14-19, A2-14-23, A2-14-25, A2-14-28, GM-14-31, GM-14-34, GM-14-35, GM-14-37, GM-14-38 and GM-14-39 found resistant.

Management of root-knot nematode (*Meloidogyne graminicola*) in rice

A management trial was taken up in paddy infested with rice root knot nematode with six treatments (Carbofuran and carbosulfan @ 1kg ai/ha, *Paecilomyces lilacinus, Bacillus macerans, Trichoderma viride* and *Pseudomonas fluorescens* @ 20g/m^2) and an untreated check.. Carbofuran 1 kg a.i/ha recorded minimum galls in root sample (22/5 g) followed by *P. lilacinus* (25/5g). The effect of carbofuran was on par with carbosulfan in reducing the nematode population and increasing the yield. Among the bio control agents *P. fluorescens* @ 20g/m^2 was

the most effective treatment in reducing the population of nematode in soil (271/ 200cc) and was on par with *T. viride* and *B. macerans* treatments.

Screening, confirmation and field evaluation of promising germplasms of vegetable crops against root –knot and reniform nematode

104 accessions of okra were screened to assess their reaction against root-knot nematode. EC-169511, IC-117020, IC-117079, IC-117093, IC-117095, IC-117238,IC-117256, IC-117262, IC-117268, IC-117298, IC-117321, IC-117324, IC-117329 and IC-117333 were found resistant.

Among 170 accessions of brinjal IC-090869, IC-090905 and IC-099676 were found resistant. EC-316226, EC-316242, EC-316275, EC-329327, EC-379244, EC-384565, EC-467271, IC-089818, IC-089888, IC-090053, IC-090160, IC-090777, IC-090785, IC-090811, IC-090915, IC-090931, IC-090938, IC-090942, IC-112993, IC-350885, IC-354562, IC-374888, IC-545854 were found to be moderately resistant.

Evaluation of biopesticides for the management of root knot nematodes (*Meloidogyne spp*) in transplanted vegetable crop (Brinjal).

Demonstration trial on the application of the bio agent *Paecilomyces lilacinus* (cfu 2x 10^6) @ 50g/m^2 in nursery bed (0.5 tons/ha) + *P. lilacinus* (cfu 2x 10^6) @ 5kg along with 2.5 tons of FYM per ha in the main field prior to planting suppressed the nematode population (88.86 per cent reduction over untreated) and increased the yield of brinjal in location 1 and 77 % reduction in population and 20 % increase in yield over untreated in location 2.

Management of root-knot nematodes in pepper

The potential of bioagents *Pseudomonas fluorescens, Bacillus macerans, Trichoderma viride, Trichoderma harzianum* and *Pochonia chlamydosporia* @ 20 g per plant in pepper was evaluated with neemcake 200g/ plant as check. The results revealed that nematode population in root in terms of root-knot (galls) was reduced significantly by *P. fluorescens* (56.6%) followed by *B. macerans* (51.4%) and were on par. Maximum yield increase was recorded in *P. fluorescens* (45.34%) followed by *B. macerans* (37.56%) and were on par. Biological control of root-knot nematode in pepper can be achieved by application of either *P. flourescens* or *B. macerans* @ 20 g/plant

Management of nematodes on banana by using bioinoculants

Application of the bio agent *Trichoderma viride*@ 20 g/ m^2 in banana pits at the time of planting suppressed the nematode population (70 % reduction over untreated) and increased the yield in location 1. In location 2, soil application of *T. viride* @ 20 g reduced the nematode population and increased the yield of banana.

Biofumigation for the management of nematodes in banana

Biofumigation with crop residues of cabbage and cauliflower @5kg/pit found significantly effective in reducing nematode population in banana rhizosphere and increasing the yield. Maximum reduction in soil nematode population was observed in biofumigation using crop residues of cauliflower@ 5kg/pit and the effect of this was statistically on par with biofumigation using crop residues of cabbage @ 5kg/pit and check treatment (Paring + Hot water treatment

55^0c for 20 min + neem cake @ 500g/plant). In the case of root-knot count and nematode population in root similar trend was observed. Effect of biofumigation with crop residues of cauliflower was statically on par with check treatment in reducing the number of lesions in root and rhizomes giving 55 to 64 per cent reduction over the untreated. The reduction in nematode population due to biofumigation using crop residues of cauliflower and cabbage directly reflected in the biometric characters and yield of banana. Highest bunch weight (9.50kg) was recorded by check treatment and it was statistically on par with biofumigation using crop residues of cauliflower (9.41 kg).

Management of major nematode pests of cardamom

Management trial on nematodes in cardamom using cartap hydrochloride, thiamethoxam, wild sunflower leaves, *P. lilacinus, B. macerans* and carbosulfan as check treatment was taken up using the variety Njallani. Application of Carbosulfan 6G@1kg a.i/ha was effective treatment for managing nematode in cardamom. Among the biocontrol agents, *B. macerans* ($1x10^7$ cfu 50g/plant) and *P. lilacinus* ($1x10^7$ cfu 50g/plant) were effective in increasing the plant growth with significant reduction in nematode population. Percentage reduction of *M. incognita* population in soil was to a tune of 70.87 per cent at 6 month after treatment. Comparing the two bioagents, *B. macerans* was found to be statistically superior in reducing the nematode population as well as improving the biometric characters and yield.

Comparative effect of mulching, biofumigation and application of organic manures for the management of nematodes in the rhizosphere of banana/ grapes

Mulching with green and dry leaves of glyricidia, bio-fumigation with green leaves of glyricidia and chopped leaves of banana were compared using neem cake as check treatment. Highest population of free living nematode was recorded in plants treated with chopped leaves of banana at vegetative and flowering stages of banana. Lowest population of plant parasites was observed in bio fumigation with green leaves of glyricidia followed by application of neem cake @500 g/plant and the effect of these two were statistically on par at vegetative and flowering stages of banana. At harvest lowest number of plant parasites was recorded in bio fumigation using green leaves of glyricidia followed by application of neem cake and bio fumigation with chopped leaves of banana and the effect of these three treatments were statistically on par. The percentage reduction in nematode population in these treatments ranged from 79 to 83 per cent. Similar trend was observed in the case of nematode population in root. Lowest number of galls (13/5g root), lesions in root (10/5g root) and rhizomes (10 per 10 g rhizome) was recorded in bio fumigation using green leaves of glyricidia and it showed statistically significant variation from other treatments.

Cordinated Trial on Exploitation of Potential Biocontrol Agents (BCA) from Different Agro-Climatic Regions of India

Biocontrol activity of *Bacillus* isolates from egg masses of root-knot nematode infected chilli plants was assayed against root-knot nematode by egg hatching and mortality tests. One isolate showed 100% egg hatch inhibition and juvenile mortality . 16SrRNA sequencing of the isolated strain showed 99% identity with *Bacillus thuringiensis* and deposited in NCBI as *Bacillus thuringiensis* strain. NMS- KAU with accession number KP 938773.1.

22. Management of *Oligonychus oryzae* - All India Network Project on Agricultural Acarology

Fourteen days after spray treatment, fenazaquin recorded the highest reduction in mite population. However, all the four novel acaricide molecules; fenazaquin, spiromesifen, fenpyroximate and propargite reduced the population of *O. oryzae* significantly from 3rd day after spray application onwards. The efficacy of wettable sulphur though was significantly inferior to novel acaricide molecules up to seven days of treatment, it was found to be on par with those molecules 14 days after treatment. The efficacy of azadirachtin was found to be superior to neem oil. However, the botanicals were inferior to all other treatments though significantly reduced mite population over untreated control. The study identified a number of novel acaricide molecules namely, fenazaquin, spiromesifen, fenpyroximate and propargite for the effective management of rice leaf mite.

Evaluation of *Acremonium zeylanicum* against *T. truncatus*

For the study, culture of *T. truncatus* has been established in the laboratory on mulberry leaves placed on wet sponge in plastic trays. Virulence of the fungal isolate, *Acremonium zeylanicum* is being maintained by periodically passing on the host, *T. truncatus* followed by, reisolation and culturing on PDA media. The study is progressing

Evaluation of *N. longispinosus* against *T. urticae* on cucumber

The feeding potential of the deutonymph and adult *N. longispinosus* was evaluated in the laboratory separately on the egg and active stage of *T. urticae* at five different prey densities of 10, 15, 20, 25, 30, 40 an 50 for 24 hours duration. The results showed that the adult *N. longispinosus* consumed more prey compared to the deutonymph. Both stages consumed more eggs of *T. urticae* compared to the active stages of the mite at all prey densities. The study clearly indicated that the predator has significantly higher preference towards eggs at all prey densities tested.

Management of banana leaf mite

The results revealed that the two novel acaricide molecules namely, Fenazaquin and Spiromesifen and also wettable sulphur effectively managed the mite population in banana in farmers' fields. In all the three trials, spiromesifen 240 SC recorded the highest percent reduction in mite population over untreated control. Based on the results of the farm trials, it is suggested that the following acaricides can be recommended against banana leaf mite.

Fenazaquin 10 EC at 125g a.i/ha (2.0 ml per litre of water)
Spiromesifen 240 SC at 70-100g a.i/ha (0.8 ml per litre of water)
Micronised wettable sulphur 80 WP (3g per litre of water).

Management of arecanut leaf mite

The results of the study are Fenazaquin was the superior acaricide which resulted in significant reduction in mite population from three days after treatment. A total reduction in mite population was recorded from seven days after fenazaquin treatment. The efficacy of spiromesifen was found to be on par with fenazaquin from seven days after treatment.

Diversity of predatory mites associated with major vegetable crops of Kerala

A purposive survey was undertaken to explore the mite fauna associated with the vegetable crops viz. amaranthus, brinjal, bhindi, bittergourd, chilli, cowpea, coccinia, cucumber,

snakegourd and snap melon from major vegetable growing tracts of Thrissur district, Kerala. A total of 17 species of predatory mites belonging to six families were encountered. The predatory mite families included Phytoseiidae, Stigmaeidae, Cunaxidae, Bdellidae and Tydeidae. represented by the genera *Neoseiulus, Amblyseius, Typhlodromips, Euseius, Paraphytoseius, Phytoseius, Scapulaseius, Agistemus, Cunaxa, Bdella, Tydeus and Pronematus*. The associated phytophagous prey mite families recorded were Tetranychidae, Tenuipalpidae and Tarsonemidae represented by the genera *Tetranychus, Eutetranychus, Brevipalpus and Polyphagotarsonemus.*

Faunal studies revealed highest diversity of mites on brinjal comprising eighteen species of five different families, of which 9 species belonging to the family Phytoseiidae and the least diversity on coccinia, cucumber, snap melon and snakegourd with five species.

Phytoseiid mites were found to be the most common predators in the vegetable fields of Thrissur district, Kerala. Among the Phytoseiid mites, *Neoseiulus longispinosus* was the predominant species recorded in association with phytophagous mites in all vegetable fields. Other species were *A. paraaerialis, A. largoensis, E. macrospatulatus, Euseius* sp. *nr. prasadi, T. syzygii, P. orientalis, P. intermedius and Scaplaseius* sp. Occurence of *Euseius* sp. nr. *prasadi* and *P. intermedius* are new reports for Kerala.

Predatory mites, Cunaxa sp. of to the family Cunaxidae and Bdella khasyana of the family Bdellidae were found in association with P.latus in chilli and Tetranychus sp. in cowpea and snap melon. *Bdella khasyana* is a new report for Kerala.

Four species of stigmaeids viz., *Agistemus gamblei*, *A. fleschneri*, *A. garrulus* and *A. macrommatus* were recorded on bhindi, bitter gourd, brinjal, chilli and snake gourd. Occurence of *A. fleschneri, A. garrulus* and *A. macrommatus* are new reports for Kerala.

The predatory mites *T. gossabaensis* and *P. anconai* of the family Tydeidae were found to be associated with phytophagous mites *T. macfarlanei*, *B. phoenicis* and *P. latus* in amaranthus, bhindi, brinjal, chilli, cowpea and snake gourd. Both the predatory mites are new.

Molecular characterization of tetranychid mites associated with major crop plants of Kerala

Extensive surveys are being conducted in the mite infested fields of rice, banana, vegetables, arecanut and spice crops from different districts of Kerala. Isolines of different spider mites collected as pure cultures are being maintained in the laboratory for further morphological and molecular characterization. The study is progressing.

23. Consortium Research Platform (CRP) on Borers in Network Mode

A roving survey was conducted in three districts of Southern Kerala *viz.*, Thiruvananthapuram, Kollam, Pathanamthitta, for the collection of borers in 2015.

About 16 species of cerambicid borers belonging to family cerambicidae and three subfamilies, *viz*., Lamiinae cerambicinae and prioninae were found to occur in the surveyed area. 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.

In the survey conducted covering homesteads of southern Kerala *Odoiporus longicollis, Cosmopolites sordidus, Rhynchophorus ferrugenius, Batocera rufomaculata* and *B.rubus* were found as major pests in banana, coconut, mango ,jack and moringa. In vegetables Bhindi shoot and fruit borer, *Earias vitella*, Brinjal shoot and fruit borer *Leucinodes orbonalis* and Amaranthus weevil *Hypolixus trunculatus* were found as serious pests.*Batocera rufomaculata* (F.) in addition to the host like mango, jack, and cashew was found to be in close association with the important perennial crop, *Moringa oleifera* and was found to cause significant damage to the crop.

Study of IPM in snake gourd revealed that damage caused by the insect pest *Diaphania indica* to the crop snake gourd was reduced significantly in the plots treated with biopesticides Dipel 1ml/l and insecticide chlorantraniliprole @ 0.3ml/l.

Damage caused by the insect pest *Earias vitella* to the crop bhindi was reduced significantly in the plots treated with biopesticides Dipel @ 1ml/l, *Metarhizium anisopliae* @ 30g/l and insecticideand Malathion 50 EC@ 2ml/l.

Among the biopesticides and insecticides treated against the shoot and fruit borer *Leucinodes orbonalis* of brinjal, biopesticide *Bacillus thurungensis* @1.0ml/l and insecticide Fipronil @ 2ml/l were found effective against the pest.

The survey and monitoring reveals that cerambycidae beetles are serious pest of horticultural crops. Sixteen cerambycidae beetles and five curculionidae beetles were identified and documented during the survey period. About sixteen species of cerambicid borers belonging to family cerambicidae and three subfamilies, *viz*., Laminae cerambicinae and prioninae were found to occur in the surveyed area .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 belong to subfamily lamiinae and ,family cerambycidae, are reported for the first time in Kerala, through our studies.

In the survey conducted covering homesteads of southern Kerala *Odoiporus longicollis, Cosmopolites sordidus, Rhynchophorus ferrugenius, Batocera rufomaculata* and *B.rubus* were found as major pests in banana, coconut, mango, jack and moringa

In vegetables, Bhindi shoot and fruit borer, *Earias vitella*, Brinjal shoot and fruit borer *Leucinodes orbonalis* and Amaranthus weevil *Hypolixus trunculatus* were found as serious pests *Batocera rufomaculata* (F.) in addition to the host like mango, jack, and cashew was found to be in close association with the important perennial crop, *Moringa oleifera* causing significant damage to the crop. Preliminary study revealed that the herbal repellent of IIHR is working well against the pest for reducing the severity of damage.

Results of the field trials revealed that the damage caused by the insect pest *Diaphania indica* to the crop snake gourd was reduced significantly in the plots treated with biopesticides and insecticides compared to the untreated plots. The analysed data revealed that among the treatments, biopesticide Dipel 1ml/l and insecticide chlorantraniliprole @ 0.3ml/l were found effective against the pest. The yield was also significantly high in these plots.

Damage caused by the insect pest *Earias vitella* to the crop bhindi was reduced significantly in the plots treated with biopesticides and insecticides compared to the untreated plots. Among the treatments, biopesticides Dipel @ 1ml/L and *Metarhizium anisopliae* @ 30g/L and insecticide Malathion 50 EC@ 2ml/L were found effective. The yield was also significantly high in these plots compared to the untreated plot.

Among the biopesticides and insecticides treated against the shoot and fruit borer *Leucinodes orbonalis* of brinjal biopesticide *Bacillus thurungensis* @1.0ml/L and insecticide Fipronil @ 2ml/L were found effective against the pest. The yield was also significantly high compared to the other treatments and control plot.

The studies are to be continued for exploring the distribution coexistence of these pests in the ecosystem and to evolve suitable management practices.

24. Bioefficacy of the acaropathogen, *Acremonium zeylanicum* (Petch) Gams and Evans against the spider mite, *Tetranychus truncatus* Ehara (Acari: Tetranychidae)

Literature relevant to research topic has been exhaustively reviewed. Culture of *Tetranychus truncatus*is being maintained in Acarology laboratory on excised mulberry leaves placed on wet sponge lined with cotton in plastic trays. Predatory mite culture of *Neoseiulus longispinosus*is also being maintained in laboratoryon prey mite culture *Tetranychus truncatus*. To maintain the virulence of fungal isolate, *Acremonium zeylanicum* was periodically passed on the natural host *Tetranychus truncatus*, re isolated, cultured in PDA media and maintained in the laboratory.

25. Characterization of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), for genetic variability, endosymbionts and vector-virus interactions in cassava

Surveys were conducted in different agro-ecological zones of Kerala and collected whitefly 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.

Morphological characterization

Morphological characters of pupal stage especially the characteristics of vasiform orifice and anterior wax margin were measured from the laboratory reared insects. Other characters of adults *viz*., body size, number of antennal segments, size of the hind tarsus and genitalia were also studied. Observations were carried out under microscope with image analyser (Leica^{TM}).

Vector- virus interaction

Cassava plants with varying degree of responses to virus infection were used in the study.

1. Known susceptible - H-226, Sree visakham
2. Purposefully virus infected susceptible
3. Infected but recovering - CMR-1, CMR-102 and
4. Known resistant varieties – CMR-9, CMR 128 to study the vector-virus interaction. 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 lifecycle. Data compilation and statistical analysis are going on.

Study of genetic variation using screened ISSR primers

The isolated DNA samples from whiteflies were used for the purpose. Total 35 ISSR primers were used for screening and 10 primers found to be promising. Analysis of genetic variation using NTSYS software is going on.

26. Diversity of leafhopper fauna in rice and vegetable ecosystems

A total of 17 species of leafhoppers belonged to three subfamilies and eight tribes, and 12 genera and an unidentified species belonging to the tribe Erythroneurini were collected. Nine species of leafhoppers collected from rice ecosystem belonged to two subfamilies, Cicadellinae (Tribe: Cicadellini- one genus, two species) and Deltocephalinae (Tribe:Chiasmini – two genus, three species, Deltocephalini- one species, Hecalini- one genus, two species and Stenometopiini- one species) were collected from rice ecosystems of Thrissur district. Out of these, seven species namely, *Cofana spectra* (Distant), *Cofanalineata* (Distant),*Nephotettixnigropictus* (Stal), *N. virescens* (Distant), *Exitianusindicus* (Distant), *Maiestasdorsalis* (Motschulsky) and *Hecalusporrectus* (Walker), *Hecaluslutescens* (Distant) and *Doratulinajacosa*Melichar were collected from the weed *Eragrostistenella.* Occurrence of *Hecaluslutescens* (Distant) in rice ecosystem is a new report for Kerala.

Eight species of leafhoppers were collected from vegetable ecosystem. Collections were made from the crops, brinjal, bhindi, bitter gourd, cowpea, ash gourd and lab lab bean. The species of leafhoppers collected from vegetable ecosystem are, *Kollaceylonica* (Melichar) (Cicadellinae: Cicadellini) from brinjal, bhindi and cowpea , *Hishimonusphycitis* (Distant) (Deltocephalinae: Opsiini) from brinjal, *Amrascabiguttulabiguttula* (Ishida) (Typhlocybinae: Empoascini) from brinjal and bhindi, *Empoasca (Empoasca) kerri*Pruthi (Typhlocybinae: Empoascini) from cowpea, *Empoasca (Empoasca) motti*Pruthi (Typhlocybinae: Empoascini) from bitter gourd, *Serianajaina* (Distant) (Typhlocybinae: Erythroneurini) from cow pea, *Tautoneura (Tautoneura) mayarami* Mathew and Ramakrishnan (Typhlocybinae: Erythroneurini) from lab lab bean and an unidentified Erythroneurine leafhopper from ash gourd and brinjal . The infestation of *Kollaceylonica*(Melichar) is a new report for Kerala in bhindi, brinjal and cow pea.

Morphometric studies of the leafhoppers were carried out and a dichotomous taxonomic key was prepared for the identification of species collected during the present study.

27. Population dynamics, biology and management of mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on okra

Preliminary survey was conducted during first week of April, 2016 in Palakkad and Thrissur districts for cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae). Mealybugs collected and reared under laboratory condition on pumpkin.

28. Bionomics and management of root mealy bugs on black pepper

A preliminary survey was conducted during 2013-14 in different panchayaths of Wayanad and Idukki districts to collect the root mealybugs on black pepper.The root mealybug samples collected from the infested pepper gardens were identified by the coccidologists of NBAIR, Bangaluru. The identification results showed that three species of root mealybugs namely, *Formicococcus polysperes*Williams, *Dysmicoccus brevipes* (Cockerell) and *Pseudococcus* sp. were found to be infesting black pepper.

Highest per cent of infestation was observed on Panniyur 1 variety. With respect to the standard used, vines trailed on *Erythrina* sp. and *Graviella robusta* was observed with highest per cent infestation in Wayanad and Idukki districts, respectively. In Wayanad, vines of four to six years was found to be highly infested whereas in Idukki highest infestation was on vines of seven to nine years age.

During the survey, the infested roots were examined thoroughly for the presence of natural enemies and coccinellid grub (*Horniolus* sp.) was observed to be predating on the root mealybugs.

Ant colonies were collected from the rhizosphere of infested vines and four ant species *viz.*, *Anoplolepis gracilipes* Smith, *Crematogaster rogenhoferi* Mayr, *Lophomyrmex quadrispinosus* Jerdonand *Paratrechina* sp. were found to be associated with the root mealybug colonies.

Population dynamics of root mealybugs was studied in an infested pepper garden in Mananthavady panchayath of Wayanad district, and showed that highest root mealybug population was in December 2015 (13.31 mealybugs/15 cm root length) followed by January 2016 (10.21 mealybugs) and November 2015 (9.94 mealybugs/15 cm root length).

A significant negative correlation was observed between root mealybug population and soil temperature (-0.707 for minimum soil temperature and -0.735 or maximum soil temperature). No correlation was existed between the mealybug population and other abiotic parameters like soil moisture, relative humidity and number of rainy days.

Biology of *Formicococcus polysperes*

The biology of *F.polysperes*, the dominant species among the three root mealybug species was studied in laboratory condition. Morphometric characters of each developmental stage also were recorded.

Susceptibility of popular pepper varieties

Four popular varieties of black pepper namely, Panniyur 1, Panniyur 2, Panniyur 8 and Karimundawere evaluated to test their susceptibility to root mealybugs. Out of the four varieties, Panniyur 2 supported significantly higher number of mealybugs (81.58) than other three varieties

Evaluation of entomopathogenic fungi against root mealybug

Efficacy of four entomopathogenic fungi *viz., Beauveria bassiana, Metarhizium anisopliae, Paecilomyces lilacinus* and *Lecanicillium lecanii*at three different doses of 2 x10^6, 2 x10^7 and 2 x 10^8 spores/ml were evaluated against root mealybug. .All the three fungal bioagents were found to be pathogenic to the root mealybugs and the mortality increased with increase in spore concentration.

Evaluation of chemical insecticides against root mealybug

Efficacy of eight chemical insecticides were tested against the root mealybug in the laboratory and in pot experiment. In the laboratory, chlorpyriphos 20 EC and imidacloprid 17.8 SL caused highest mortality of 80 per cent at one day after treatment. In pot experiment, imidacloprid17.8 SL caused highest mortality of 59.44 per cent at one week after first drenching and 63.89 per cent at one week after second drenching

Compatibility of effective entomopathogenic fungus with insecticides

Most effective entomopathogenic fungus (*L. lecanii*) identified against the root mealybug from the pot experiment was tested for its compatibility with all the insecticides tested in the present investigation and two fungicides. The results indicated that imidacloprid and copper hydroxide were compatible with respect per cent inhibition, sporulation and spore viability

Management of root mealybugs in pot culture experiment

The best treatments from the screening tests of entomopathogenic fungi and chemical insecticides were evaluated alone and in combination of entomopathgenic fungi and insecticides along with the common practice adopted by farmers against the root mealybug. The result showed that highest per cent mortality was caused by imidacloprid 17. 8 SL (56.67) followed by chlorpyriphos 20 EC and combination treatment of imidacloprid17. 8 SL + *L. lecanii*at 2x 10^8spores/ml (53.89) at one week after first drenching. At one week after second drenching also highest mortality of 65.00 per cent was recorded by imidachloprid 17.8 SL

Field evaluation of effective treatments

Field evaluation of the best treatmentof the pot experiment with imidacloprid 17.8 SL was conducted in a root mealybug infested field at Kaniyampatta panchayat of Wayanad districtand its efficacy was compared with that of chlorpyriphos 20 EC. According to the results obtained, imidacoprid 17. 8 SL was found to be superior to chlorpyriphos 20 EC.

29. Characterization, evaluation and formulation of *Beauveria bassiana* (Bals.) strains against rice bug *Leptocorisa* spp.(Hemiptera: Alydidae).

Work is in progress

30. Efficacy of *Neoseiulus longispinosus* (Evans) (Mesostigmata: Phytoseiidae) for the management of *Tetranychus urticae* Koch (Prostigmata : Tetranychidae) in cucumber under protected cultivation

Roving surveys were undertaken to explore the mite fauna associated with cucumber in randomly selected fifteen polyhouses located in four districts of Kerala namely, Palakkad, Waynad, Thiruvananthapuram and Thrissur. The different species of phytophagous mites recorded on cucumber in polyhouse are presented in Table. Of the different species of spider mites on cucumber under protection cultivation, *Tetranychus truncatus* Ehara was found to be the predominant one. *T. urticae* was recorded only from Thrissur and Wayanad districts. *Tetranychus okinawanus* Ehara, an exotic pest was recorded on cucumber from one polyhouse located in Anthikadu block of Thrissur district. *Eutetranychus orientalis* (Klein) was observed in few numbers from two polyhouses of Thrissur district alone. The incidence of yellow mite *Polyphagotarsonemus latus* (Banks) was recorded from two polyhouses of Thrissur district.

Table 1. Phytophagous mites associated with cucumber in polyhouse

Sl. No.	Mite species	Family	District
1	*Tetranychus urticae* Koch	Tetranychidae	Thrissur, Wayanad
2	*Tetranychus truncatus* Ehara	Tetranychidae	Thrissur, Palakkad, Wayanad, Trivandrum
3	*Tetranychus okinawanus* Ehara	Tetranychidae	Thrissur
4	*Eutetranychus orientalis* (Klien)	Tetranychidae	Thrissur
5	*Polyphagotarsonemus latus* (Banks)	Tarsonemidae	Thrissur, Trivandrum, Wayanad

Natural enemies of phytophagous mites on cucumber

A total of ten predators were recorded during the survey in association with spider mites of which four were insect predators and six were mite predators. The insect predators recorded were *Stethorus pauperculus* (Weise) (Coleoptera: Coccinellidae), *Oligota* sp. (Coleoptera : Staphylinidae), *Scolothrips* sp. (Thysanoptera: Thripidae) and a species of Cecidomyidae. Predatory mites recorded included two species of Phytoseiidae, one species each of Stigmaeidae, Tydeidae, Cunaxidae and Cheyletidae. The predatory mite fauna associated with phytophagous mites on cucumber were *Neoseiulus longispinosus* (Evans), *Agistemus garrulous* Chaudhari, *Tydeus gossabaensis* Gupta, *Amblyseius paraaerialis* (Muma), *Cunaxa* sp. and *Cheyletus* sp.. The phytoseiid predator *N. longispinosus* was the predominant mite predator and recorded from all the polyhouses surveyed during the study. During the survey, mycosis of *T. urticae* was observed on cucumber grown in one polyhouse of Thrissur district during June, 2014. The pathogenic fungus was isolated and identified as *Acremonium strictum* W. Gams. This is the new report of natural *epizootic of A. strictum on T. urticae.*

Biology of *Tetranychus urticae* Koch on cucumber

The life cycle of *T. urticae* consisted of five different stages such as egg, larva, protonymph, deutonymph and the adult. Three short quiescent intervals called nymphochrysalis, deutochrysalis and teliochrysalis were present in between each life stage until deutonymph stage.

Biology of *N. longispinosus* on *T. urticae* Koch on cucumber

The life cycle of *N. longispinosus* consisted of five different stages such as egg, larva, protonymph, deutonymph and the adult.. *N. longispinosus* preferred to lay eggs on the underside of the leaf. Gravid female mite laid eggs singly or in groups, usually amidst *T. urticae* egg colony. Egg was oval in shape and shiny white translucent when freshly laid. Later the colour turned dirty white or turbid, prior to hatching. The average incubation period was 1.46 days for male and 1.57 days for female. Newly hatched larva was shiny white with three pairs of legs. It was pure white coloured and small in size. The mean larval period recorded was 0.60 days for male and 0.65 days for female. Protonymph was characterized by four pairs of legs and was larger in size. The protonymph was dark greenish in colour initially, but later turned to pale orange. The mean protonymph period lasted for 0.86 days for male and 0.98 days for female. The deutonymph, a very actively moving and feeding stage. Deutonymph was bright orange in colour with brownish tint. The typical orange sclerotization pattern was visible at this stage. Female deutonymph was larger and broader than its male counterpart while male deutonymph was elongate. The mean deutonymph period was 0.98 days for male and 1.05 days for female. Deutonymph moulted to adult. The adult mite exhibited sexual dimorphism in colour, size and shape. Male was light brown in colour and smaller in size compared to the female. The shape of male was elongate and the hysterosoma was oblong, more or less like the base of a test tube. Female was dark brown in colour and bigger in size. The hysterosoma of female was round like a pot. Older female was more plumber in size and darker in colour. The total development period from egg to adult emergence was 3.91 days for male and 4.27 days for female. Adult male recorded a mean longevity of 19.66 days while female lived on an average for 22.75 days

31. Bioefficacy of entomopathogenic fungi against rice bug *Leptocorisa acuta* Thungberg (Alydidae: Hemiptera)

The pot culture experiment was carried out to evaluate bioefficacy of entomopathogenic fungi against rice bug. Three different EPF's *viz. B. bassiana, M. anisopliae*and *L. lecanii*at four concentrations ranged from 10^5 to 10^8 spores per ml were used for the experiment. The local strain of *B. bassiana* isolated from rice bug was found effective at different concentrations. The superior treatment obtained in pot culture experiment was *B. bassiana* at 10^8 spores/ml with 97.77% mortality after 10 days of treatment. Which is on par with the insecticide check, malathion 50 EC 500 ai ha^{-1} at 7 DAT onwards. Also, *B. bassina*@ $1x10^7$ spores ml^{-1} was at [par with *B. bassiana* @ $1x\ 10^8$ spores ml^{-1}. *M. anisopliae*at 10^8 spores per ml causes a significant reduction in rice bug population (71.16%) which is on par with lower concentrations of *B.bassiana.* The least effective treatment in pot culture studies were the lower concentrations of *M. anisopliae* and *L. lecanii.*

Field evaluation

Field evaluation of entomopathogenic fungi were conducted in two different seasons at Vellanikkara and Muthuvara. Higher concentrations of all the three entomopathogenic fungi, produced highest mortality in pot culture experiment were selected as the treatments for field evaluation.

In the first experiment, the results reveals that the plots treated with *B. bassiana* showed a significant reduction in rice bug population at 10 DAT, which is on par with the insecticide check. The per cent damage due to rice bug infestation was significantly less in plots treated with *B. bassiana* @ $1x10^8$ spores/ml. In terms of per cent grain damage, it was the second best treatment after insecticide. There were no significant variation among treatments with respect to rice yield. *M. anisopliae*and *L. lecanii*were the least effective treatments under field conditions.

The second field trail was carried out at farmer's field, Muthuvara. A rapid reduction in rice bug population was observed in insecticide check. A similar trend was also observed in B. *bassiana.* After 5 days of treatment application *B. bassiana* was at par with chemical both in terms of rice bug population and per cent grain damage. There were no significant reduction in rice bug population and damage in plots treated with *M. anisopliae*and *L. lecanii.*

32. Bionomics and distribution of banana leaf roller *Erionota*sp.(Lepidoptera: Hesperiidae)

Survey is going on at monthly intervals 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 species of leaf roller was identified as *Erionota torus.* Study on biology of banana leaf roller is in progress

33. Systematics of the tribes Scymnini and Stethorini (Coleoptera: Coccinellidae) from South India

Purposive survey was conducted at twenty five localities in Kasargode, Kannur, Wayanad, Kozhikode, Malappuram, Palakkad, Thrissur, Ernakulam, Kottayam, Alappuzha and Idukki districts of Kerala, Coimbatore and Trichi district of Tamil Nadu and Bangalore and Shimoga of Karnataka. Grubs and adults of coccinellid beetles belonging to the tribe Stethorini associated with mites were collected from banana, amaranthus, cowpea, arecanut, coconut, bhindi, tapioca, pomegranate, bauhinia, jack, cosmos and papaya. Members of the tribe Scymnini associated with mealybugs and aphids were collected from brinjal, bhindi, guava, anona, cocoa, chilli, croton, hibiscus, evergreen, tapioca, papaya, zinnia, pepper, thippali, casurina, duranta, eupatorium, celosia, maize, jatropha and cowpea. The collected beetles and prey were preserved for further study. The mealybugs and aphids collected as prey of many species of Scymnini got identified from National Bureau of Agricultural Insect Resources, Bengaluru. There were ten species of mealybugs and three species of aphids collected as prey. Preliminary work on the dissection of collected specimens and standardization of DNA isolation protocol for stethorini was carried out.

34. Isolation and characterization of biocide molecules from potential plant sources

The present work involves the extraction of Phytochemicals from different plant samples such as flower of *Quisqualis indica*, leaf of *Samadera indica*, arial parts of *Mikania micrantha* and seed of *Simarouba glauca* which showed pesticidal properties under invitro condition. The effective botanicals were dried and extracted with solvents such as Methanol, Ethyl acetate, Ethanol, Chloroform, Acetone and hexane. The Quantitative phytochemical analysis of different extracts of plant samples indicates the presence of secondary metabolites like flavanoids, Terpenes, Phenols, tannins, Steroids and glycosides. Silica gel column chromatography was carried out using different solvent systems and various fractions were collected. Bioactivity studies *viz*. antifeedant action, growth retardation, morality of insects were carried out in *Pseudostem weevil*, *Spodoptera litura* and *Epilachna beetle.* Effect of different solvent fractions on growth inhibition and sporulation of fungi were carried out against *Fusarium solani* and *Pythium spp*. in ginger. 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*. 5% methanol extract of *Q. indica* flower showed maximum percentage mortality of *S. litura* and caused significant reduction in leaf area damage of cowpea in polyhouse condition.The results of the present study revealed the excellent insecticidal activity of extracts of *Q.indica, S.indica, M.micrantha* and *S.glauca*.

35. Exploitation of bionematicide from potential plants of Western Ghats

I00 plants were screened for egg hatch inhibition and larval mortality of *M.incognita* . Among the plants *Quisqualis indica, Widelia trilobata, Leucas aspera, Antigonon leptopus, Lantana camera, Simarouba glauca, Tithonia diversifolia, Andrographis paniculata, Samadera indica, Swietenia macrophylla seed, Cleome viscose, Adathoda vasica,* showed *Panicum maximum* more than 50 per cent larval mortality. Dried powders of the effective plants were extracted using solvents of different polarity using ASE 150 and bioefficacy studies were conducted. Results revealed that Methanol (MF III), Ethanol (EF IV), Hexane (HF III) fractions of *Q.indica* flower showed nematicidal property (78 to 91% mortality) against 2nd stages juveniles of *M.incognita.* Ethyl acetate fraction XII of *S. indica* at 0.5% concentration showed 57 and 61 % mortality of *M. incognita* at 24 and 48 hours after treatment respectively. Acetone fraction IX of *M. micrantha* at 5% concentration showed 63 and 64 % mortality of *M. incognita* juveniles at 24 and 48 hours after treatment respectively. Methanol fraction I of *Simarouba glouca* at 0.5% concentration showed 58 and 62% mortality of *M.incognita* juveniles at 24 and 48 hours after treatment respectively**.**

36. Isolation and characterization of biocide molecules from potential plant sources.

Different plant samples were screened in-vitro condition in Dept.of Entomology, College of Agriculture. Among these hundred plant samples crude aqueous extracts of *Chromolaenaodorata, Lantana camera, Clerodendroninfortunatum, Hyptissuaveolens, Samaderaindica, Adathodavasica, Tithoniadiversifolia, Andrographispaniculata, Pongamiapinnata, Capsicum fruitescens, Calotropisgigantea, Gloriosasuperba, Annonasquamosa, Wedeliatrilobata, Phyllanthesnirurii, Cipadesa baccifera, Quisquaulisindica, Simaroubaglauca and Mikaniamicrantha* showed pesticidal properties under in vitro condition. Bioactivity studies (antifeedant action, growth retardation, mortality of insects Psedostem weevil, *S. litura*, epilachna beetle); penetration, multiplication, egg production of *Meloidogyne incognita*, growth inhibition and sporulation of fungi (*Fusariumsolani* and *Pythiumspp*in ginger) using solvent extracts of selected weeds viz. *M. micrantha, Q. indica flower, T. diversifolia, A. squamosa, C.odorata* and *S. glauca*seed were done.

Following results were obtained

- Hexane extract of *A. squamosa*seed, *Q. indica*flower, *S. indica*leaf; ethyl acetate extract of *A.squamosa*seed and *Q. indica*flower showed more than 50% mortality of *O.longicollis* grubs
- Aqueous extract of *S.indica*leaf, methanol and ethyl acetate extract of *Q. indica*flower, hexane extract of *S.indica*leaf, ethyl acetate extract of *A.paniculata* and methanol extract of *S.glauca* seed showed antifeedant activity against *S.litura* in banana
- Hexane and methanol extract of of*S.glauca* seed, ethyl acetate extract of *S. indica*leaf ethyl acetate and methanol extract of *Q. indica*flower showed insecticidal property against *S.litura* in banana

- Minimum egg hatching of root- knot nematode *M. incognita*(1-1.46%) was observed in *T. diversifolia*leaf extract 100% concentration at 3-8 days after treatment. Lower concentration (50, 33.3 and 25%) of *T. diversifolia*leaf showed significant superiority over other treatments (*C.odorata, L. camera and E.crassipes*)giving 3 to 11.5% egg hatching.
- *T. diversifolia* 100, 50,33.33and 25% concentration found to be effective in increasing mortality of *M. incognita* juveniles at 24,48,and 72 hours after treatment (63 to 100%)
- Methanol and hexane extract of *Q. indica*flower, *M.micrantha* leaf, methanol and ethyl acetate extract of *A.squamosa*seed, ethyl acetate extract of *S.glauca* seed showed antifungal activity against *F.solani*and *Pythiumspp* of ginger.
- Phytochemical screening of *Q. indica*flower, *S.indica* leaf and *S.glauca* seed showed the presence of tannins, phenolic compounds, flavinoids, phytosteroid and coumarins
- GC-MS analysis of ethyl acetate extract of *Q. indica*11th fraction showed maximum probability of 2-chloro-6-(furan-2-ylmethoxy)-4-(trichloromethyl) pyridine,2-hexylfuran, cis-13octadecenal, dl-Furfenorex and Octamethylcyclotetrasiloxane
- GC-MS analysis of ethyl acetate extract of *Q. indica*12th fraction showed maximum probability of Benzoic acid,{6-[(benzoyloxy)methyl]-2,8, 2-chloro-6-(furanylmethoxy)-4-(trichloromethyl)pyridine,4-allyl-2-methoxyphenyl acetate, cis-13-octadecenal and Cyclohexyldimethylsilyloxybutane.

37. Exploitation of bionematicide from potential plants of Western Ghats - WGDP

Aqueous leaf extracts of *Tithoniadiversifolia*(Hemsl.) Gray, *Lantana camara*L., *Eichhorniacrassipes*(Mart.)Solms and root extract of *Chromolaenaodorata*L. at 100,50,33.3 and 25% concentration were screened for ovicidaland larvicidaleffect against *M. incognita* under *in vitro* condition.All the concentrations of *T.diversifolia*was statistically superior over all other concentrations of different plant extracts tested. *T.diversifolia*(100%) caused egg hatching of 1 to 1.46 per cent for an exposure period of one to eight days. Hatching percentage in*T.diversifolia*(50% concentration) was within the range 3 to7 per cent for a period one to eight days after treatment. The percentage of egg hatching in *T.diversifolia*(33.3%) ranged between 4.95 to 9 per cent one to eight days after the exposure of egg mass to the plant extract. *T.diversifolia*(25%) gave hatching of egg masses in the range of 7.49 to 11.5 per cent one to eight days after treatment (Fig.1).*T.diversifolia*(100%) caused a larval mortality in the range of 90.49 to100 per cent at 24 to 72 hours after treatment. Percentage larval mortality in*T.diversifolia*(50%) was within the range of 85 to 99 per cent at 72 hours after exposure The larval mortality in *T.diversifolia*(33.3% concentration) ranged between 73.99 to 98.75 per cent at 24 to 72hours after exposure. *T diversifolia*(25%) gave a larval mortality in the range of 63.48 to 96.10 per cent 24 to 72 hours after treatment(Fig.2)

It has been concluded from present research that certain plant extracts are a source of cheap and effective nematicides of root-knot nematodes. As*T. diversifolia* 25% concentration being the lowest concentration of extract giving more than 50 % larval mortality (63.48 % at 24 hours after treatment) and high egg hatch inhibition (88.5 to 92.51 % at three to eight days after treatment) it can be recommended as a biorational component for integrated nematode management strategy

Concluded PG Projects

1. **Response of selected banana varieties to root knot nematode *Meloidogyne incognita* (Kofoid and White)**

The study revealed that considerable variation exists among the banana varieties in terms of resistance to *M. incognita*. The varieties SH–3640 (AAAB) and SH–3436-6 (AAAA) were found to be resistant. FHIA-1(AAB), FHIA-3 (AABB), SH–3436-9 (AAAA), TMB × 5295-1 (AAAB), Udayam (ABB), Dudhsagar (AAB), Manjeri Nendran II (AAB), Big Ebanga (AAB) and Pisang Nangka (AAB) were moderately resistant, TMP 2829 (AB), Mysore Ethan (AAB), Sugandhi (AAB), Yangambi Km5 (AAA), Bangrier (ABB), Popoulu (AAB) and Pisang Madu (AA) were susceptible and FHIA -17 (AAAA), FHIA -18 (AAAB), Karpooravally Dwarf (ABB), Pisang Ceylan (AAB), Pisang Jari Buaya (AA), Pisang Buntal (AA) and Robusta (AAA) were highly susceptible. Notable differences were also observed in the biometric characters of these varieties.

From the findings it was evident that biochemical changes observed after the infestation of *M. incognita* plays a key role in nematode resistance in *Musa* spp. Biochemical parameters like total phenol content and activities of enzyme like polyphenol oxidase, peroxidase, and phenylalanine ammonia lyase were found to increase in resistant varieties and could be used for screening the varieties against *M. incognita.* Such an information could be used in the selection of parents in further breeding programmes.

2. **Pathogenicity of indigenous Entomopathogenic fungi against select lepidopteran pests.**

The study entitled "Pathogenicity of indigenous entomopathogenic fungi against select lepidopteran pests" was carried out in the Department of Agricultural Entomology, College of Agriculture, Vellayani during 2014-2016 with the objective to identify indigenous entomopathogenic fungi and evaluate their pathogenicity to lepidopteran pests of banana and vegetables.

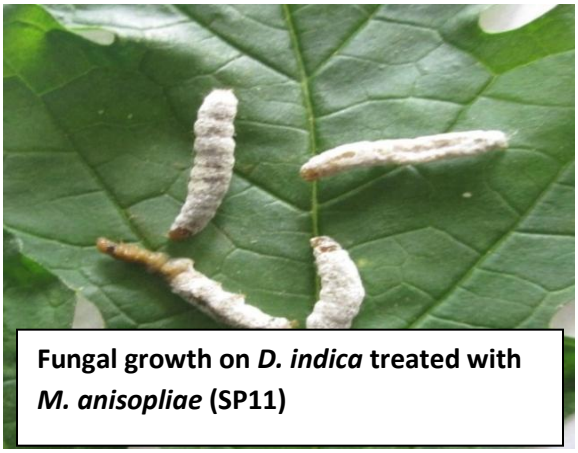
Of the ten isolates of fungi selected from the 115 fungal isolates obtained, three were from mycosed cadavers which consisted of two isolates of *Beauveria bassiana* (Balsamo) Vuillemin (SP2 and SP4) and one isolate of *Fusarium oxysporum* Schlecht (SP1). Of the seven isolates from soil, one isolate was *Fusarium solani* (Mart.) Sacc. (SP6), five were isolates of *Metarhizium anisopliae* Metchnikoff (Sorokin) and one isolate was *Purpureocillium lilacinum* Thorn (Samson). Four isolates of *M. anisopliae* isolates were trapped using *Galleria melonella* L. and one was trapped using grubs of *Odoiporous longicollis* Oliver. The isolate, S10 was obtained through soil plate method, with selective media.

The isolate *M. anisopliae* (SP8) recorded the highest mortality of 83.33 to 100 per cent and 64.44 to 95.83 per cent against the second instar larvae of *Diaphania indica* Saunders and first instar larvae of *Leucinodes orbonalis* Guenee at 10^7 to 10^9 spores ml^{-1} seven days and five days after treatment respectively. The isolates SP11 and Ma4 of *M. aniopliae* that caused mortality of 83.33 to 100 per cent and 63.33 to 100 per cent were the most effective isolates against second instar larvae of *Sylepta derogata* Fabricius and *Hymenia recurvalis* Fabricius respectively.

A pot culture experiment was conducted in the Instructional farm, Vellayani during April to June 2016, for the evaluation of seven indigenous isolates and two NBAIR isolates against leaf webbers in amaranthus, variety Arun. The lowest number of plants infested by webbers, webbings $plant^{-1}$ and larvae web^{-1} at 14 days after treatment and the highest yield was recorded

was recorded in the isolate *M. anisopliae* (SP11) @ 10^8 spores ml^{-1} and it was followed by *M. anisopliae* Ma4 and SP8.

Fungal growth on *D. indica* treated with *M. anisopliae* (SP8)



Fungal growth on *D. indica* treated with *M. anisopliae* (SP11)

Ongoing PG Projetcs

1. **Response of selected banana varieties to root knot nematode Meloidogyne incognita (Kofoid and White)**

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From the findings it was evident that biochemical changes observed after the infestation of *M. incognita* plays a key role in nematode resistance in *Musa* spp. Biochemical parameters like total phenol content and activities of enzyme like polyphenol oxidase, peroxidase, and phenylalanine ammonia lyase were found to be increased in resistant varieties and could be used for screening the varieties against *M. incognita.* Such an information could be used in the selection of parents in further breeding programmes. The possibility of using these induced biochemical changes in evolving new management strategy could not be ruled out.

Name of the Project Coordination Group (12)

Plant Pathogens and Beneficial Microbes

Project Coordinator: Dr. Girija V.K

Concluded Projects: 10 Nos
Continuing Projects: 16 Nos

Concluded PG Projects: 19 Nos
Continuing PG Projects: 22 Nos

Concluded Projects

1. **Development and adoption of microbial Inoculant technology for cropping systems of Kerala - Plan Project**

   The microbial inoculant production started during 2012-13 initially with 6 subcenters of KAU and extended to 9 subcenters during 2013-14. By 2015, a total of eleven centers of KAU were strengthened for scaling up production of biocontrol agents and biofertilizers. In KAU, the total production was limited to less than 22.50 tons per year before 2012-13 which increased to 63.682 tons during 2012-13 to 111.867 tons during 2013-14 and to 179.211 during 2014-15 and to 148.551 tons during 2015-16**.** Substantial revenue increase was also observed in KAU due to sale of microbial inoculants. With the implementation of the present project, the production capacity of KAU could be scaled up to **800** tons per year. The unit at College of Agriculture, Vellayani alone is now equipped with a capacity of 400 tons per year. However, even with such an enhanced capacity, production will be taken up only based on demand from beneficiaries. Now quality inoculants are being made available to maximum farmers spread throughout the different districts of Kerala through the different identified subcentres of KAU.

   Another major achievement of the project is that the FACT has signed MOU with KAU for marketing the microbial products viz., PGPR Mix-I, PGPR Mix-II and Composting Inoculum. FACT has marketed **14,236 kg of PGPR Mix I, 4,000 kg of PGPR Mix II and 2,000 kg of Composting Inoculum till March 2016.**

   Quality analysis of microbial products is being undertaken in the project. A total of 57 samples were analysed during 2015-16. The technology of waste management in households using Composting Inoculum was further refined. A protocol was developed for composting kitchen waste in earthern pots for households.

   A Pilot Solid Waste Processing Plant was constructed under Lead centre and waste collected from the ladies hostel and the food waste from Ayyankali Memorial Sports School being processed.

   Continuous advisory service provided to the farmers visiting the centre. Regular supply of microbial inoculants to the farmers.

2. **Standardization of liquid formulation for enhancing the shelf life of *Azospirillum* and phosphate solubilizing bacteria (PSB)**

   The highest population of *Azospirillum* (1.77×10^8 cfu/ml) was recorded in the case of trehalose (15mM) whereas, highest population of PSB (3.77×10^8 cfu /ml) was in the case of PVP (2.5 %) upto 9 MAI. Hence, trehalose (15 mM) and PVP (2.5 %) were the most suitable chemical additive for enhancing the shelf life of *Azospirillum* sp. and PSB respectively with a population of 10^8 cfu/ml, which is the quality standard prescribed for liquid formulations of *Azospirillum* sp and phosphate solubilizing bacteria. These results indicated that the shelf-life of *Azospirillum* sp. and PSB could be enhanced upto 9 months at room temperature when compared to shelf-life of carrier based inoculant which is about 5-6 months.

3. **Exploitation of native agriculturally important microorganisms (AIMS) for integrated nutrient management in various agro-ecosystems of Kerala**

   Five most promising and efficient diazatrophs*viz., Microbacterium testaceum,Microbacterium* sp*, Cellulosimicrobium*, *Paenibacillus* and *Azotobacter* were evaluated for their efficiency in enhancing plant growth and yield using Bhindi as a test crop.

Microbacterium sp (100% N) inoculated plants recorded maximum plant height, which was on par with *Paenibacillus*(100%N) and *Microbacteriumtestaceum* (100%N). *Microbacterium*sp (100% N) inoculated plants recorded maximum stem girth, which was on par with *Cellulosimicrobium*, *Azotobacter*, *Paenibacillus* (100% N) and *Paenibacillus* (50%). All these were significantly superior to uninoculated control. *Paenibacillus* (100% N) inoculated plants recorded maximum root length and root volume. *Azotobacter* (100% N) inoculated plants recorded maximum root weight compared to control. Yield per plant was highest in *Paenibacillus* (50%) which was on par with *Paenibacillus* (100% N) and *Microbacterium* sp (100% N).

4. **Microbial Inoculants Technology for cropping systems of Kerala – (State Plan Project)**
Six hundred and thirty (630) soil samples were collected from various agro-ecosystems of Kerala. The samples were studied for the population of various agriculturally important microorganisms. *In planta* evaluation of selected bacterial isolates in bhindi was done, in which application of *Paenibacillus* showed increased biomass.

   A novel actinobacteria *Microbacterium testaceum* was found to be an efficient nitrogen fixer and plant growth promoters.

5. **The management of stem bleeding and basal stem rot in coconut – RKVY** Hexaconazole @1ml/litre is the most effective fungicide for stem bleeding and basal stem rot.

6. **Molecular characterization and virulence analysis of *Pyricularia grisea*&*Xanthomonas oryzae*, the blast & bacterial blight pathogens of rice in Kerala**
Studied the genetic variability of *Xanthomona oryzae pv oryz*ae in Kerala. The existence of high genetic variability of *Xoo* was revealed. Single genes are not effective against the Xoo populations in the state. Combinations of 3 or more particularly Xa3, Xa5< Xa4 and Xa21 are effective against most of the isolates. The genetic variablilty of *Pyricularia grisea* was also studied. The Nils / differentials, Tetep, Tadukan, C101Lac are showing resistance to *P.grisea.*

7. **Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala**
In the case of sheath blight both the fungicides tested were found to be compatible with both the insecticides *i.e* Flubendiamide 20 WG and Buprofezin 70 WP during *Kharif* 2015-16.The pest incidence was low during the season. Hence no conclusive results were obtained. But during the next season, *rabi* 2015-16, only Tebuconazole250 SC showed compatibility with the insecticides Flubendiamide 20 WG and Buprofezin 70 WP.

   Different doses of fungicides, lower and higher doses along with recommended dose were evaluated for label expansion of the fungicides for the management of brown spot , sheath rot and glume discolouration. Three doses of three fungicides Hexaconazole5 EC, Trifloxystrobin + Tebuconazole 75 WG and Copperhydroxide 101WP were tested for efficacy against brown spot sheath rot and glume discoloration. The recommended dose was found to be most effective in the case of Hexaconazole 5 EC and Trifloxystrobin + Tebuconazole 75 WG for all the three diseases. In the case of Copperhydroxide 101WP the disease severity recorded in the lower dose tested (1.5g/l) was found to be statistically on par with that of recommended dose. There was no significant difference among the treatments in yield.

8. **Integrated management of Fusarium wilt of Cowpea**

The objective of the study was to develop integrated management strategies for Fusarium wilt of cowpea and to impart training for diagnosis and management to the farmers. Soil disinfection by pit burning prior to cultivation, Seed treatment with *Pseudomonas fluorescens* (20 g/kg seed), Soil incorporation of *Trichoderma* multiplied in cowdung – neem cake mixture (1 kg/pit) at twining stage, Soil drenching with *Pseudomonas fluorescens* (2%) 20, 40 , and 60 DAS were found effective.

9. **Ecofriendly Management of Water Hyacinth in Water Bodies**

The objectives of the project included application of the already developed technology of eco-friendly management of water hyacinth with a myco-herbicide from *Fusarium pallidoroseum* along with Cashew Nut Shell liquid (CNSL), in the water bodies; to explore the feasibility of utilizing secondary metabolites of fungi for the effective management of water hyacinth; refinement of existing technology and application in the field.

Cashew nut shell liquid along with *F. pallidoroseum*, the metabolites *F. pallidoroseum* or *M. advena*alone or in combination gave good reduction of the biomass of water hyacinth. This treatment is found to be safe to the aquatic fauna.

Standardised the technique of mass multiplying *F. pallidoroseum* in fermenter. On third day, *F. pallidoroseum* sporulated well in all the substrates tried, the maximum being fifth day after inoculation.

Of the different substrate tried, jaggery water recorded maximum sporulation of 3.44×10^6. The least sporulation was observed in rice gruel.

Mite infected water hyacinth plants when sprayed with *F. pallidoroseum* (WP) at 5% showed yellowing and blighting third day after inoculation and these plants dried up within 10 days. This study confirmed that injury caused by mite favours the initial development of symptoms due to fungi and thereby helps in faster mortality of weeds.

Studied the effect of different fractions of the metabolite *M.advena* and *F. pallidoroseum*on water hyacinth. The metabolite of *M.advenae*, collected after 30min. developed symptoms on water plants at 3 DAS and the plants get killed at 7 DAS. The metabolite of *F. pallidoroseum* took more time for symptom development (7DAS) on water hyacinth.

10. **Investigations on etiology and management of yellowing disease of coconut and the productivity enhancement of palms in South Kerala.**

The objectives of the study was to investigate the extent of disease incidence and symptomatology of yellowing disease of coconut in Thiruvananthapuram district; to investigate the etiology of the disease with particular reference to the probable involvement of phytoplasmas, fungi, bacteria, viruses, nematodes, physiological disorders etc. with the disease. The association of phytoplasma DNA with yellowing of coconut could not be proved by PCR technique utilising the rootwilt specific, yellow leaf disease specific primers and universal primers of phytoplasma. New primers have to be designed for yellowing disease to prove its phytoplasmal etiology.

Ongoing projects

1. **Identification of Pathotypes / races in red rot pathogen.**
   Reported no emergence of new pathotype in the zone.

2. **Evaluation of pre-zonal/IET/zonal varieties/ genotypes for resistance to red rot.**
   Out of 62 genotypes evaluated for red rot resistance, 37 entries found to be resistant /moderately resistant.

3. **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.

4. **All India Network Project on Soil Biodiversity and Biofertilizers**
   A total of Four isolates of *Azospirillum, t*welve isolates of *Azotobacter* and eight of *Rhizobium* were obtained from rhizosphere soils of Wayanad. One isolate of *Azotobacter* PBAZ1 has been confirmed by cultural, morphological and biochemical characteristics as per the Bergey's Manual of Systematic Bacteriology. Eight rhizobial isolates were characterized and identified from Wayanad.

5. **Centre of Excellence in Microbial Technology**
   Objectives of the project were to act as a nodal center for catering the technological requirement of the State by supplying mother cultures of biocontrol and biofertilizer organisms, development of Liquid formulations of Biocontrol agents and Biofertilizers-PGPR's, evaluation of shelf life of the liquid and bead formulations developed and its efficiency, training for creating awareness on microbial technology to farmers, extension officials, private entrepreneurs, job trainees etc, dissemination of technologies through publication of pamphlets, leaflets, popular articles etc; continuous advisory service to the farmers visiting the centre, quality analysis of microbial products marketed in Kerala, search for new organisms of agricultural importance.

   The Centre is functioning as a nodal center of the State by providing mother cultures of Biocontrol agents and biofertilizers, catering the technological requirement of all the production centers in Kerala. All technical support is being provided to the production centers functioning with our technology. The Technology of household waste management using composting inoculum was further tested in different types of bins. The composting inoculum developed by the Department is being purchased by different service providers across the State for waste management . Initiated studies on development of liquid formulations of biofertilizers. Continuous advisory service provided to the farmers visiting the centre. Regular supply of microbial inoculants to the farmers.

6. **Integration of Biofertilizer Technology with farming practices of tribal farmers of Attappady - AINP on Soil Biodiversity- Biofertilizers**
   Objectives of the projects were Mass production and distribution of Biofertilizer organisms such as *Azospirillum, Azotobacter,* AMF, P solubilizers and PGPR MIX-I developed by KAU for cashew , millets and vegetables cultivated by tribal farmers; Field trials at different locations of Attappady to demonstrate the beneficial effects of microbial inoculants; Training to create awareness on beneficial aspects and method of application of biofertilizers to tribal farmers, SHG's and Extension officials; Publication of bulletins in vernacular language for dissemination

of biofertilizer technology among tribal farmers; isolation and evaluation of native efficient strains of biofertilizer organisms such as *Azospirillum*, *Azotobacter* and *Rhizobium* from Attappady hill tract.

A consortium of NPK biofertilizers (PGPR Mix I) developed by Kerala Agricultural University was mass multiplied and distributed to selected farmers of Attappady area. A total quantity of 612 kg of PGPR Mix I was distributed to 612 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.

In order to create awareness on Biofertilizers, training programmes were conducted in three different locations of Attappady area. As envisaged, approximately 100 tribal farmers were selected from each location comprising of Agali, Sholayoor and Puthoor Panchayat of Attappady hill tract. As scheduled in the programme, 3 trainings were conducted on biofertilizers at above three locations of Attappady for the tribal farmers, Agricultural Extension officers and officials of Attappady. A total of 312 tribal farmers and 54 extension officers participated in the training programme.

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. The quantity of chemical fertilizers that could be saved will also be worked out. The trials are in progress. An experiment was also laid out at Puthoor panchayat to study the effect of PGPR Mix I on growth of Arecanut seedlings. A technical leaflet in Malayalam was published covering different aspects of biofertilizers for the benefit of farmers and it was distributed to the farmers during the training.

7. **Commercial micropropagation of high value crops as per national certification system for tissue culture plants- network project**

The objectives of the study was 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; to give training on commercial micro propagation and quality assurance of micropropogated plants.

As an experimental basis banana tissue culture samples were multiplied and virus indexed for four major banana viruses BBTV (Banana bunchy top virus), BBrMV (Banana Bract Mosaic Virus), CMV (Cucumber Mosaic Virus), BSV (Banana Streak Virus), multiplied and approximately 700 plants were sold to farmers. A demonstration of virus indexed Nendran banana plants was undertaken in the Instructional farm, Vellayani, Thiruvananthapuram.

Samples from Department of Plant Biotechnology, College of Agriculture Padannakkad and thirty seven samples from RARS Pattambi were tested for four viruses of Banana and reports were given.

Immunology and molecular detection of banana viruses was studied.

8. **Commercial micropropagation of high value crops as per national certification system for tissue culture plants- network project –** Plan Project

The objectives of the study were to co-ordinate the virus indexing activities at different participating centers; to assure quality of micropropogated plants produced at various centers through clonal fidelity testing and virus indexing; and to give training on commercial micro propagation and quality assurance of micropropogated plants. Trials were undertaken

9. **Development of technologies including alternative for banned pesticides for the management of pests and diseases of major crops in Kerala.**
   Objectives of the study are identification of alternative technologies for banned insecticides, fungicides nematicides and weedicides for management of pests, diseases, nematodes and weeds infesting major crops in Kerala; evaluating the safer pesticides (blue and green labeled) for the management of pests, diseases, nematodes and weeds infesting major crops in Kerala; evaluating the non chemical methods (including bio-pesticides and botanicals) for the management of pests and diseases in field level to implement the organic policy of the Government of Kerala; testing the compatibility of pesticides and bio-control agents; evaluating the pesticide residues in produce and soil due to the application of the chemical pesticides; registering the potential biological control agents as per the insecticide act of CIB&RC

10. **Development of technologies including alternative for banned pesticides for the management of pests and diseases of major crops in Kerala.**
    Objectives of the study are developing eco-friendly management measures for the control of amaranth leaf blight caused by *Colletotrichum gloeosporioides* and *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.

11. **Establishment of an Advanced Research Centre for Plant Disease Diagnosis**
    Objectives include, establishment of an Advanced Research Centre for Plant Disease Diagnosis; to establish a referral quarantine facility for the State, whenever Government need additional facilities; Consultancy/Advisory Services; training for scientists working in this field of specialization; maintain a type culture collection for reference during diagnosis; production of antiserum for major plant pathogens, maintain a cryptogrammic herbarium. Trials were undertaken

12. **Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala – Disease management in ginger**
    Based on the result of the experiments and farmer's field trials conducted in Vellanikkara and Ambalavayal centres, the following recommendations are included in POP.

    Management of rhizome rot, *Fusarium* yellows and bacterial wilt of ginger

    - Rhizome treatment with mancozeb (3g/l) for 30mts + soil application of bleaching powder (15g) + lime(250g)/3m^2 bed at 2 and 4 months after planting .
    - Soil application of bleaching powder (15g) & lime (250g/3m^2 bed) at the time of planting, 2 and 4 months after planting.
    - Seed treatment / soil drenching of *P. fluorescens* (2%) + cowdung supernatant (2%) at the time of planting, 2 and 4 months after planting
    - Seed treatment / soil application of PGPM (50g/ 3m^2 bed) at the time of planting, 2 and 4 months after planting.

Adhoc recommendation of fungicide for the management of rhizome rot and *Fusarium* yellows of ginger.

- Rhizome treatment with combination fungicide, carbendazim + mancozeb (2g/l) for 30mts + soil drenching of carbendazim + mancozeb (2g/l) at 2 and 4 months after planting.

13. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala– Disease management in Vegetables

a. Management of leaf blight of amaranth

Based on the pooled result of the experiments conducted at different centres and farm trials, the following treatments were included in POP.

- Turmeric powder + baking soda mixture (5:1 per litre) (foliar spray and soil drenching) .
- Cowdung slurry supernatant 2% + *Pseudomonas fluorescens* – 2% (soil application and foliar spray).
- *Pseudomonas fluorescens* – 2% (foliar spray) + *Trichoderma viride* – 2% (soil application).

Treatments at time of planting and 3 applications at 14 days interval

Adhoc Recommendation of fungicide

- Two foliar spray of copper hydroxide @1.5g/l for seed purpose

b. Management of collar rot, web blight and *Fusarium* wilt of cow pea

Collar rot & root rot

- *Trichoderma viride* - seed treatment (2g/ kg seed) + soil drenching (2%) thrice at 20 days interval.
- Soil drenching of *P.fluorescens* 2% + cowdung slurry 2% thrice at 20 days interval.

Adhoc Recommendation of fungicides

- Flusilazole – 1ml/l - soil drenching 20 and 40 days after sowing.
- Combined formulation of carbendazim + mancozeb seed treatment (2g/kgseed) + soil drenching (2g/L) 20 and 40 days after sowing.

c. Management of powdery mildew disease of bitter gourd

Based on the pooled result of the experiment conducted at different centres and farm trials, the following treatments were included in POP.

- Foliar spray of cymoxanil + mancozeb combination fungicide @ 2g/l
- Foliar spray of *Pseudomonas fluorescens* 2%

Adhoc Recommendation of fungicide

- Foliar spray of pyraclostrobin 0.5g/l.

d. Management of downy mildew of bitter gourd

Based on the pooled result of the experiment conducted in different centres and farmer field trial, the following treatments were included in POP.

- Foliar spray of *Trichoderma viride* 2% thrice at fortnightly intervals on symptom appearance.

Adhoc recommendation of fungicide

- Foliar spray of tebuconzole 1ml/l twice at fortnightly intervals symptom appearance
- Foliar spray of wettable sulphur 2g/l thrice at fortnightly intervals on symptom appearance.

e. Management of *Cercospora* leaf spot of bhindi

Based on the pooled result of the experiments conducted in different centres and farm trials, the following treatments were included in POP.

- Foliar spray of *Trichoderma viride* 2 % or *Pseudomonas fluorescens* 2%
  Adhoc recommendation of fungicide
- Foliar spray of tebuconazole (1.5ml/l)

14. Base line studies on vegetable crops under protected cultivation in Kerala as a prelude to precise disease management

Incidence of fungal diseases like powdery mildew, leaf spot, fruit rot, stem and fruit rot were noticed on capsicum under protected structures at various locations. Symptomatology of fungal diseases of capsicum observed during the survey was studied. The fungi associated with the diseases were isolated and the pathogenicity was proved.Among the treatments, T4 (soil solarisation + soil application of *Trichoderma viride* +seed treatment with carbendazim+ mancozeb (2g.kg-1) + foliar spray with mancozeb (0.2 %) was the most effective for management of Cercospora leaf spot in both poly house and rain shelter, followed by T2(soil solarisation+ seed treatment and foliar spray with *Pseudomonas fluorescens*(20g.L-1) and T1(soil solarisation+ soil application of *Trichoderma viride* and these were statistically on par. Among the treatments, T5 (soil solarisation +soil application of *Trichoderma viride*+ foliar spray with tebuconazole (0.1 %) was the most effective for management of powdery mildew in rain shelter and poly house, followed by T6 (soil solarisation +soil application of *Trichoderma*+ foliar spray with difenoconazole (0.05%) and these were on par.

15. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops of Kerala (RKVY).

16. Network project on Microbial inoculant Technology for cropping systems of Kerala – Development and adoption of microbial inoculant technology for cropping systems of Kerala.

Concluded PG Projects

1. Evaluation of abiotic stress tolerant PGPR and *Trichoderma* sp. for growth and disease management in black pepper (*Piper nigrum* L.)

Objective of the project was to screen *Azospirillum* sp., *Micrococcus* sp., *Burkholderia* sp., *Pseudomonas fluorescens* and *Trichoderma* sp. for abiotic stress tolerance under *invitro* and evaluate for growth and *Phytophthora* disease management in black pepper.

Rhizosphere soil samples were collected from ten different black pepper growing areas of Thrissur district for isolation of *Azospirillum* sp, *Micrococcus* sp., *Burkholderia* sp.,

Pseudomonas fluorescens and *Trichoderma* sp. The isolates obtained were screened for PGPR activities, abiotic stress tolerance and screening for antagonistic activity against *P. capsici*. The most promising isolate from each type of microorganism were selected for pot culture experiment to evaluate the selected abiotic stress tolerant isolates for growth promotion and disease management in black pepper.

Azopsirillum sp. was not recorded in the black pepper rhizosphere soil collected from Thrissur district. In the case of *Micrococcus* sp., the highest population was recorded in Pazhayannur (45×104 cfu g-1). In the case of *Burkholderia* sp., was highest in Kannara (116.5×104 cfu g-1). In the case of Fluorescent pseudomonads, the highest population was recorded in Chellakkara (55×10^4 cfu g-1). And *Trichoderma* sp., was highest in Mupliyam (96.5×103 cfu g-1).

A total of 34 different microbial isolates were screened for PGPR activities (IAA production, % P - solubilisation, Ammonia production and HCN production) and abiotic stress tolerance (temperature tolerance 280C, 370C, 410C and 500C, acidity tolerance and drought tolerance). Based on the PGPR activities and abiotic stress tolerance, the most promising isolates selected for pot culture experiment were *Micrococcus* sp. - VKM isolate (410C, pH 5.5 and -0.15 M Pa osmotic stress) *Burkholderia* sp. - PAB isolate (410C, pH 5.5 and -0.15 M Pa osmotic stress), fluorescent pseudomonads - PAP isolate (410C, pH 5.5 and -0.15 M Pa osmotic stress) and *Trichoderma* sp. - CKT isolate (370C, pH 5.5 and -0.15 M Pa osmotic stress). The maximum Per cent inhibition (64.75 %) was recorded in the case of *Burkholderia* sp. (KKB) and in the case *Trichoderma* sp. the maximum per cent inhibition (66.95 %) was recorded with CKT isolate.

The isolates were further screened under pot culture experiment. There were two pot culture experiments with polyhouse condition (with elevated temperature as stress) and natural condition (without stress). Under polyhouse condition (with elevated temperature as stress), T5 (*Trichoderma* sp. - CKT isolate) and T6 was the most efficient isolates for enhancing the growth of black pepper. However, T4 (*Pseudomonas fluorescens*- PAP isolate) and T5 (*Trichoderma* sp. - CKT isolate) were the most promising treatments for *Phytophthora* disease management.

Under natural condition (without stress), T8 (PGPR Mix - II - KAU ref. culture) and T4 (*Pseudomonas fluorescens*- PAP isolate) were the most efficient isolates for enhancing the growth of black pepper under natural condition (without stress). However, T3 (*Burkholderia* sp. - PAB isolate), T4 (*Pseudomonas fluorescens*- PAP isolate) and T5 (*Trichoderma* sp. - CKT isolate) were the most promising isolates for *Phytophthora* disease management.

Among the isolates obtained in the present studies, the most promising abiotic stress tolerant isolate for growth promotion and disease management in black pepper under polyhouse condition was *Trichoderma harzianum* (T5-CKT isolate), whereas *Pseudomonas fluorescens* (T4 - PAP isolate) was the most promising abiotic stress tolerant isolate under natural conditions.

Most promising abiotic stress tolerant isolate for abiotic stress tolerance, growth promotion and *Phytophthora* disease management in black pepper nursery under both polyhouse and natural conditions was *Trichoderma harzianum* (T5 - CKT isolate).

2. **Impact of weather variables on the functional efficiency of beneficial microflora in the rhizosphere of black pepper (*Piper nigrum* L.)**

To study the effect of weather and micro-climatic variables on *Azospirillum*, phosphorus solubilising bacteria, *Pseudomonas fluorescens* and *Trichoderma* sp. under different seasons and to study their effects on the functional efficiency of beneficial microflora was objective of the project.

The rhizosphere soil samples from black pepper were collected at monthly interval for a period of one year from Pepper Unit, Kerala Agricultural University (KAU), Vellanikkara. The selected beneficial microorganisms were enumerated and *in vitro* screening was done at monthly interval for IAA, ammonia, HCN, siderophore production, phosphate solubilization and antagonistic activity against *Phytophthora capsici*. Simultaneously, the weather and microclimatic parameters were also recorded.

The *Azospirillum* and PSB were not obtained throughout the study period from July, 2015 to June, 2016. The population of fluorescent pseudomonads was the highest in September, 2015 and was absent in March, 2016 and April, 2016. *Trichoderma* sp. recorded the highest population in July, 2015 and lowest in June, 2016. A total of 31 isolates of fluorescent pseudomonads and 3 isolates of *Trichoderma* sp. were obtained during the entire study period.

3. **Base line studies on vegetable crops under protected cultivation in Kerala as a prelude to precise disease management.**

Incidence of fungal diseases like powdery mildew, leaf spot, fruit rot, stem and fruit rot were noticed on capsicum under protected structures at various locations. Symptomatology of fungal diseases of capsicum observed during the survey was studied. The fungi associated with the diseases were isolated and the pathogenicity was proved.

Among the treatments, T4 (soil solarisation + soil application of *Trichoderma viride* +seed treatment with carbendazim+ mancozeb (2g.kg-1) + foliar spray with mancozeb (0.2 %) was the most effective for management of Cercospora leaf spot in both poly house and rain shelter, followed by T2 (soil solarisation+ seed treatment and foliar spray with *Pseudomonas fluorescens* (20g.L-1) and T1(soil solarisation+ soil application of *Trichoderma viride* and these were statistically on par. Among the treatments, T5 (soil solarisation +soil application of *Trichoderma viride*+ foliar spray with tebuconazole (0.1 %) was the most effective for management of powdery mildew in rain shelter and poly house, followed by T6 (soil solarisation +soil application of *Trichoderma*+ foliar spray with difenoconazole (0.05%) and these were on par.

4. **Plant growth promotion and root knot nematode management in tomato by *P. indica* and rhizobacteria**

The programme aims to standardize the fertigation schedule for precision farming in tomato. It also aims to assess the impact of precision farming practices on growth and yield of the crop and to work out the economics

The experiment was conducted as *in vitro* and *in vivo* studies involving interaction assay between the biological agents and the nematode pest, and *in vivo* pot culture studies. Egg hatching and J_2 mortality as influenced by treatment with rhizobacteria and their cell free extracts (CFE) were analyzed. Cell free extracts of rhizobacteria significantly reduced egg hatching and increased the

mortality of *Meloidogyne incognita* juveniles. After 72 hours, the minimum egg hatching was with CFE of *Pseudomonas fluorescens* AMB8 (22.33 %) followed by *B. amyloliquefaciens* (22.66 %) and the maximum was with *B. subtilis* (27%). Juvenile mortality was highly influenced by the cell free extracts of all the isolates. Higher rate of mortality was observed with undiluted CFE than the diluted ones. Mortality percentage ranged from 68.21% to 99.71% with highest accounted for CFE of *B. amyloliquefaciens*. Treatment with undiluted CFE of *P. indica* resulted in mortality of the J_2 by 98% and egg hatching was reduced to 23.33%.

All the rhizobacterial strains ($1x10^8$ bacterial cell/ml) negatively influenced the egg hatching (from 30 to 50%) as compared to the control (99 % hatching). Upon 72 hours of incubation, there was only 30 % egg hatching in the case of egg masses treated with *Pseudomonas fluorescens* AMB8 and in the case of *Bacillus amyloliquefaciens* it was 30.66 per cent. However, reducing the cell concentration in the test suspension of all the rhizobacterial strains had positive effect on egg hatching. Treatments with cell suspension of all rhizobacterial strainsshowed significantly low mortality of J_2 juveniles, with highest mortality for *B. amyloliquefaciens* (8.56 %) indicating less influence by the rhizobacteria as such.

Piriformospora indica showed no egg parasitism. Compatibility between *Piriformospora indica* and rhizobacteria was assessed by dual culture plate assay under *in vitro* condition and it was found that *B. pumilus* and *Pseudomonas fluorescens* AMB8 were compatible with the fungus though the test medium differed. The compatible bacteria as single inoculation and combination with *P. indica* were used for *in vivo* analysis.

Pot culture experiments using sterile planting medium with single inoculation of the selected rhizobacteria, *Piriformospora indica*, and their combinations in the presence or absence of nematode were carried out. All treatments with *P. indica* showed root colonization by the fungus. In the presence of nematode, percentage root colonization was found to be increased and the highest was for combination of *P. indica* and *P. fluorescens* AMB8. Higher biometric characteristics were observed with nematode untreated plants for all parameters. In the nematode inoculated treatments, application of combination of *P. indica and P. fluorescens* AMB8 had positive effect on leaf number, fruit number, shoot weight and root weight when compared to the control. Treatment with *P. indica* resulted in formation of less galls/plant (33.30), egg mass/root system (3.41), eggs/egg mass (306.405), number of nematodes/g of root (54.415) and final nematode population/100cc soil (58) as compared to the control plants, where the values were 142.24, 24.91, 663.54, 220.57, 294.16 respectively.

The study established the biocontrol potential of *P. indica* against root knot nematode in tomato. Application of *P. indica* in the protray seedling production ensures better performance in terms of plant growth and suppression of root knot nematode infection in the main field.

5. Standardization of techniques for cultivation of Button mushroom (*Agaricus* spp.) in Kerala.

Objective was to explore the possibility of cultivation of *Agaricus* spp. and develop a modified technique for the production of quality compost with alternative agricultural waste.

Results indicated that growth of *A. bisporus* was maximum in PDA at a temperature of 24^0 C with a pH of 6 in dark phase. Glucose and beef extract was found to be the best C and N_2 sources respectively. Compost prepared from pearl millet straw, poultry manure, urea and gypsum

overlaid with coir pith compost as casing material supported maximum growth and yield of *A. Bisporus*

6. **Immuno molecular detection and characterization of poty viruses infecting cowpea and papaya.**
   The proposed research programme aimed at the study of symptomatology and transmission of *Poty* viruses infecting cowpea and papaya, along with its biological, immunological, molecular detection and characterization.

   Transmission studies revealed that *Poty* viruses were transmitted mechanically and by insects. BICMV was transmitted through seeds, but not PRSV. Molecular study confirmed that BICMV infecting cowpea was closely related to BCMV a strain of black eye. PRSV in the present investigation was found related to PRSV isolates reported from other parts of India.

7. **Choanephora pod rot of cowpea and its ecofriendly management.**
   The objective of the present study was to study the symptomatology, etiology and ecofriendly management of Choanephora pod rot of cowpea. The ecofriendly management of the disease can be achieved by application of fish amino acid 10% or *T. virens* 10^6 cfu/ml or fungicides such as copper hydroxide (0.2%), mancozeb (0.3%) and propiconazole (0.1%) during the pod formation stage.

8. **Integrated management of anthracnose in Chilli (*C.annuum* L.)**
   The study aimed at evolving an integrated management package for the control of the anthracnose in chilli. Integrated management of anthracnose in Chilli could be achieved by seed treatment with propiconazole (1 ml / kg) or biocontrol agents like *Pseudomonas fluorescens* (10 g / kg) to prevent seed borne infection; removing infected crop debris and destroying alternative hosts such as tomato, brinjal, green gram, black gram, sesamum, ivy gourd and sweet potato, and weed hosts such as *Richardia scabra* and *Commelina bengalensis* to prevent disease incidence; and foliar spraying of propiconazole (1 ml/l) or difenoconazole (0.5 ml/l) or panchagavya (2.5 ml/l) at fortnightly intervals after the onset of the disease controls the disease.

9. **Physiological and cultural studies on blue oyster mushroom.**
   The objective of the study was to standardize the technology for cultivation of *Hypsizgus ulmarius* and to study its morphological and physiological aspects. Results revealed that blue oyster mushroom can be cultivated in tropical areas on locally available materials like paddy straw and rubber saw dust under favorable climatic conditions viz., $26\text{-}28^0$ C , more than 90% RH and good aeration . The variety is superior to the presently growing oyster mushroom in terms of yield, presence of proximate constituents and keeping quality.

10. **Integrated management of Rhizoctonia leaf blight of Amaranthus.**
    The present study aims to investigate the effect of soil solarisation, biocontrol agents, chemical activator, indigenous formulations, and new generation fungicides on growth, yield and severity of foliar blight of Amaranthus. It is concluded that soil solarisation for 31 days with the foliar application of tebuconazole (0.1%) can effectively control the Rhizoctonia leaf blight disease severity of Amaranthus with plant growth and yield promotion under field conditions.

11. **Integrated management of Anthracnose of Snake gourd (*Trichosanthus cucumeris* L.)**
    The present study aims at comparative evaluation of the efficiency of foliar application of bio-control agents and newer fungicide for the management of anthracnose (*Collectotrichum* sp.) of

snake gourd. Results revealed that the use of potassium silicate helps in the attainment of growth promotion, flowering, yield components as well as the control of anthracnose. Integration of the fungicide mancozeb with *P. fluorescens* & *Trichoderma viride* helps in improving growth and disease management under green house conditions.

12. **Strain evaluation and production technology of Shitake (*Lentinula edodis)***

The objective of the study was to exploit various strains of *Lentinula* spp. for novel production technology and their molecular characterization through physiological and molecular studies. As part of the study paddy grain was found to be the most suitable substrate for spawn production of *L.edodis* and teak wood saw dust amended with 20% wheat bran was the most efficient bed substrate. LE6 was superior in terms of biological efficiency and yield. Study recommended the adoption of a suitable cultivation package for Shiitake mushroom by using low cost substrate (hard wood saw dust) available in Kerala in plains and hilly regions

13. **Integrated management of foliar fungal diseases of culinary melon (*Cucumis me. L. var. acidulus* Naudin)**

The objective of the study was to make a comparative evaluation of the efficacy of the foliar application of fertilizers, micronutrients, bio-control agents and newer fungicides for the management of powdery mildew (*Sphaerotheca sp*.) and Colletotrichum leaf spot *(Collectotrichum sp.)* diseases of culinary melon.

The study presents the first report of the pathogen *C. fructicola* causing anthracnose of culinary melon in India. In field conditions, combination of foliar fertilizers NPK 19:19:19 (0.5%) and azoxystrobin (0.15 ml/l) along with adjuvant applied twice at 50 days interval was most effective in controlling anthracnose and also increasing the yield of the crop.

14. **Management of Bittergourd mosaic by enhancing host resistance**

Bitter gourd is one of the important vegetable crops that occupy a pivotal position among fruit vegetables. The three different viruses causing mosaic in bitter gourd are cucumber mosaic virus, pity virus and bitter gourd distortion mosaic virus. The symptoms developed by different viruses were collected under natural and artificial conditions were recorded CMV produced mosaic specks, yellow- green mosaic patches, leathery leaves and downward rolling of leaf margin. Symptoms of potyvirus infection were vein clearing, puckering, malformed leaf with reduced size and rugosity. BDMV infection produced mosaic, puckering, leaf distortion, hairy growth on leaves and vine with reduction in leaf size and intermodal length. Among 22 accessions screened three of them *viz.,* TCR 285, TCR 39 and TCR 53 were highly resistant to CMV. One accession Biliagala highly resistant to potyvirus and 11 accessions resistant to BDMV. The field experiment was undertaken for bittergourd mosaic by using defence inducers. Three different defence inducers *viz.,* salicyclic acid 25ppm, barium chloride 0.1% and pseudomonas 2 % were evaluated on the moderately resistant cultivar white long and susceptible variety Preethi. A time gap of 5-10 days after spray of defence inducers was required for development of resistance in plants. The lowest disease severity was observed in cultivar white long treated with salicyclic acid.

15. **Potential of fortified spent mushroom substrate for the management of soil borne diseases of tomato**

The major soil borne diseases associated with the tomato is damping off and bacterial wilt diseases. The diseased specimens of damping off and bacterial wilt were collected and pathogens *viz. P. aphanidermatum, P. palmivora, F. oxysporum, R. solani* and *S. rolfsii* associated with damping off and *R. solanacearum* associated with bacterial wilt were isolated. The antagonists

viz., *T. hamatum*, *T. viride* and *B. subtilis* obtained fromoyster SMS in the previous studies along with reference culture of KAU, *T. viride* and *P. fluorescens* were evaluated against soil borne pathogens of tomato.The bacterial antagonists *viz*., *B. subtilis* and *P. fluorescens* were evaluated against *P. aphanidermatum*. The maximum per cent inhibition was recorded with *P.fluorescens*. While *B. subtilis* have no effect. The *in vitro* studies against *P.palmivora* showed that *B. subtilis* was found to be best. A compatibility study was carried out with fungal and bacterial antagonist. *P. fluorescens* and *T. hamatum* were found to be mutually more compatible than others,while *B. subtilis* was found to be incompatible with all the fungal antagonists. The pot culture evaluation for the management of tomato damping off revealed that the maximum seed germination, at 7 and 14 days after fortification, was recorded in the treatment potting mixture + soil drenching with *P. fluorescens.* But 21days after sowing the maximum seedling emergence was recorded in the treatment potting mixture amended with 50 per cent SMS fortified with microbial consortium of *T. hamatum* and *P. fluorescens*. The initial inhibition in germination of seeds in the SMS supplemented treatments may be due to the coarse texture of SMS which is not favourable for seed germination. The challenge inoculation was given at 21 days sowing. The minimum disease incidence was recorded in the treatment potting mixture amended with fortified SMS with microbial consortium of *T. hamatum* and *P. fluorescens*. The highest biometric characters *viz*., root length, shoot length and plant vigour index were also recorded in the treatment potting mixture + soil drenching with microbial consortium of *T. hamatum* and *P. fluorescens*. Potential of fortified SMS was evaluated against bacterial wilt disease by pot culture experiment. The highest biometric characters were recorded on SMS supplemented treatments at different intervals. The maximum shoot length was recorded in the treatment potting mixture amended with 50 per cent SMS fortified with a microbial consortium of *T. hamatum* and *P. fluorescens*. The maximum yield and fresh weight of root were recorded in the treatment potting mixture amended with fresh SMS, while maximum shoot weight and root length were recorded in the treatment potting mixture amended with 50 per cent SMS fortified with *P.fluorescens*. The challenge inoculation was given at 30 days after transplanting. The minimum disease incidence was recorded in the treatment SMS with microbial consortium of *T. hamatum* and *P. fluorescens*. The other SMS supplemented treatments also showed reduced disease incidence. From this study it is clear that the fortified SMS opens a new way in the plant disease management. Apart from the disease management property, it also provides plant growth promotion.

16. Endophytic and epiphytic microbial diversity in major tree spices and their potential for biocontrol of total microflora

The study on "Endophytic and epiphytic microbial diversity in major tree spices and their potential for biocontrol of foliar pathogens" was carried out during 2013-2015. Endophytes and epiphytes were isolated from leaf samples collected from different locations of Kerala. An attempt has been made to identify the selected epiphytic and endophytic antagonists. The fungal antagonists were identified as *Acremonium kilense* (N ted f 2), *Phytophthora cactorum* (Nt ep f 1), *Trichoderma viride* (C1 ed f 2) and *Trichoderma harzianum* (Cn ep f 5). Three of the bacterial isolates (Nt ep b 2, Nt ed b 6, C1 ed b 2) were tentatively identified as *Pseudomonas* spp. while the other one (C1 ep b 6) as *Bacillus* sp.

17. Phenotypic and molecular characterization of *Phytophthora* inciting leaf fall of nutmeg

The study on "Phenotypic and molecular characterisation of *Phytophthora* sp. inciting leaf fall of nutmeg" was conducted & major objectives were, to study the cultural, morphological and molecular characters and variability of different isolates of *Phytophthora* sp. associated with leaf fall of nutmeg and also to study the host range of the pathogen and to chalkout suitable management strategies. In molecular characterisation, out of 18 isolates of nutmeg *Phytophthora*, 15 showed maximum homology with *P. colocasiae* and three *viz.* PPoL-3, PMaL-4 and PVaL-15 with *P. meadii.* Isolates PPaL-1, PKoL-2, PVeL-5, PKtL-6, PKaL-7, PMtL-8, PThL-9, PTuL-11, PKnl-2, PPaF-17 and PMoF-18 also showed homology with *P. citrophthora* and PMaL-4 and PSrL-10 with *P. botryosa. In vitro* evaluation of chemicals/ bio agents showed complete inhibition of the pathogen with 1 % Bordeaux mixture, copper hydroxide (2g/l), copper oxychloride (2.5g/l), Potassium phosphonate (3ml/l), combination fungicides, iprovalicarp+ propineb (1.5 and 2.0g/l), cymoxanil+mancozeb (2g/l) and *Trichoderma viride*-1, *T. harzianum* and *T. Viride-2*, the isolates from nutmeg and the reference cultures *viz. T, viride* (KAU) and *T. harzianum* (IISR).In *in vivo* experiment,all treatments were superior to control of which, spraying of 1% Bordeaux mixture + soil drenching of copper hydroxide (2g/l) and spraying of 1 % Bordeaux mixture and soil application of *T. viride* showed maximum reduction of the disease. In addition, spraying and drenching of copper hydroxide and copper oxy chloride were also found equally effective.

18. Enhancement of resistance to bacterial wilt in tomato by endophytic microbial Communities

The endophytes were isolated from root and stem of healthy tomato plants from 16 locations of north, central and south Kerala. Endophytic microbial population varied with the plant samples and the population was more in root than stem. Bacterial population was higher than fungi and actinomycetes in root and stem. Among 154 endophytes isolated, 12out of 79 bacteria, 16 out of 68 fungi, and fourout of seven actinomycetes were antagonistic to*R. Solanacearum*in *in vitro*. Among them, five bacteria, eight fungi, and two actinomycetes were promising *in planta*.Mutually compatible endophytic isolates were selected for the development of consortia and these were identified based on cultural, morphological and molecular characters. Of the five consortia tested,the one consisted of *Trichoderma viride-1*, *T. viride-2*,*T. harzianum-1*, *Bacillussubtilis*, and *Streptomycesthermodiastaticus*showed effect in reducing wilt incidence. Comparative study of the microbial consortium with individual endophytes showed the higher efficacy of consortium in reducing the wilt incidence.The endophyteswere reisolated from soil, root, and stem of tomato plants. In pot culture experiment, the consortium applied as seed treatment + seedling dip +soil application at 45 DAP showed the minimum wilt incidence.Studies on the mechanism of antagonism of endophytic isolates showed, positive reaction towards ammonia and negative for HCN and siderophore production.The volatile and nonvolatile metabolites of the endophytes inhibited the pathogen. The endophytes showed varying levels of IAA andsalicylic acid production with the maximum in *T. harzianum*-1 and *B. subtilis* respectively.

Study on the effect of secondary metabolites of endophytes on the disease indicated that, seedlings dipped first in culture filtrate for 2 h and later dipped in bacterial inoculum for30 min before planting showed the lowest per cent wilt incidence with the minimum for *T. viride-2.* Induction of systemic resistance was studied by assay of defense related compounds such as phenols, oxidative enzymes and PR proteins. The plants treated with microbial consortium

showed higher activity of the defense related compounds with the maximum in plants inoculated with both consortium and pathogen. Field evaluation of endophytic consortium against bacterial wilt showed reduction in wilt incidence of 40.85 per cent in highly susceptible variety, PKM-1, 46.94 per cent in susceptible F1 hybrid,COTH-3, and 52.81 per cent in moderately resistant variety, Mukthi. Thus, the study revealed that, the application of endophytic consortium can enhance the resistance mechanism in tomato against bacterial wilt pathogen, *R. solanacearum*.

19. Efficacy of lignophenolic compost in the suppression of soil borne plant pathogens

Lignin-tannin rich agrowastes generated from various sources poses serious threat to the environment due to lack of sustainable management practices. Decomposition is a natural process where complex organic matter is broken down into simpler compounds by the aid of various microorganisms. The exploitation of metabolic versatility of microorganisms in consortium is advantageous for the rapid decomposition of various organic wastes. Soil borne pathogens are important among the major limiting factors in agriculture that are often difficult to control with the use of chemical fungicides. Biocontrol with the use of composted organic matter has been proposed as an effective method for the management of many soil borne pathogens. With this view, we attempted on the decomposition of various ligno-phenolic agro wastes using microbial degraders and the management of two important soil borne pathogens *viz. Ralstonia solanacearum* causing bacterial wilt of tomato and *Rhizoctonia solani* causing leaf blight of amaranth.

Samples of soils and degraded substrates were collected from 57 sources of 34 locations of Kerala and Palakkad borders from Tamil Nadu for the isolation of microbial degraders. Maximum population of cellulose (562×10^{7} cfug^{-1}) and lignin (684×10^{-4} cfug^{-1}) degraders were recorded in samples of ayurvedic pharmaceutical units whereas, tannin degrader population was highest in the samples of teak plantation (680×10^{-4} cfug^{-1}). Of the two types of samples, population was found higher in degraded substrates than in the soil samples. Among the samples, those from ayurvedic units showed maximum population and diversity of cellulose, lignin and tannin degraders. Total of 378 microbial degraders which included 125cellulose, 133 lignin and 120 tannin were isolated from various samples from different locations. Fungi were the most effective degraders of cellulose, lignin and tannin with largest diffusion zones on selective medium. Actinomycetes were the predominant degraders of cellulose whereas fungi dominated the population of both lignin and tannin degraders. Major fungal degraders of cellulose, lignin and tannin belonged to *Aspergillus* spp. and *Penicillium* spp. Thirty five degraders selected from *in vitro* studies showed the ability to degrade all the three chemical components on selective medium. *In vitro* decomposition of host substrates showed that, **12** degraders of various sources were effective in degrading their host substrates with lowest maturity period. Among these, six degraders of ayurvedic waste and five of coir pith were found to be most effective with composting periods of 45 & 43 days respectively. Most of the degraders which were effective on the host substrates under laboratory condition performed well under *in vivo* condition also. Among the degraders, ALF-26, CLF-13, ECF-2, TLF-8, ECA-8 & CaLF-5 were the promising ones. The degraders which were effective on their respective host substrates also showed degrading ability of other lignin-tannin rich substrates and lowest composting period were recorded by TLF-8, CLF-13, CCB-8, CaLF-5 & ATB-1 on various substrates. All the selected degraders were found mutually compatible without any antagonistic interactions. Characterisation of degraders selected for consortium revealed fungal degraders as *Trichoderma harzianum, Paecilomyces variotii, Penicillium citrinum, P. chrysogenum, Talaromyces* sp.,

Aspergillus nidulans & A. sclerotiorum. Bacterial degraders included in the consortium were *Arthrobacter mysorens* & *Massiliatimonae*. Three actinomycetes selected belonged to *Streptomyces albus* (2) &*S. niveus* and the yeast was identified as *Candida* sp. Two different microbial consortia were developed with and without *Aspergillus* spp. Much variation was not noticed in the composting periods with and without *Aspergillus* spp. Among the two, microbial consortium –I (without *Aspergillus* spp.) recorded lowest maturity periods of35-57 days for various substrates with minimum period of 35 days in mixed substrate & coir pith under *in vitro* condition. Selected consortium was also found effective under *in vivo* conditions with maturity periods 43-65 days with mixed substrates recording lowest maturity of 43 days. Large scale composting experiments with liquid and talc formulations of microbial consortium showed maximum reduction in the composting period and mixed substrate recorded lowest maturity periods of 28 and 32days respectively. Among the composts treated with microbial consortium, ayurvedic compost was the ideal, with lowest C: N ratio (10.4:1) and alkaline pH of 8.6. Treatment with microbial consortium showed enhancement of NPK in all composts and ayurvedic compost recorded maximum of N & P (4.8 & 0.46 per cent) whereas maximum K(1.86 %) was noted in coir pith compost. The composts also recorded presence of various micronutrients. Heavy metal contamination in various composts was ruled out with only negligible presence of lead, chromium and nickel. Recalcitrant chemicals *viz*. cellulose, lignin and tannin were found reduced in the consortium treated composts and maximum reduction of cellulose was recorded in ayurvedic compost, lignin in coir pith and tannin in leaf litter compost. The inoculated degraders retained their viability during the entire composting period and were highly thermophilic in nature with temperature tolerance upto 60^{o}C. All microbial degraders included in the consortium exhibited direct antagonistic potential against major soil borne pathogens. Among the degraders, *Trichoderma harzianum* was found to be most effective against all test pathogens.

Under field conditions all composts showed better control of bacterial wilt and ayurvedic compost was the most effective with respect to disease reduction and yield. Field trials conducted against leaf blight of amaranth did not show reduction in the disease incidence. However, all compost treatments were effective in reducing disease severity. Among the composts, maximum reduction of severity and highest yield was recorded for ayurvedic compost.

Ongoing PG Projects

1. **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. Trials were undertaken
2. **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. Trials were undertaken

3. **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. Trials were undertaken

4. **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. Trials were undertaken

5. **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. Trials were undertaken

6. **Integrated management of viral diseases of bittergourd *(Momordica charantia L.)***
   The proposed research programme aims to study the occurrence and distribution of viruses in bittergourd in the cultivated areas of Thiruvananthapuram, Idukki and Palakkad, immunomolecular characterisation of viruses, screening of antiviral chemicals, products of animal, plant and microbial origin for the management of the diseases. Trials were undertaken

7. **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. Trials were undertaken.

8. **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

9. **Etiology and management of mosaic disease in ginger (*Zingiber officinale* Roscoe)**
   Objectives include to identify, characterize, clone and sequence the genes of *Ginger mosaic virus* along with the management of the disease. Trials were undertaken

10. **Identification of graft transmissible resistant factors and development of Si RNA mediated resistance in Cassava against cassava mosaic Gemini virus.**
    The proposed research programme aims at the identification of transfer of resistance factor from resistant cassava, Sree Padmanabha to susceptible Vellayani Hraswa by grafting and to develop siRNA mediated technology for the development of cassava plants resistant to *Cassava mosaic geminivirus*. Trials were undertaken

11. **Exploitation of production potential and genetic improvement of Oyster Mushrooms - *Pleurotus cystidiosus* O.K. Mill and *Pleurotus opuntiae* (Dur. and Lev.) Sacc.**
    Objectives include standardization of the technique for production of oyster mushrooms, *Pleurotus cystidiosus* and *Pleurotus opuntiae* and to study their morphological, physiological and cultural characteristics as well as nutritional and organoleptic qualities and to undertake genetic improvement by protoplast fusion. Trials were undertaken

12. Variability of *Colletotrichum* isolates inciting anthracnose in mango

The research work was approved by the FRC. Purposive sampling surveys were conducted at different locations of Thrissur and Palakkad districts. Disease samples were collected from seven selected varieties of mango *viz.* Muvandan, Neelum, Prior, Banganapalli, Alphonso, Chandrakaran and Sindhooram. Totally 30 isolates were obtained of which six isolates were from Muvandan, eight from Neelum, four each from Prior, Banganapalli and Alphonso, one from Chandrakaran and three from Sindhooram. Pathogenicity of all the thirty isolates was proved on their respective hosts and observed symptom development in two to three days.

13. Enhancement of systemic resistance to soil-borne pathogens of ginger by enriched spent mushroom substrate of *Pleurotus sajor-caju*

In vitro evaluations of micro flora of SMS against soil borne pathogens were carried and the most efficient 10 fungal and bacterial antagonists each were selected as effective antagonists of fungal and bacterial pathogen separately. Mutual compatibility of selected fungal and bacterial antagonists was carried out and two combinations of fungal and 3 combinations of bacterial antagonists were selected. Bio softening efficiency of the antagonists on SMS was evaluated and three each isolates of fungal and bacterial antagonists, 1 compatible pair of antagonists were selected for pot culture experiments. Two pot culture experiments were carried out to evaluate the efficiency of biosoftend SMS against rhizome rot and bacterial wilt diseases of ginger. The lowest rhizome rot incidence was recorded in SMS softened with P_3B_3 and $P_1F_1+M_1F_2$. The lowest bacterial wilt incidence was recorded by SMS softened with T_1F_2. SMS softened with $K_1B_1+ T_2B_1$ recorded the highest yield.

14. Enhancing bio-efficacy of *Trichoderma*spp. for the management of soil borne Fungal Pathogens

Invitro evaluation on antagonistic efficiency of selected isolates of *Trichoderma* spp. against six important soil borne fungal pathogens were carried out and among them 12 native isolates were selected for the pot culture experiment. Five isolates (Tr43,Tr76,Tr9,Tr41&Tr48) which showed better plant growth promotion and disease suppression activity were selected for field evaluation. From the field study, two isolates (Tr9&Tr43) which showed the highest bio-efficiency were selected for strain improvement by mutation and protoplast fusion technology. These isolates were identified as *T.erinaceum* and *T.asperellum* respectively by molecular characterization. The two mutants *viz.* M40M3 & K80M13 and two fusants*viz.*F2 &F4 were selected for pot and field evaluation

15. Molecular characterization of virus causing infectious chlorosis disease of banana

The research work was approved by the FRC. The present research was envisaged to study the symptoms, biophysical and molecular characterization and immune – molecular diagnosis of the virus. Development of nanobiosensors for the quick and more sensitive detection of virus was also attempted. Purposive sampling surveys were conducted in Thrissur district revealed highest disease incidence of 90 % was recorded 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.

16. **Evaluation of *Bacillus thuringiensis* isolates against *Diaphania indica* (Saund.) (Lepidoptera: Pyralidae)**
    The project was started with an objective to develop a commercial formulation of *Bacillus thuringiensis* and evaluate its bioefficacy for the management of *Diaphania indica* (Saund.).

17. **Biocontrol potential of plant associated bacteria from *Piper* spp. against *Phytophthora capsici* infecting black pepper"**

    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. Trials were undertaken.

18. **Cataloguing and documentation of fungal disease of Gerbera in Kerala**
19. **Cataloguing, documentation and management of fungal diseases of strawberry (*Fragaria* x *ananassa* Duch.)**
20. **Characterization and management of fungal pathogens of cabbage (*Brassica oleracea* var. *capitata* L.) and cauliflower (*Brassica oleracea* var. *botrytis* L.)**
21. **Management of fungal diseases of capsicum (*Capsicum annuum* L.) under protected cultivation**
22. **Characterization of *Mycosphaerella* sp. causing sigatoka leaf spot disease complex of banana in Kerala and its management.**

Name of the Project Coordination Group (13)

Postharvest Technology and Value Addition

Project Coordinator: Dr.Sheela K.B

Concluded Projects : 2 Nos
Ongoing Projects : 6 Nos

Concluded PG Projects : 2 Nos
Ongoing PG Projects : 14 Nos

Concluded Projects

1. **Transfer, demonstration and refinement of technologies for production of generic products from major fruits of Kerala**

Scientific knowledge of entrepreneurs in development of generic products was assessed. It was seen that majority of processing entrepreneurs were young with 63% belonging to 20-30 years age group. The extent of people having experience in fruit processing was less and majority had not attended any training programme in processing.

Jackfruit constitutes the major fruit tree owned by 32% processors, followed by banana (24.6%). Only 32.5% respondents were preparing processed products from major fruits, totally avoiding the minor fruits. Plastic bottles are the major packaging materials and majority gets a storage period of 0-3 months only. None of the generic products were prepared by many. Mango was the only fruit, which was available in all the districts and was utilized by the processors in all the districts. Respondents in Trivandrum had maximum awareness in processing of generic products and those in Malappuram and Wayanad the least. The survey revealed the necessity of thorough exploitation and popularization of the traditional knowledge in generic products with longer shelf life. Existing technologies for preparation of the selected generic products were refined, standardized, commercialized and disseminated. Banana peel was proved to be a potent antioxidant for enhancing shelf life of banana chips thus exploring the possibility of scientific waste utilization. The processing laboratory was renovated partially so as to establish a modern processing plant in future with a vast range of generic products of premium quality.

2. **Post harvest handling, storage and value addition in banana and pineapple for domestic and export market- GoK Plan Project**

- Harvesting bunches of 80-90% maturity is optimum for long term storage
- Fruits stored at 13°C and 90 to 95% RH(T1-T4) remained fresh and green even after 14 days of storage. There was no loss of weight. No spoilage due to post harvest rots was observed.
- Fruits kept under ambient condition (25°C and 71% RH) (T5) ripened completely when observed after 10 days of storage and were in senescent stage.
- Fruits could be uniformly ripened using ethylene treatment (1000ppm) for 24 hrs at 18°C and 90-95% RH and also under ambient conditions.
- Color development was uniform during ripening. Color, texture and flavor of fruit pulp were normal.
- Fruits reached marketable stage 48 hours after ethylene treatment.
- The same procedure can be applied to domestic produce to manage glut and price fluctuation
- Suitability of 20 banana varieties for jam preparation was studied and thirteen were found suitable. The suitability of banana varieites blended with jackfruit and pineapple pulp were also tested. The sensory evaluation done on a nine point hedonic scale of different preparations are given below. Nendran and Popoulu varieties yielded better product when blended with jackfruit or pineapple pulp. The colour of the product varied with variety used

- Of 12 varieties tested, nine were found suited for chips including 5 Nendran types.FHIA-21, TMBx 5295-1, Mysore Ethan, and Popoulu were the non Nendran varieties selected. The variety Popoulu had the highest chips recovery (33.0%) followed by the horn plantain cultivar Zanzibar(32.6%) and Big Ebanga (32.5%). Chips yield per bunch was highest in TMB x 5295-1 (7.0 Kg) followed by Popoulu(5.28 Kg).Chips produced by Popoulu closely resembled Nendran Chips.
- Twenty five banana varieites were evaluated for fig preparation.Fully ripe fruits were peeled and dried in an oven at 50-60 °C for 6-8 hrs. Kapooravalli, Nendran, Popoulu, FHIA-17, FHIA-21, Mysore Ethan, Karimkadali and Pisang Nangka produced good quality figs. The figs had a storage life of 2 months under ambient conditions and could be stored for up to 1 year under refrigeration.

Ongoing Projects

1. Postharvest characterisation and management of elite jackfruit types of Kerala

Characterization of elite jackfruit types of Kerala is underway. Around 30 elite types have been characterized to identify superior types with excellent organoleptic properties, off season types from homesteads of Kerala.

Technology for the production of minimally processed tender jackfruit has been developed. The product is cent percent edible and is in a ready-to-cook form. When packed in LDPE pouches and plastic boxes over wrapped with cling film, the product could be stored for nine days under refrigerated conditions.

Minimal processing involves a series of operations like washing, cleaning, sorting, slicing or chopping followed by pre-treatments, packaging and storage. The resultant effects of this technique are 100% edible, ready to cook product which can be prepared and consumed in less time. Moreover, it takes care of garbage disposal in urban and rural areas and thereby eliminates the problem of environmental pollution in urban areas. Tender jackfruit, widely consumed as vegetable in Kerala, is an ideal produce which can be subjected to minimal processing operations. Tender jackfruit about 45 days after fruit set, was harvested, cleaned and surface sanitized with 100 ppm chlorine for 15 minutes. The surface sanitized fruits were peeled to remove the thick rind and the hard core. Minimal processing of tender jackfruit revealed that the edible portion amounted to only 40% and the inedible parts like peel and core constituted 47.82 and 13.04% respectively. The edible portion was diced, rinsed in warm water (50 ± 2oC), followed by pretreatment with anti browning agents like citric acid and ascorbic acid (0.5%) separately, in combination with an antimicrobial agent, sodium benzoate (0.005%) for 30 minutes. The pre-treated, tender jackfruit pieces, after draining out excess surface moisture, weighing about 250g, were enclosed in two types of packaging materials viz. low density poly ethylene bags (200 gauge) and rigid plastic trays over wrapped with cling film. Tender jackfruit,

after primary processing and packaging, was stored at ambient (30 ± 5oC) and low temperature (5 ± 2oC).

Primary processed tender jackfruit treated with 0.5% anti browning agents (citric acid / ascorbic acid) in combination with 0.005% sodium benzoate, when packed in LDPE bags and plastic trays over wrapped with cling film, recorded a maximum shelf life of nine days when stored at low temperature. The same samples when held at ambient temperature became unmarketable after three days. Whole tender jackfruit (control samples) could be stored up to five days at ambient and low temperature. Physiological loss of weight increased in all the samples during storage. Control samples stored at low temperature recorded maximum physiological loss in weight. Total carbohydrate, ascorbic acid, titratable acidity and total phenols decreased during storage in all the treatments. Bacterial and fungal population showed an upward trend during storage, whereas *Escherichia coli* and *Staphylococcus aureus* could not be detected in any of the samples. Tender jackfruit when minimally processed after pre-treatment with 0.5% ascorbic acid in combination with 0.005% sodium benzoate, followed by enclosing in plastic trays over wrapped with cling film and subsequently held at low temperature (5 ± 2oC), was beneficial in prolonging shelf life and maintenance of quality.

2. Establishment of Centre of Excellence on Post-Harvest Technology-Quality control lab - State Plan Project

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.

3. Development of Animal Feed from Jack Fruit and Mango Processing Waste - State Plan Project

The feed trial in heifer was repeated with 2 levels of Jack fruit seed flour. Standard concentrate mixtures were compounded with 20 and 40 percent of jack fruit seed flour. Each group comprised of 5 animals of the age group 10 -12 months. There were 3 experimental rations and one control ration Individual feeding of animals using the concentrate mixture was carried out throughout the period of study. The duration of feeding trial was two months for heifer. The animals were fed with 2 kg feed concentrate and 4 kg straw/day and maintained under identical conditions of management.

Initial weight of the animals was recorded. Subsequent weight gain at fortnightly intervals was recorded for a period of two months . The statistical analysis of the data revealed significant weight gain in animals fed with the different rations. Highest weight gain was recorded in Ration II which was on par with control. The result of the study indicated that Jack fruit seed flour could be incorporated up to 40% in the feed concentrate for cattle completely replacing maize. The cost of production of cattle feed could be significantly reduced and nutritive value increased by incorporation of Jack fruit seed flour in the feed. The developed technology was disseminated

through 4 training programmes on processing industry waste utilization. The beneficiaries of the training programme were dairy farmers, entrepreneurs and women farmers.

4. **Establishment of centre for postharvest management and value addition for under exploited fruits and vegetables of southern Kerala.**
   - Process protocols were developed for spray dried cashew apple juice powder, jack fruit wine, fresh-cut papaya, osmo air dehydrated carambola.
   - Kerala's traditional fruit viz., karaka and water apple was utilized for product development.
   - Possibility of waste utilization in jack fruit and ash gourd was explored.
   - Potential for utilization of velvet apple (Diospyros discolor) for value addition was studied
   - Value chain management practices to reduce post-harvest loss in papaya was standardized

5. **Demonstration and training on production and distribution of Keraamrutham (Neera) and Kerachakkara from coconut inflorescence**
   Plant was functioning mainly under RF mode. Budget allotted was utilized for minor operational expenses.

6. **Value Addition and Post harvest Management under Establishing a Food Processing Value Addition Centre at RARS Pilicode - Network Project**
   Established a mechanized VCO 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.

Concluded PG Projects

1. **Extraction and utilization of anthocyanin pigments from Jamun (*Syzygium cumini* Skeels)**
   The objectives of the study were standardization of method of extraction of anthocyanin pigment and evaluation of pigment stability to pH, light, temperature, storage conditions and in processed products. Method for extraction of anthocyanin pigments from jamun was standardized. Among the four extraction methods compared, highest content of anthocyanin (61.07mg/100g), recovery per cent (13.75%), colour hue (1.30) and colour intensity (1.13) was obtained for acidified solvent extraction method (20% ethanol + 0.5% citric acid).

   The effect of light and storage conditions on pigment stability was evaluated. Storage in amber coloured bottles under refrigerated conditions was found to be best for anthocyanin pigment due to lesser degradation of the pigment compared to that stored under ambient conditions.

   The effect of temperature on the anthocyanin content was studied at 70, 80 and 90^0 C and anthocyanin content was measured at intervals 30 minutes, 45 minutes and one hour of incubation at each temperature. Anthocyanin content decreased from an initial value of 61.25mg/100g to 50.24mg/100g, one hour of heating at 90^0 C.

   The effect of pH on stability of anthocyanin pigment was studied at different pH ranging from 2.5 to 7 and incubating it for different intervals from one hour to 20 days at room temperature.

Anthocyanin content was found to decrease with increase in pH and maximum retention of the pigment was found at pH 2.5. Anthocyanin content was found to decrease from an initial value of 61.25mg/100g to 34.28mg/100g 20 days after incubation at a pH of 7.

Least changes in pH were observed in T_{10} (RTS beverage prepared with AC + 0.3% citric acid (CA) + 0.01% ascorbic acid (AA) and stored at refrigerated condition). Acidity of the RTS beverage followed an increasing trend during storage, greatest change in acidity was observed in T_8 (product coloured with synthetic colour). Ascorbic acid content was found to decrease with increase in duration of storage, minimum changes in ascorbic acid was observed in T_1 (RTS beverage prepared with 0.3% citric acid and 0.01% ascorbic acid).

RTS beverage stored under refrigerated conditions retained colour throughout the storage period as compared to ambient condition where there was a greater loss of the colour. Addition of ascorbic acid was found to hasten the colour degradation of the beverage under ambient conditions, but under refrigerated conditions there was not much change in colour.

Pigment stability in mixed fruit jam was also studied by storing the prepared product under ambient and refrigerated conditions for a period of three months. pH of the mixed fruit jam followed a declining trend during storage, least change in pH was observed in T_1 (control under refrigerated condition) during storage. There was no significant change in the colour of the mixed fruit jam stored under refrigerated conditions. A slight darkening of the colour was seen in the bottles stored at ambient condition.

In organoleptic evaluation, the products kept under refrigerated conditions recorded highest scores for flavor, texture, taste and overall acceptability three months after storage.

2. Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa spp*.)

The objectives of the study were to standardize different process variables like fruit slice shape and thickness, osmotic solution concentration and immersion time for osmo-air dehydration of Nendran banana and to optimise the conditions suitable for better mass transfer kinetics.

Optimally ripened nendran banana (cv. Kaliethan) sliced into three shapes viz. long (5cm), round and ring of thickness 5 mm, 10 mm, 15 mm were osmosed in sugar syrup of concentration (50^0 B, 60^0 B, 70^0 B) with an immersion time of 40, 60 and 80 minutes. Potassium meta bisulphite (0.1%), citric acid (0.1%), and ascorbic acid (0.2%) was added to the osmotic solution and the ratio of fruits to osmotic solution was maintained at 1:1 and temperature of osmotic solution was kept at 40^0 C with occasional stirring. Osmosed fruit slices were air dried in cabinet drier at 50^0 C till it attains moisture content of 17 ± 1 % and analysed for physical, nutritional and sensory qualities. Observations on mass transfer, physical and nutritional parameters were analysed using Response Surface Methodology (RSM) and response surface design was fitted using SAS software (ver 9.3).

Mass transfer characters viz. solid gain, water loss, weight reduction and ratio of water loss to solid gain increased with increase in concentration of osmotic solution, thickness of slices and duration of immersion time irrespective of fruit shapes. Nutritional parameters of osmosed nendran banana exhibited an increase in total soluble solids, reducing sugars, total sugars with the increase in thickness, concentration and time of immersion and a decreasing trend in acidity and vitamin C in all the three shapes. During drying, water loss, weight reduction, drying rate and rehydration ratio decreased with increase in thickness and increased with concentration and time of immersion. Whereas shrinkage (%), browning index and textural qualities like cutting force and cutting energy increased with thickness, concentration and time. Quadratic regression equation models were developed for all the responses with R^2 > 90 %. Predictive model for water loss of longitudinally sliced nendran banana is $WL= -7.01+8.77X_1+6.52X_2-0.91X_{11}-0.89X_{22}$ where X_1 is thickness, X_2- concentration and X_3 is time of immersion. Estimated minimum water loss for longitudinal slices was 15.14 % (thickness 5.54 mm, concentration 56.94 ^{0}B , immersion time 53.26 minutes) and estimated maximum water loss of 29.38 % was obtained for slices with thickness 14.09 mm, concentration 62.38 ^{0}B and immersion time 70.41 minutes. Sensory analysis of osmo-air dehydrated nendran banana was conducted by 9 point hedonic scale and analysed using Kruskall Wallis chisquare test. Based on highest rank for appearance, taste, colour, flavour, texture and overall acceptability, best ten treatments were selected for storage studies.

The selected osmo-air dried banana were packaged in 200 gauge polypropylene and stored at room temperature for 6 months and analysed at monthly interval for nutritional, physical and sensory qualities . During storage, moisture content of osmo-air dehydrated banana increased with storage from 17.51 % at the time of storage to 24.61 % after 6 months of storage. Acidity of osmo-air dehydrated fruits decreased with the storage and recorded 1.71 % and 1.12 % initially and 6 months after storage respectively. Reducing sugar increased from 44.95 % to 51.19 % whereas total sugars decreased from 55.91% to 50.65% during storage. Vitamin C of samples decreased from 27.85 (mg/100g) to 27.73 (mg/100g), rehydration ratio decreased from 1.82 % to 1.35% and browning index increased from 148.29 to 165.60 during storage. Textural qualities viz. cutting force and cutting energy were determined at 3 months interval and found that cutting force (N) increased from 34.73 to 41.76 and cutting energy (Ns) increased from 31.80 to 39.13 during storage. No microbial growth was found till the end of 6 months storage. Sensory qualities of the product decreased slightly towards the end of storage.

Second order response surface models were developed for mass transfer, drying and nutritional parameters for osmo-air dehydrated nendran banana slices of ring, round and longitudinal shapes for osmotic concentration ranging from 50 to 70^0 B with an immersion time of 40 to 80 minutes. Ripe nendran banana sliced in ring shape with thickness 5 mm followed by 10 mm and round slices with 5mm thickness osmosed in 50 B^0 sugar syrup containing 0.1% potassium meta bisulphite, 0.1% citric acid and 0.2 % ascorbic acid for a period of 40 minutes with 1:1 ratio of fruits to osmotic solution maintained at 40^0 C were observed as suitable conditions for

developing good quality osmo-air dehydrated nendran banana . The products stored at room temperature in 200 guage polypropylene packages were found acceptable and microbiologically safe up to 6 months.

Ongoing PG Projects

1. Standardization of minimal processing of Amaranthus (*Amaranthus* tricolor L.)

The study entitled "Standardization of minimal processing of Amaranthus (*Amaranthus tricolor* L.)" 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%).

2. Development of *Aloe vera* gel supplemented Ready To Serve fruit beverages.

The present study entitled "Development of Aloe vera gel supplemented Ready To Serve fruit beverages" 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 of uniform size, free from pests, diseases and mechanical damages 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 after 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.

3. **Development, packaging and storage of intermediate moisture jackfruit (*Artocarpus heterophyllus* L.)**

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.

4. **Processing quality evaluation of pickling mangoes**

Twenty one accessions (8 from RARS, Pilicode and 13 from RARS, Pattambi) were selected for the study out of which one was Chandrakaran. The programme was divided into two major experiments. Experiment I was "Evaluation of the accessions for quality" and experiment II "Evaluation of accessions for product development". 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 of these products was made at monthly intervals for three months. Microbial load was also observed in pickles 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. Polyphenol content was higher at tender stage, which decreased during maturation and 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 from0.28 to 1.4 per cent at ripe stage. 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.

5. **Value addition of passion fruit (*Passiflora edulis* Sims)**

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 0Brix), 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.

6. **Shrink wrap packaging of selected tropical fruits**

   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. PLW% 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.

7. **Post harvest studies in Neelamari (*Indigofera tinctoria* L.)**

   Harvesting trial (Experiment 1) was done in neelamari plants grown AICRP on M and AP. Physiochemical analysis at all stages was completed.

8. **Development of osmodehydrated bilimbi (*Averroha bilimbi* L.) and assessment of bioactive compound.**
9. **Postharvest handling studies for extending shelf life of rambutan (*Nephelium lappaceum* L.)**
10. **Optimization of methods for juice extraction and value addition of passion fruit (*Passiflora edulis sims)***
11. **Product development from late season cashew nut**
12. **Post harvest evaluation and management of cherry tomato (*Solanum lycopersicum L.var. cerasiforme*(Dunal) A. Gray) genotypes**
13. **Post harvest characterization and value addition of sweet lovi-lovi (*Flacourtia cataphracta* Roxv.ex. Willed.)**
14. **Evaluation and utilisation of edible lichen *Parmotrema tinctorum* (Nyl.) Hale. for food preservation**

Name of the Project Coordination Group (14)
Food Science and Nutrition

Project Coordinator: Dr. Nirmala. C

Concluded PG Projects: 8 Nos

Concluded PG Projects

1. **Development of an extruded product from raw jackfruit**

   Raw jackfruit flour and seed flour along with refined flour was exploited successfully for development of extruded product. The physical characteristics, cooking qualities, organoleptic analysis and shelf life of developed noodles were ascertained and it was concluded that refined flour, jackfruit bulb and seed flour in the ratio of 5:1:4 & 5:2:3 ratio derived high consumer acceptance with good nutritional, organoleptic and shelf life qualities

Raw jack fruit based noodles formulations

2. **Development of value added products from banana peel**

   Banana peel of cv nendran was utilized for the standardization of products viz. soup mix, ready to cook curry mix and sauce. Different proportions of ingredients and food adjuncts were used in standardization and organoleptic parameters like colour, appearance, flavor, texture and overall acceptability of three products were evaluated. Results showed that all the three products developed from banana peel were very acceptable nutritionally rich and with good shelf stability.

3. **Quality evaluation of fibre enriched cookies**

   Wheat based cookies enriched with cereal bran was evaluated for their quality parameters and glycemic index. Sweet & savoury cookies were standardized using wheat flour, cereal bran-upto to 50% level along with other food adjuncts and it was found that significant difference existed in the energy content between control and bran enriched cookies. The products were nutrient rich, high in fibre and cost effective.

4. **Development and quality evaluation of probiotic honey beverage**

Probiotic honey beverage was standardized utilizing honey, alovera and soya milk. Protocol for probiotication process was successful with 1% inoculum at pH 6.5 at 6 hours of incubation period. The developed probiotic honey beverage was found to have one week shelf life at refrigerated condition and well acceptable for consumers.

Treatments of probiotic honey based beverage

5. **Standardisation and quality evaluation of coconut based filled paneer**

Standardisation and quality evaluation of coconut based paneer was undertaken incorporating coconut milk, coconut slurry and soya milk in 20,30 and 40 per cent levels. The maximum yield of paneer was noticed in filled paneer prepared out of coconut slurry. Based on mean scores of organoleptic qualities, whole milk and coconut milk combination was the most acceptable treatment followed by skimmed milk + coconut milk & whole milk + coconunt milk + soya milk. Products were within the range of FSSAI standards specified for paneer.

6. **Development and quality evaluation of nutribars**

Nutri bars were developed with cereal flakes, dehydrated fruits, nuts and functional ingredients and evaluated the physical, chemical, nutritional, organoleptic and shelf life qualities. Nutribars prepared using glucose syrup had better mean scores in different quality attributes than nutribars prepared with jaggery honey mix. Best treatment was vacuum packed in polyethylene and laminated pouches and stored at ambient condition for six months. Microbial growth was noticed in poly ethylene pouches after third month of storage.

7. **Standardisation and quality evaluation of tender coconut based blended products**

Jam and spread were standardized using tender coconut pulp(TCP) with different fruit pulps and fruit extracts. Jam and spreads prepared using TCP and fruit pulp/extracts were found to be

organoleptically acceptable. Jam prepared with 25% TCP and 75% blended fruit pulp and spread prepared with equal quantity of TCP & plantain extract obtained maximum score for organoleptic qualities.

8. Quality evaluation of newly released KAU rice (*oryza sativa* l.) varieties and their suitability for traditional food products

Quality evaluation of newly released KAU Rice (*Oryza Sativa* L.) varieties and their suitability for traditional food products indicated that milling per cent was highest in ezhome-2 variety and highest head rice recovery obtained for Vyttila-8. Highest volume exapnsion ratio of 5.60 and highest water uptake was noticed in ezhome-2 but cooking time was more. Mo-21 and Vyttila-8 were having soft gel, low content of amy lose in these rice varieties. Newly released rice varieties were nutritionally better compared to control varieties Jyothi and Uma. For traditional food products, such as rice flakes and unniyappam Vyttila-8 was suitable. While Uma for idli, Prathyasha (Mo-21) for appam, Vaishak (PTB-60) for puttu & ada.

Name of the Project Coordination Group (15)

Agricultural Economics, Statistics and Agri Business Management

Project Coordinator: Dr. Latha Bastin

Concluded Projects: 1 No
Ongoing Projects: 4 Nos

Concluded PG Projects: 11 Nos
Ongoing PG Projects: 3 Nos

Concluded Projects

1. Cost of cultivation of major crops in Kerala

The study gives an indication of the total cost incurred in raising crops based on data from different research stations/farms under the Kerala Agricultural University. Rice, Vegetable cowpea, Amaranth, Bitter gourd, Banana, Pineapple, Cardamom, Cashew, Coconut and Pepper are the crops included in the study.

Rice: Economics of rice cultivation was worked out based on data collected from five research stations viz., CSRS, Karamana, RARS, Kumarakom, RRS, Moncompu, ORARS, Kayamkulam and RRS, Pattambi. In CSRC, Karamana total income from one hectare of rice including paddy seed and straw was Rs. 1, 64,500 resulting in a net loss of Rs. 2,895. Estimated cost of production was Rs. 26.98 per kg.

Maximum net income from paddy cultivation was observed in the Kari lands of Kumarakom, which was Rs. 76,716 per hectare. Labour cost was observed to be the major input component in cultivation, which was more than 60 per cent in all stations except Kumarakom, where it was only around 52 per cent.

Vegetables: Cost of cultivation was worked out for three vegetables, viz., Vegetable cowpea, Amaranth and bitter gourd.

Cost of cultivation of vegetable cowpea seed production worked out based on ABC cost concept revealed that Cost A was □ 2,73,094, Cost B, □ 2,79,414 and cost C □ 3,07,355. Net profit estimated at Cost A, B and C, were □ 9, 26,906, □ 9, 20,586 and □ 8, 92,645 respectively. BC Ratios were 4.39, 4.29 and 3.90.

For Amaranth Total Cost of Cultivation came to □ ***2,41,556.*** An estimation of ABC cost of amaranth cultivation showed that seed production is a highly profitable with high net profits at all costs. BC Ratios were 2.07, 2.02 and 1. 84 respectively at cost A, B and C.

The per hectare cost of cultivation of bitter gourd was found to be □ 2,40,896. Cost of labour accounted for 63.4 per cent of the total cost followed by cost of pandal materials. Net profit at cost A, B and C, were □ 1,59,104, □ 1,65,424 and □ 1.18,508 respectively and BC Ratios were more than one at all three costs.

Cashew: Data were collected from RARS, Pilicode, ARS, Anakkayam and CRS, Madakkathara for working out the cost of cultivation of Cashew. Since plantations are very old and past data were not available, cost of cultivation was worked out collecting current details. Net profit realised from cashew during 2014 were respectively Rs.25307, Rs.20233 and Rs. 47,646 at RARS, Pilicode farm, ARS, Anakkayam and CRS, Madakkathara.

Coconut: Maintenance cost of coconut cultivation was collected from CRS, Balaramapuram and RARS, Pilicode and the total income was Rs. 2,09,000 per hectare and net income was Rs. 1, 17, 606 per hectare at RARS, Pilicode.

Cardamom: Cardamom is a perennial crop and starts yielding from the 2nd year and expected to give profitable returns up to 15 years. Total expenditure at cost A was Rs.

2,78,735 during the 1st year and it ranged between 1,21,000 and 1,29,000 during the subsequent years. Even though net income at cost A was negative during the 1st year due to the establishment cost, it was positive in all the subsequent years. IRR and BC ratios were 43 per cent and 1.41 respectively.

Pepper: Data on pepper cultivation was collected from PRS, Panniyur. As data on previous years were not available, only maintenance costs were collected and analysed. Cost A, B, and C were respectively Rs. 1,50,976, Rs.1,53,191, Rs. 1,68,510 and the respective net profits were Rs.5,69,024, Rs.5,66,809, Rs.5,51,490

Banana: For working out the cost of cultivation of banana, data were collected from Banana Research Station, Kannara. Total expenditure per hectare was estimated as Rs. 8,41,769 with a net return of Rs.1,08,231.

Pineapple: Data on Pineapple cultivation was collected from College of Horticulture, Vellanikkara and PRS, Vazhakulam. Pineapple was found to be a highly profitable crop with an NPW and BC ratio of Rs.8,55,245 and 2.31, Rs. 7,12,707 and 2.31 and 5,02,327 and 2.63 respectively for variety Kew and Mauritius at CoH, Vellanikkara and Mauritius at PRS, Vazhakkulam.

The heterogeneity of varieties, soil, climatic conditions etc, in the research stations throughout Kerala explain the variability in cost of cultivation of the same crop in different stations. The cost of cultivation of crops raised for seed production is much higher than the production for the general market and returns were also high. Labour cost forms the major component of cost of all the crops. With respect to the labour also heterogeneity exists because of the difference in the wage rate and the number of labour days required for the same crop.

Ongoing Projects

1. **Impact of prominent KAU rice varieties on the economic status of farmers in Kerala and Karnataka**

The objectives of the study are 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 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) have been selected, questionnaire prepared and data collection started.

2. **Analysis of supply chain management of horticultural nurseries**

The present 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. 40 nurseries were selected by simple random sampling method and were classified with some specifications. Pre-tested interview schedules were used to collect information from sample nurseries. Secondary data were collected from KrishiBhavan, Principal Agricultural office and various published sources.

3. **Value Chain analysis (VCA) of coconut based food products**

The study was taken up to identify the value chains, price spread, profitability and marketing efficiency of coconut based value added food products using the value chain analysis framework. The study also focused on the constraints faced by various chain players and measures for improving the performance of the chains.

The study is 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. Focus group discussions were held to identify the key chain players involved in the value chain. Survey method will be used for the primary data collection.

4. **Centre for IP Protection**

The centre has so far organized 6 awareness programs in the area of IPR and its management resulting in a better awareness about IPR and its impact in Agricultural sector. PI also acted as resource person in 3 awareness programmes organised by sister concerns. Changalikodan Nendran Banana got GI registration on 25/3/2015. Registration process of Nilambur teak and Tirur Vettila are progressing. The Centre also facilitated the application of 8 farmers for Plant Genome Saviour award and 2 for community awards.

Concluded PG Projects

1. **Impact of Agro Machinery Service Centres on mechanisation of paddy cultivation in Kerala.**

Mechanisation of paddy cultivation is provided mainly through AMSCs, which provide all agro machinery operation services with respect to crop production on contract basis.

Land preparation, transplanting and harvesting are the major mechanised activities in paddy cultivation. Among the three services, AMSCs are mainly providing the mechanised transplanting service to the farmers. In Thrissur district, there are areas where farmers cannot adopt mechanised transplanting in paddy cultivation, like Kole lands and water logged paddy lands. Such farmers are adopting mechanisation only for land preparation and harvesting.

The farmers' experience in the field of paddy cultivation, reduced cost of cultivation, timeliness in farm operations and increased production are the major factors that influence the farmers to adopt mechanisation in paddy cultivation. The mechanisation index model as suggested by Nowacki indicates that users of AMSCs are adopting more mechanisation in paddy cultivation than non-users. By adopting mechanised transplanting services of AMSCs, user farmers are saving around 30 per cent of labour cost incurred in manual transplanting.

The impact of AMSCs on mechanisation of paddy cultivation among paddy farmers with respect to cost of cultivation, production and labour cost revealed that mechanised transplanting service of AMSCs has resulted in labour displacement especially in the process of transplanting. Regarding paddy production, significant difference exists between the average paddy production per hectare between the users and non-users of AMSCs, i.e. through mechanised transplanting service of AMSCs, users are getting more production with less grain loss. The labour displacement in transplanting leads to the lowest cost of cultivation per hectare among users of AMSCs.

Co-operatives, Regional Rural Banks (RRBs), Scheduled Commercial Banks (SCBs) and Non–Banking Financial Institutions (NBFIs) are the major institutions providing credit for agricultural mechanisation to the farmers by the way of loans and subsidy. Ignorance of small and marginal farmers regarding loan facilities from banks, absence of loans for mechanisation to AMSCs, and lack of EMI facility for loans from manufacturing companies are the hindrances faced by the farmers from taking loan for farm mechanisation. Hence a system of credit should be developed by financial institutions to cater to the mechanisation needs of small and marginal farmers, and AMSCs. This will promote the use of mechanisation in agriculture in an increasing scale, and ensure displacement of labourers from agricultural operations, leading to reduced cost of cultivation and increased production.

2. Economic analysis of orchid flower trade in Kerala

The objectives of the study were to study the economics of orchid cultivation in Kerala and to find out the opportunities and challenges in orchid flower trade in Kerala.

Cost of cultivation using ABC cost concepts showed that cost A1 was Rs.1, 25,585. Considering all variable and fixed costs, cost C3 came to Rs.1, 53,868. The total cost of establishment worked out to Rs.1, 49,504. The average annual return obtained from a unit of 1000 orchid plants was Rs.1, 06,789. Capital productivity analysis revealed that orchid cultivation is a viable enterprise with B-C ratio of 1.64 and net present worth of Rs.1, 37,898 and IRR of 55 per cent. Orchid cultivation was found to be more remunerative in Thiruvananthapuram compared to Ernakulam. Opportunities are optimal for new entrepreneurs to start orchid cultivation since there is high demand for orchid flowers in domestic market. Marketing is a major challenge faced by growers in cut flower production, because of the small unit size and unorganized marketing.

3. Pepper economy of Kerala in the pre and post WTO regimes.

The study was initiated to assess the structural instability of pepper over a period, to analyse the trade competitiveness of pepper in the global market, to forecast pepper exports, suggest policy measures to improve pepper trade and to analyse the changes in economics of pepper cultivation.

The study covered a period of 34 years from 1980-81 to 2013-14. The results of the instability index revealed that the instability in area, production and productivity of Pepper in Kerala was more pronounced during the post WTO period with 9.27 per cent, 17.41 per cent and 16.36 per cent respectively. The analysis of trade competitiveness using Nominal Protection Coefficient (NPC) revealed that pepper had competitive advantage in all lustrums except during 1995-96 to 1999-00.The regression of export value with area, production and productivity showed that production had a positive and significant influence on export value of pepper. The major problems faced by pepper farmers were incidence of pest and diseases, unavailability of labour and changes in climate.

During the pre WTO period the total cost of cultivation was Rs.45672.8/ha and it was Rs.298296.9/ha in the post WTO period recording an increase of 6.5 times. It was found that the cost of all major inputs like human labour, seeds, fertilizers and manures increased tremendously in the post WTO over the pre WTO period. The net returns at cost A, cost B_1 and cost B_2 and cost C showed an increase of 89 per cent, 134 per cent and 768 per cent and 754 per cent respectively during the period.

4. Adequacy of procurement price for paddy farmers in Kerala. 2015

The study was taken up to analyse the adequacy of procurement price of paddy in relation to its cost of production, to compare the procurement price of paddy with farm harvest price and to study the scale of procurement of paddy in Kerala and constraints experienced by the stakeholders in procurement.

Analysis on adequacy of procurement price in relation to cost of production for the period of 2000-05 to 2013-14 in autumn season revealed that at cost A, procurement price of paddy was adequate in all the years except 2007-08. At cost B, inadequacy was seen in all the years except 2006-07. The procurement price was also inadequate in all the years at cost C. The analysis on adequacy in winter season and summer season revealed that at cost A, procurement price was found adequate in all the years in the study period. At cost B and cost C the ratio was inadequate. Cost of cultivation and cost of production were found higher in Palakkad district with B-C ratio of 1.47 than Alappuzha district with B-C ratio 1.60. Comparing the trend analysis of farm harvest and procurement price of paddy, there was more significant growth rate for procurement price (10.94 per cent) than farm harvest price at the rate of 7.25 per cent per annum. The trend analysis of procurement price and scale of procurement revealed that there was a sharp increase in the scale of procurement of paddy at the rate of 20.03 per cent annum with increase in its procurement price. The major constraints faced by the paddy farmers in selling paddy to

procuring agency were that the amount due for procurement was available only in instalments and the amount was not given in time.

5. Ecosystem analysis of wetlands. A case study of Vellayani Lake. 2015

The objectives of the study were to assess the TEV of the wetland ecosystem of Vellayani lake by stakeholder analysis, to quantify the level of dependence of local communities on the lake for their livelihood and socio cultural services, to forecast the aggregate demand for products and services and to assess the anthropogenic forces affecting the sustainability of the system.

The income generation activities of the lake such as fishing, lotus collection and duck rearing were evaluated using the market price method and it accounted to Rs.1.83 crores/year. Provision of irrigation water by the lake valuated using opportunity cost method accounted to Rs.20.69 crores/year. The economic value of the lake was estimated using contingent valuation method which was Rs.2.91 crores/year. The mean stated willingness to pay (WTP) was Rs.225.22/yr for local residents. Based on the study, it was concluded that the major reason for degradation and loss of wetland services provided by Vellayani lake is the lack of awareness on the value of its ecosystem services, non-enforcement of property rights and lack of lake management policies. The major anthropogenic stressors on lake are unsustainable agricultural and fishing activities, watershed impact due to degradation and destruction of canals carrying water to the lake and habitat modification.

6. Determinants and dynamics of lease land farming in pineapple

Pineapple farming in the study area is mainly undertaken as an intercrop in rubber plantations. Hence, there are two major situations of lease farming ie. pineapple as an intercrop in areas which are proposed to be developed as rubber plantation for the first time (Situation I) and pineapple cultivation in slaughter tapped plantations (Situation II). The second situation includes already planted areas as well as areas where planting is to be done. In slaughter tapped areas, there are three specific systems of lease rent fixing. System I- where the rent payment is entirely as cash, System II- where the lessee plant and manage the main crop rubber, along with a cash payment and System III- where the lessee has to manage already planted rubber crop and also pay the cash .ie. the lease rent involves two components, the payment to be effected as cash and the investment towards the planting and/or management of rubber plantations. In this study 50 per cent of the respondent lessees were opting for the payment of rent as cash alone, and the rest 50 per cent opted for a combination of cash and planting and/or management of main crop..

In majority cases the lease period was 3.5 years. Most of the tenancy agreements were written as per the rules of civil contracts, and are not formally registered.

In situation I, the total lease amount was found to be Rs.2,05,499 which vary across farm sizes. The total rent was 27 per cent higher in Large Farmers (LF) group compared to Small Farmers (SF) as well as Marginal Farmers (MF). Under system I, the entire rent payment is effected as cash which averages to Rs.67031/ha/yr, thus making the total rent amount at Rs.2,01,094 during

the lease period of three years. Under system II, the total rent paid was estimated at Rs.2,41,954 of which 53.84 per cent was as cash and the rest as investment towards planting and management of rubber. In system III, the average rent was Rs.2,56,666 per hectare. About 25 per cent of the cash component was paid in the first year and in the subsequent years the payment was equally distributed.

The decision of lessor to lease out was influenced by several factors, of which the size of holding was the most important one, as revealed by the statistical analysis employing the logistic regression model. There was considerable difference in the management practices followed in the owner operated and leased-in farms. In the owner operated farms, more of organic inputs were used and as such they were more inclined towards sustainable line of farming whereas chemical fertilisers were intensively used in leased-in farms. By employing the Discriminant Analysis, out of the seven significant factors, total operational holdings, fertiliser cost and organic input cost were identified as the important factors that differentiate the owner operated and leased-in farms.

The cost of cultivation (Cost C2) in leased-in farms was estimated at Rs.4,22,114 as compared to the owned farms (Rs.3,86,139). Similarly, the yield obtained from leased-in farms was 20 per cent higher than the owner operated farms and the net income realised was nearly 12 per cent higher.

Though lease land farming is extensively being practiced in the area, both the land owners and the lessees face several problems. In case of the lessors, the anxiety on probable land degradation due to soil erosion, intensive chemical usage causing environmental hazards and abandoning the crop at low price situations were the major ones. On the other hand, difficulty in availing quality land, social resistance on application of poultry waste, exorbitant rent rates and difficulty in availing agricultural credit and subsidies were the serious problems faced by the lessees.

7. Price volatility of black pepper and its implications in Kerala

The intra-annual volatility of monthly nominal prices in rupee as well as dollar declined marginally in the post-WTO period. A similar pattern was observed for real prices with the exception of Cochin Malabar Garbled in rupee, for which it increased in the post-WTO period. In the case of international prices, the decline in intra-annual volatility was comparatively more when compared to the Indian prices. The difference between the values of the intra-year volatility indices for Malabar Garbled pepper in both Cochin (domestic) and New York (international) markets decreased in the post-WTO period. The intra-annual volatility indices for monthly prices were less than 10 per cent for all the periods under consideration.

The magnitudes of the estimated intra-annual volatility indices for weekly black pepper prices were larger in comparison with those computed for the monthly prices indicating that the weekly prices were more volatile. The weekly real and nominal prices in domestic as well as

international markets showed decrease in intra-annual volatility in the post-WTO period. The intra-annual volatility for weekly international nominal prices was comparatively lower than that for the domestic prices in pre-WTO and post-WTO periods. In the case of weekly real prices, the magnitude of within the year price fluctuations was lower for Newyork Malabar Garbled 1 in comparison with Cochin Malabar Garbled in the post-WTO period.

The results of the analysis of instability in annual prices showed that the magnitude of the volatility indices of nominal as well as real prices in both rupee and dollar increased in the post-WTO period. The annual price instability of nominal and real prices in the international market was higher than the domestic price instability in the pre-WTO period, where as in the post-WTO period, the instability in domestic prices was higher.

The determinants of price volatility identified were, (i) variations in US dollar-rupee exchange rate (ii) behaviour of black pepper prices including the seasonal and cyclical components (iii) changes in international trade (iv) futures trading, and (v) variations in domestic and world production as well as consumption.

The estimates of the GARCH (1,1) model revealed that even though the magnitude as well as significance of volatility in black pepper prices has increased in the post-WTO period in the Indian markets, there was no evidence of persistence in volatility in the domestic markets. The GARCH models for real prices showed very low volatility in the post-WTO period in the domestic market. The increase in volatility in the domestic market was clearly identifiable in the case of Cochin Malabar Garbled prices. In the case of international prices, the magnitude, significance and persistence of volatility substantially declined in the post-WTO period.

The nature and extent of price transmission between the domestic and international markets of black pepper for the pre-WTO and post-WTO periods were analysed using both pair-wise and multiple cointegration analyses. The markets were found to be cointegrated and hence, it could be established that the Indian prices moved in unison with the international prices even before liberalization and liberalization *per se* has not much improved or affected the co-movement of prices between the domestic and international markets.

The cointegration analysis proved the transmission of price signals and that there was causality at least in one direction between the domestic and international markets. The Granger causality tests carried out on monthly prices proved that there was unidirectional causality from domestic to international market in pre-WTO period and it developed into bidirectional causality in the post-WTO period. In the case of weekly prices, the existence of bidirectional causality between domestic and international markets was found in both the periods. The spot and future markets prices were also found to be cointegrated and bidirectional causality could be established between them in the long-run.

For assessing the implications of price volatility at the farm level in terms of input use, production, employment and income, primary data was collected from Idukki district as it accounted for the largest share of the area under pepper in Kerala. Two blocks in the district having largest area under the crop were purposively selected. From each of the block, purposive selection of two panchayats was made. 40 farmers each were randomly selected from the PDS and non-PDS categories, making the total sample size to 80. Data 80 farm households at two points of time in an interval of ten months.

The impact of price volatility of black pepper on producer households was studied by comparing the price, production, employment, income and number of plants replanted in two years (2014 and 2015) for PDS and non-PDS farmers. The results showed that there was slight reduction in price in 2015 when compared to 2014 for both PDS and non-PDS farmers. The decline in price of black pepper received by the non-PDS farmers was found to be marginally higher than the decline for the PDS farmers. Even though the average production of black pepper has increased in PDS as well as non-PDS farms, the growth in production was slightly high in the case of PDS farms. Hence, the non-PDS farms experienced a higher decline in income between 2014 and 2015 when compared to the PDS farmers. Consequent to the reduction in price, the number of pepper plants replanted per farm decreased for PDS and non-PDS farmers, but there was higher percentage decline in the case of non-PDS farmers (29.58 per cent). When the replanting of black pepper per hectare was considered, it was found that the number of plants replanted increased in the case of PDS members, whereas it decreased in non-PDS farms. The cost incurred on labour and inputs also showed a similar nature of increasing pattern in PDS farms and a decreasing pattern in non-PDS farms.

Linear regression model fitted to study the vulnerability of farmers to price volatility revealed that the variables like age, gender and education reduced the vulnerability to price volatility, whereas number of family members and share of income from pepper increased the vulnerability. It was also found that the membership in PDS was not a significant factor reducing the vulnerability to price fluctuations. The prices that were paid to the PDS farmers also varied with the market price and they were only paid 25-30 as premium in addition to the prevailing market price. They had the flexibility regarding the settlement of price for 50 per cent of the produce sold to PDS, which could be settled on any day within six months of handing over the commodity to PDS at the prevailing market price on that day.

Various constrains in production of black pepper were identified and ranked using Garrett ranking technique. Among the various constraints faced by pepper farmers, disease and pest incidence and climate change were ranked as the major ones. The other constraints identified were labour shortage, price variability and high wage rate

8. Impact of Green Army Labour Bank on the welfare of agricultural labourers

Green Army Labour Bank (GALB) is an organization formed as a self-sustaining group of skilled labour force fostered by the local body of Wadakkanchery block panchayat in Thrissur district of Kerala. A systematic study has been taken up with the objectives of studying the institutional structure and capital investment of GALB, to assess the impact of GALB on the welfare of Green Army Members (GAM) and farmers who avail the services of GALB. Data were collected from 40 GAM, 40 user farmers, 40 agricultural labourers who are not the members of GALB and 20 officials through personal interviews.

The membership of GALB is open to marginal farmers and agricultural labourers aged above 18 years residing in the jurisdiction of Wadakkanchery block. GALB functions on a six level hierarchy system in the order of High power committee, Executive Committee, Chief coordinator, Green Army Group, Green Army Team and Green Army Members.

Average number of working days of members of GALB showed a significant increase from 203 days per year to 225 days after joining GALB. The average annual family income of GA members showed 40.51 per cent increase at current price. The monthly consumption expenditure of GA member was increased by 54.81 per cent after joining GALB. Savings of GA members after joining GALB has also increased by 137.5 per cent.

The results of regression analysis to study the household welfare taking family consumption as the dependent variable showed significant relationship with economic category, education, age, family size, wages per month received by the members, per month contribution to outstanding loan, empowerment and number of employment days per month.

Analysis of the constraints faced by GA members showed that rigidity with time norms was the greatest constraint, followed by drudgery in using machineries and their maintenance.

A significant reduction in the number of employment days of Ordinary Agricultural Labourers (OAL) from 221 days per year before GALB formation to 166 days per year was observed consequent to the intervention of GALB. This may be due to consequent reduction in employment opportunities due to the substitution of manual labour with mechanization by GALB. The mean annual family income of agricultural labourers who were not members of GA significantly increased from Rs.92,826 per year to Rs.1,20,263 after GA. The mean monthly expenditure of the family of agricultural labourer before GA formation has significantly increased to Rs. 4686, from Rs.3,314. Nearly 43 per cent of the agricultural labourers have opined that they are not in a position to work away from their village and hence they have not joined the GALB. Many of them (35%) admitted that they were not aware of the establishment of GALB.

Due to the intervention of GALB, the area under rice cultivation in Wadakkanchery block has increased to 4559 ha in 2010-11, compared to 3161 ha in 2009-10. The mechanization

intervention has resulted in increasing the cost of cultivation from Rs.33,440 per ha to Rs. 50,736 per ha. At the same time, an increase of grain yield by 2432 kg/ha was reported by the farmers, contributing to an increase in gross income to the tune of Rs. 83,896. The BC ratio at cost A1 improved from 1.6 to 2.59 as a result of GALB intervention. The labour utilization pattern indicated a savings of 108 days per ha due to GALB in rice cultivation to the farmers.

GALB over the period has proved itself as a replicable model for supplying labour to the farming community and also for safe guarding the welfare of labourers. Through more diversified activities, undertaking lease land farming and through skill upgradation, the GALB can sustain in the future.

9. Economic feasibility of vegetable production under polyhouse cultivation

Polyhouse cultivation of vegetables is emerging as a specialized production technology to overcome biotic and abiotic stresses and to break the seasonal barrier to production. It also ensures round the year production of high value vegetables especially, during off-season. Recent statistics show that about 115 countries in the world are into polyhouse vegetable production. The area under polyhouse production is a capital-intensive technology requiring substantial initial investment, cost is the major issue in sustaining this technology.

The present study was undertaken to assess the economic feasibility of polyhouse cultivation of vegetables in Kerala. The profitability and resource use efficiency of vegetable production in polyhouse and open field situations and the factors which influence the decision making of farmers with regard to adoption of precision farming was also found. The major challenges faced by polyhouse farmers of Kerala were also enlisted.

Out of the five agro ecological zones of Kerala, central and high range zones were selected as the study area, as these zones accounted for the maximum number of polyhouses in the state. In the high range zone both Idukki and Wayanad districts and from the central zone, the districts of Ernakulam, Thrissur and Palakkad were selected. Twenty polyhouse and 20 open field vegetable farmers selected randomly from each zone formed the respondents of the study. The number of respondents in a district was fixed proportional to the total number of farmers in the district concerned. Thus the total sample size comprises of 40 polyhouse vegetable farmers and 40 open field vegetable farmers. Data were collected by personal interview method using pre-tested structured interview schedules.

The survey indicated that majority of the farmers owned polyhouses of area 400m2. Salad cucumber and cowpea were the commonly cultivated polyhouse crops in the study area. Hence, economic analyses were conducted for the crops salad cucumber and cowpea and for a polyhouse of standard size 400m2. Comparative studies were done for cowpea alone, as farmers cultivating salad cucumber in open field were not available.

Economic feasibility of vegetable production analysed using Capital Productivity Analysis revealed that production of salad cucumber in polyhouse and cowpea in open field is highly feasible and profitable. Production of cowpea in polyhouse indicated unfavourable Benefit Cost Ratio, negative Net Present Value and low Internal Rate of Returns.

The resource use efficiency of production was estimated using Cobb-Douglas production function. The best fit model for salad cucumber production in polyhouse could explain 59 per cent of the variations in the net returns per m2. The best model for cowpea in polyhouse could explain 57 per cent of variations in the net returns per m2. Increasing returns to scale was observed in the production of salad cucumber in polyhouse (1.60), cowpea in polyhouse (1.57) and cowpea in open field (2.01) conditions.

The efficiency ratio of vegetable cultivation in polyhouse and open field estimated revealed that resources are not efficiently utilized in polyhouse cultivation of vegetables to the maximum economic advantage. There was high level of agreement between the polyhouse farmers of the central and high range zone in enlisting the high initial investment involved, followed by farmers' lack of technical knowledge, non availability of technical experts in local area and non availability of premium price for produce as the major challenges faced. Higher returns to scale in polyhouse signifies its economic potential in large scale cultivation. The extension linkage has to be strengthened to aid the polyhouse farmers in selection of crops, cultivation, post harvest handling and marketing of produce.

10. Supply chain Analysis of Marine Fish Marketing system in Kerala. 2015

The major objectives of the study were to identify the supply chain of selected fish species; to assess the structure and performance of domestic fish markets; to examine the market integration and price transmission among the markets; to assess the consumer perception and suggest policy guidelines for improved fish marketing in Kerala.

The supply chain of the four high value (seer fish, shrimp, pomfret and tuna) and four low value (sardine, mackerel, anchovies and thread fin bream) fishes were studied. The generic supply chain of the selected fish species was identified and the fish species having additional nodes are discussed separately. Generally, in domestic marketing system, the fish follows a general pattern of distribution i.e., from producer to wholesalers through auctioneers and to retailers before reaching the consumers. In international marketing, agents and processors/ exporters played a vital role. Most of fishes followed the generic supply chain except sardine, thread fin bream and tuna which were used for feed preparation, surimi and sashmi grade tuna respectively.

The socio-economic profile showed that all the market functionaries are in the age of less than 50 years in both coastal and land locked regions. They were young, active and capable of performing the marketing functions. In coastal regions, functionaries had secondary level of education, while in land locked regions, majority of them completed only primary education.

The profile of domestic fish markets in the both coastal and land locked regions showed that each market has different structure and there are variations based on type of markets, timing, number of consumers visited per day. It was observed that the majority of markets lacked basic marketing infrastructural facilities for effective market functions. The performance of fish markets was assessed through the performance of producers, wholesalers and retailers using Data Envelopment Analysis (DEA).

There were differences in technical efficiency of market functionaries between DMUs, between districts and regions selected for this study. Based on the technical efficiency scores, producers performed well in Ernakulam districts and both wholesalers and retailers performed well in Kollam district. The low performance of DMUs was due to scale inefficiency (units are operated below economies of scale). The technical efficiency was influenced by the average daily revenue (AVR) and Average quantity sales (AQS) by the respective market functionaries. Improving the infrastructure facilities at the markets will improve their performance.

Price transmission and market integration was studied using co-integration analysis. The Augmented Dickey Fuller (ADF) test was used for testing the stationarity of price series of selected fish species. The Johansen Co-integration test showed the number of possible co integration equations derived and the same was estimated for Error Correction Mechanism (ECM) to explore the long run equilibrium. The result explained low degree of long run equilibrium in price series of co-integrated markets. The impact of market concentration index found that markets showed only short run integration.

The consumer perception towards fish purchasing behaviour was analysed from their fish consumption pattern i.e., place of fish purchase, species and product preference. The determinations of consumer preferences on fish purchase were analysed using conjoint analysis. The attributes viz., species and income were the attributes relatively deciding the consumer preference of fish in Ernakulam, Kollam and Idukki districts, While in Pathanamthitta, it was determined by income and price.

Based on Rank Based Quotient (RBQ), the constraints of the producers, wholesalers, retailers and consumers were ranked and prioritised. The major constraints of market functionaries were middlemen intervention, poor road facilities and lack of infrastructure facilities. Formaldehyde contamination and high fish prices were the constraints expressed by the consumers.

11. Economic analysis of production and marketing of organic vegetables in Wayanad district.

The study was taken up with the objectives of studying the economics of organic vegetable production, consumer preference and marketing of organic vegetables. The crops selected were yard long bean and bitter gourd. For organic yard long bean, cost A was Rs.150277/ha and cost C3 was Rs. 591042/ha. For conventional yard long bean crop, cost A was Rs.146277/ha and cost C3 was Rs.471498/ha. For organic bitter gourd cost A was Rs.159077/ha and cost C3 was worked out to be Rs.785405/ha. For conventional bitter gourd crop, cost A was Rs.221059/ha

and cost C3 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. Over utilization of manures, bio-fungicides, family labour, hired labour was observed in organic yard long bean farmers and under utilization of seed and pesticides was seen in case of conventional yard long bean farmers. Under utilization of seeds and manures and over utilization of hired labour, family labour, bio pesticides, bio fertilizers and bio fungicides were observed in organic bitter gourd farmers. Under utilization of seed, pesticides and over utilization of hired and family labour, fertilizers, manures and fungicides were seen in case of conventional bitter gourd farmers.

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. For organic yard long bean, the coefficient of determination was 0.74. Out of the variables selected, only seed quantity and hired labour were observed to be statistically significant and positive. For conventional yard long bean, coefficient of determination was 0.77. Out of the variables selected, quantity of the seed used, hired labour number, family labour quantity and quantity of pesticide applied were observed to be statistically significant and positive.

Ongoing PG Projects

1. **Economic analysis of production and marketing of organic vegetables in Wayanad district.**

   The study was taken up with the objectives of studying the economics of organic vegetable production, consumer preference and marketing of organic vegetables. The crops selected for the study were yard long bean and bitter gourd. Organic vegetable growers have been selected and data is being collected with the help of pretested questionnaires.

2. **Economics of dairying in Thrissur District**

   Collection of data in progress.

3. **Pre-harvest forecasting models and trends in production of banana (*Musa* spp.) in Kerala.**

   The project aims to build models to predict yield of banana with the help of minimum number of variables as possible in early stages of growth. Best prediction models will be selected based on the significance of the model, R^2 (coefficient of determination), which explains the variation in dependent variable due to independent variables. Models for Nendran, Robusta, Red banana and Njalipoovan cultivars will be developed.

Name of the Project Coordination Group (16)

Agricultural Extension and Development Studies

Project Coordinator: Dr. Kishorekumar. N

Concluded PG Projects: 5 Nos

Concluded PG Projects

1. Specifications of an integrated information system for micro level planning in agriculture: a user-centered analysis

Micro level planning is a dynamic process which involves planning at the grassroots level taking into consideration the individual, family and category of the community. Considering the diversity of crops and the geographical and socio- economic characteristics of agriculture, micro level planning has been suggested as the best way to plan agricultural development projects. Kerala has evolved a robust mechanism for micro level planning through democratic decentralization. Micro level planning is highly information intensive and it requires information flow from different hierarchical levels. This study appraised the current status of micro level planning in agriculture in Kerala with respect to use of databases and information. The study tried to characterize the legacy databases and types of information used for this purpose, with focus on availability and completeness of data. Along side, 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. The study employed an ex-post facto design to suit the objectives. Sample included 132 respondents, with 66 officers of the Department of Agriculture working with the GramaPanchayat, Block Panchayat and District Panchayat selected and 66 People's Representatives who were Chairmen of the working groups on agriculture at the rate of one from each local body. In order to find out the legacy databases available at the local level, details of various registers kept in KrishiBhavans and Grama Panchayaths were compiled and classified. Krishi Bhavans maintained 140 registers under six major categories and Grama Panchayats were found to maintain171 registers under 23 categories. The registers were classified based on practical use, nature of data entry, mandatory nature and based on purpose. Registers were again categorized based on the frequency of updating, number of data fields, completeness, subsectors of agriculture and adequacy. The data support provided by legacy registers for different stages of micro level planning viz., resource appraisal, planning, beneficiary selection, implementation, monitoring, evaluation and follow up was also explored. 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 updating 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.

2. Transition to organic agriculture in Kasaragod District: A multi dimensional analysis

Following the widely reported issues of ‘endosulfan’ victims in Kasaragod and in view of the increasing concerns on the impact of indiscriminate use of pesticides, the Government of Kerala has banned the use of chemical inputs for plant protection in Kasaragod district, as a pilot initiative and declared it as ‘organic district’ in 2012.While activists and a section of farmers supported the ban and conversion to organic agriculture, a considerable section of the farming community and extension personnel were apprehensive of the functional difficulties involved in conversion. 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 historical review showed that organic policy of the state and the pilot project evolved from the recommendations of various committees and commissions that had examined the reports on congenital malformations and diseases reported widely from Kasaragod since 1979. 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.

3. Enhancing livelihood security and local socio economic development through Mahatma Gandhi national rural employment guarantee scheme : An analysis

The Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) is widely appreciated as a unique attempt towards empowering rural poor through assured employment on demand. The programme guarantees at least 100days of wage employment in every fiscal year to the adult members of all households who volunteer to do unskilled manual labour at the minimum wage rate specified by the state government. MGNREGS which was initially launched in 200 districts was later extended to 130 districts. The scheme intends to use this man power for constructing productive assets and conserving natural resource with a view to facilitate agricultural production. Taking this into consideration, 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 employed ex-post facto design based on the objectives. Out of twenty three districts, six districts were selected randomly. One Grama Panchayat from each district was selected randomly for the study. Five beneficiaries of MGNREGS, five implementing officers and five people's representatives were randomly selected from each Grama Panchayat to make the sample size 90. .The final interview schedule was prepared by necessary modifications, additions and deletions based on pre-tested results. Percentages, paired 't' test, Kendall's coefficient of concordance and Mann-Whitney U Test were used for analyzing the data. The data were analyzed using Statistical Package for Social Science (SPSS). 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. 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. Accomplishing food security through community based initiatives in Thrissur: A participatory analysis

Food security has become a matter of serious concern the world over. Recently in Kerala there is an increased emphasis on community-based organizations (CBO) as a means of increasing agricultural production and thereby food security. The study intended to appraise the nature and relative role of CBOs 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 GramaPanchayat 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.

5. Impact of the Rice Variety, Uma (MO 16) on Farmers

Rice is the staple food of the people of Kerala, and traditionally, the cultivation of rice has occupied pride of place in the agrarian economy of the state. Palakkad and Alappuzha are the two major rice-producing districts of Kerala. About 600 varieties of rice were grown in the sprawling paddy fields of Kerala. One of the most popular rice varieties of Kerala is Uma (Mo.16) developed by the Rice Research Station, Moncompu of Kerala Agricultural University and it occupies more than 60 percent of the paddy cultivation area in Kuttanad region.

The study intended to analyse the attributes of the rice variety, Uma (Mo16) vis-a-vis other rice varieties as perceived by farmers and to assess the socio economic impact of Uma on rice cultivating farmers.

The study was confined to Kuttanad tract of Alappuzha. An ex-post facto research design was adopted for the study. Five *padasekharams* were selected through simple random sampling method, and from each *padasekharam,* 20 farmers cultivating the rice variety, Uma were selected, thus constituting a sample size of 100. A pretested structured interview schedule and PRA techniques were employed for data collection.

The results revealed that tolerance to pests and diseases was ranked first with an index of 94.60followed by non-lodging nature of plant (92.60), non-shattering nature of panicle (86.70), amenability to mechanization (75.40), millers' preference(49.60) and cooking quality (42.00).

Varietal comparison of other rice varieties prevalent in Kuttanad area with 'Uma' using PRA technique revealed that 'Uma' was perceived as the superior variety with a score of 520.42 followed by Jyothi (443.95) and Prathyasa(418.72).

Results of SWOC analysis done using PRA techniques, revealed that among the strengths, 'high yield 'ranked first with an index of 98.80 followed by 'tolerance against pest and disease incidence'(96.00),'high grain weight'(91.00), 'high tillering capacity' (89.00) and 'high seed dormancy' (85.2). However, low cooking quality (96.10) and less preference of the rice variety by millers (94.2) were emerged as the major weaknesses.

It was, also found that all the respondents were continuously cultivating 'Uma' without any varietal shift. Majority (56 per cent) of the farmers had been continuously cultivating the rice variety, Uma for the past 15-17 years.

With regard to the social impact on farmers, it was revealed that social participation has improved significantly. Similarly, information seeking behaviour has also increased positively, where as labour use has decreased significantly. However, there was no significant change in the communication behaviour of farmers. As regards economic impact, 'annual income', 'family expenditure', 'savings' and 'asset creation' of farmers have increased significantly after cultivation of the rice variety, Uma as compared to pre-Uma period. Indebtedness of farmers was also found to have decreased. Thus, the rice variety Uma could make a very promising impact on the socio- economic variables of farmers.

Regarding comparative income advantage of Uma, it was found that this variety had an income advantage of Rs.38000/- per ha over the variety, Jyothi and Rs.95000/- per ha over local varieties. Thus, for a single *puncha* season, Uma had given an additional income of Rs.104.30crores as compared to Jyothi and Rs.260.75 croresas compared to local varieties, in Kuttanad tract of Alappuzha alone.

With regard to constraints faced by Kuttanad farmers, ‘non-availability of labour’ was ranked first with an index of 98.60 followed by ‘high cost of inputs’ like fertilizers and pesticides (89.60), ‘vagaries of weather and climatic conditions’ (81.20) and ‘non fixing of floor price on time’ (70.80).

Name of the Project Coordination Group (17)

Sugar crops and Tuber crops

Project Coordinator : Dr. Sheela K.R

Ongoing Projects: 16 Nos

Ongoing PG Projects: 3 Nos

Ongoing Projects

1. **Agronomic evaluation of promising sugarcane genotypes**

   The experiment was conducted with three promising cultures from AVT at three nitrogen levels of 75, 100 and 125% of the recommended dose. Even though no significant effect on germination resulting from the genotypes and nitrogen level was visible, considerable effect on tiller count was seen and the genotypes V_2 , CoSnk 08101,recorded higher value compared to others. Interaction effect of the genotypes with N was significant for cane length, MCC, CCS% and cane yield and the maximum values for the said parameters were recorded by V_2 when 125 % of the recommended dose of N was applied. Among the treatment combinations, the highest BC ratio of 1.40 was recorded by V_2.

2. **Impact of integrated application of organics and inorganics in improving soil health and sugarcane productivity**

   In plant crop, 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 and resulted in maximum yield. With regard to ratoon crop also, the same trend was visible where T_8 itself recorded the highest values for cane length), MCC, cane yield and sugar yield.

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 was recorded by T_2 (planting of setts after overnight soaking in water).

4. **Identification of pathotypes of red rot pathogen**

   All the isolates tested exhibited more or less similar reaction to red rot as that of the standard isolate and hence it is concluded there is no emergence of new pathotype of red rot pathogen in this zone.

5. **Evaluation of zonal varieties for resistance to red rot**

   Initial Varietal Trial (Early): Out of the 15 entries tested in the IVT (Early) trial with the standard isolate CFO6, eight varieties *viz*., Co12003, Co 12006, Co 12008, CoM 12072, Co 12001, Co 12082, CoT12367 & CoT 12366, showed moderate resistance (MR) reaction

   Out of the 15 entries tested in the IVT (Early) trial with the standard isolate cf94012-0, nine varieties *viz*., Co12003, Co 12006, Co 12008, CoM 12072, Co 12001, Co 12082, Co 12081, CoT12367 & CoT 12366, showed moderate resistance (MR) reaction.

   Initial Varietal Trial (Mid late): Out of the 17 entries tested in the IVT (midlate) trial with the standard isolate CFO6, eight varieties *viz*., Co 12009, Co 12012, Co 12014, Co 12016, CO

12017, Co 12019, Co 12086 & Co 12073 showed moderate resistance (MR) reaction. Out of the 17 entries tested in the IVT (midlate) trial with the standard isolate cf 94012-0, one variety *viz.*, Co 12014 showed resistance (R) reaction, eight varieties *viz*., Co 12009, Co 12012, Co 12016, CO 12017, Co 12019, Co 12086, VSI 12121 & Co 12073 showed moderate resistance (MR) reaction.

Advance Varietal Trial (Early) I Plant: Out of the eleven entries tested in the AVT (Early I Plant) with the standard isolate CFO6, six varieties *viz*., CoT 10367, Co 10027, Co 10026, Co 10006, Co 10005 and Co 10004 showed moderately resistance (MR) reaction. Out of the eleven entries tested in the AVT (Early I Plant) with the standard isolate cf 94012-0, seven varieties *viz*., CoT 10367, Co 10027, Co 10026, Co 10024, Co 10006, Co 10005 and Co 10004 showed moderately resistance (MR) reaction. **Advance Varietal Trial (Early) II Plant:** Out of the six entries tested in the AVT (Early II Plant) with the standard isolate CFO6, one variety *viz*., Co 09004 showed resistance (R) reaction. Out of the six entries tested in the AVT (Early II Plant) with the standard isolate cf 94012-0, one variety *viz*., Co 09004 showed resistance (R) reaction, one variety *viz* ., CoN 09072 showed moderate resistance (MR) reaction. **Advance Varietal Trial (midlate) I Plant:** Out of the thirteen entries tested in the AVT (midlate I Plant) with the standard isolate CFO6, eight varieties *viz*., Co 09009, Co 10031, Co 10033, CoT10368, Cot 10369, CoVc 10061, PI 10131, PI 10132 exhibited moderately resistant (MR) reaction. Out of the thirteen entries tested in the AVT (midlate I Plant) with the standard isolate cf 94012-0, ten varieties *viz*., Co 09009, Co 10015, Co 10031, Co 10033, Co 10083, CoT 10368, CoT 10369, CoVc 10061, PI 10131, PI 10132 exhibited moderately resistant (MR) reaction.

6. Survey of sugarcane diseases naturally occurring in the area on important sugarcane varieties

In the current year (2015–16), the most predominant disease was the foliar disease *viz*., ring spot but was not found in a severe form so as to cause any drastic yield loss. Sheath blight due to *Rhizoctonia solani* was also observed in the field. However, no severe infestation on the plants was observed. Proper field sanitation and detrashing controlled the disease. The other diseases observed as usual were rust, mosaic as well as Pokkah Boeng. But none of the diseases were in a severe stage to cause any drastic yield decline.

7. Initial Varietal Trial – Early

CCS (t/ha): Clone Co 12006 (7.45 t/ha) recorded highest CCS (t/ha) among the entries followed by CoN 12071 (6.81 t/ha), CoT 12367 (6.67 t/ha), CoM 12082 (5.87 t/ha), Co 12007 (5.53 t/ha) and CoT 12366 (5.53 t/ha) and on par with best standard Co 85004 (6.15t/ha)

Cane yield (t/ha): Clone Co 12006 (58.75 t/ha) recorded highest cane yield (t/ha) among the entries followed by CoN 12071 (56.25 t/ha), CoT 12367 (51.67 t/ha), CoM 12082 (51.25 t/ha), Co 12007 (44.17 t/ha), CoT 12366 (43.06 t/ha), Co 12003 (40.00 t/ha), CoN 12072 (39.72t/ha) and Co 12008 (37.36 t/ha) and on par with best standard Co 85004 (48.33 t/ha)

CCS % (10m): Clone CoT 12366 (12.88) recorded highest CCS % (10m) among the entries followed by CoT 12367 (12.80), Co 12006 (12.68), Co 12007 (12.51) and CoM 12083 (12.44) and on par with best standard CoC 671(12.91)

Sucrose % (10m): Clone CoT 12366 (18.62) recorded highest sucrose % (10m) among the entries followed by CoT 12367 (18.52), Co 12006 (18.29), Co 12007 (18.07), CoM 12083 (17.96) and CoN 12071(17.51) and on par with best standard CoC 671 (18.63)

8. Advanced Varietal Trial (Early I Plant)

CCS (t/ha): Highest CCS (t/ha) was recorded by clone Co 10026 (8.72) and on par with best standard CoC 671 (9.45). Cane yield (t/ha): Highest cane yield (t/ha) was recorded by clone Co 10026 (68.33) and on par with best standard CoC 671 (78.08)

CCS % (10m): Among the entries, highest CCS% (10 month) was recorded by CoT 10367 (13.38) followed by Co 10026 (12.80), Co 10004 (12.51), Co 10027 (12.48) and Co 10005 (12.26) and on par with best standard CoC 671 (13.10)

Sucrose % (10m): Among the entries, highest sucrose % (10 month) was recorded by CoT 10367 (19.19) followed by Co 10026 (18.38), Co 10004 (17.93), Co 10027 (17.86) and Co 10005 (17.57) and on par with best standard CoC 671 (18.82)

Brix % (10 m): Among the entries, highest brix % (10 month) was recorded by CoT 10367 (21.3) followed by Co 10026 (20.5), Co 10004 (19.9), Co 10027 (19.8) and Co 10005 (19.5) and on par with best standard CoC 671 (21.0). The trial was severally affected by root grub and sheath and shoot rot

9. Advanced Varietal Trial (Early II Plant)

CCS (t/ha): Highest CCS (t/ha) was recorded by clone Co 09004 (13.89) followed by CoN 09072 (12.77) and on par with best standard Co 85004 (12.35). Cane yield (t/ha): Highest cane yield (t/ha) was recorded by clone Co 09004 (105.63) followed by CoN 09072 (96.14) and on par with best standard Co 85004 (96.58). CCS % (10m): Highest CCS% (10 month) was recorded by clone CoN 09072 (13.31) followed by Co 09004 (13.15) and on par with best standard Co 85004 (12.77)

Sucrose % (10m): Highest sucrose % (10 month) was recorded by clone CoN 09072 (19.08) followed by Co 09004 (18.87) and on par with best standard Co 85004 (18.81)

Brix % (10 m): Highest brix % (10 month) was recorded by clone CoN 09072 (21.20) followed by Co 09004 (21.03) and on par with best standard Co 85004 (20.35).

10. Advanced Varietal Trial (Early - Ratoon)

CCS (t/ha): Highest CCS (t/ha) was recorded by clone CoN 09072 (10.44) and on par with best standard Co 85004 (10.43)

Cane yield (t/ha): Among entries, highest cane yield (t/ha) was recorded by clone CoN 09072 (78.65) and on par with best standard Co 85004 (80.00)

CCS % (10m): Highest CCS% (10 month) was recorded by clone Co 09004 (13.35) followed by CoN 09072 (13.27) and on par with best standard Co 85004 (13.07)

Sucrose % (10m): Highest sucrose % (10 month) was recorded by clone Co 09004 (19.14) followed by CoN 09072 (19.03.87) and on par with best standard Co 85004 (18.81)

Brix % (10 m): Highest brix % (10 month) was recorded by clone Co 09004 (21.3) followed by CoN 09072 (21.2) and on par with best standard Co 85004 (21.1)

11. Initial Varietal Trial (Midlate)

CCS (t/ha): Among entries, highest CCS (t/ha) was recorded by clone Co 12021 (9.31), VSI 12121 (8.49), Co 12009 (7.49), Co 12016 (7.47) and CoT 12368 (7.38) on par with best standard Co 99004 (9.54)

Cane yield (t/ha): Among entries, highest cane yield (t/ha) was recorded by clone Co 12021 (73.47) and on par with best standard Co 99004 (80.14). CCS % (10m): All the entries were on par with best standard Co 86032 for CCS% (10 month). Sucrose % (10m): No significant difference were observed among the entries and standards. Brix % (10 m): No significant difference were observed among the entries and standards

12. Advanced Varietal Trial (Midlate I Plant)

CCS (t/ha): Highest CCS (t/ha) was recorded by clone CoVC 10061 (7.81), Co 10015 (7.33), Co 09009 (7.20), CoT 10369 CoT 10369 (6.32), CoM 10083 (5.82) and Co 10033 (5.70) on par with best standard Co 99004 (6.82)

Cane yield (t/ha): Highest CCS (t/ha) was recorded by clone CoVC 10061 (59.17), Co 10015 (57.64), Co 09009 (53.75), Co 10033 (47.37) and CoT 10369 (46.12) on par with best standard Co 99004 (56.25). CCS % (10m): No significant difference were observed among the entries and standards. Sucrose % (10m): No significant difference were observed among the entries and standards. Brix % (10 m): No significant difference were observed among the entries and standards

13. **Performance of improved short duration tapioca varieties under different population densities in flood prone upper Kuttanad area**

    Farm trial for varietal evaluation was conducted in 13 different locations coming under Pathanamthitta and Alappuzha districts during 2015-16 under a spacing of 75X75 cm and Vellayani Hraswa as check.A similar trend was noticed in the farm trial also where Vettikavala Local recorded significantly superior higher yield compared to the check.The mean yield recorded by the Vettikavala Local was 55.60 t/ha whereas Vellayani Hraswa recorded only 33.64 t/ha.

14. **Standardisation of agronomic techniques for minisett cultivation of elephant foot yam (*Amorphophallus paeoniifolius* Dennst. Nicolson)**

    The objective of the project is to standardise the spacing and nutrient package for minisett raised *Amorphophallus* under pure crop and intercrop situations in homesteads and to assess the response of minisetts to organic nutrition in homesteads. The first year experiment on standardization of spacing and NPK dose for minisett Amorphophallus was laid out in farmer's field at Kottarakkara during May 2014 in RBD. Minisetts of 100-150 g were used for planting. The yield data revealed that a wider spacing of 60 cm x 60 cm with a nutrient level of 80: 40: 120 kg NPK ha^{-1} in two splits (45 and 105 DAP) recorded higher yields of corms compared to the closer spacing of 60 cm x 45 cm. The second year crop for confirmatory studies has been laid out and treatments imposed. Intercrop of minisett Amrophophallus in banana and coconut was also initiated.

15. **Performance of cassava varieties in lowlands**

    The experiment to evaluate the performance of released and local varieties of cassava in the lowlands in the Instructional farm, CoA Vellayani during 2015-16. The experiment was laid out in RBD with eight treatments and 3 replications as envisaged in the technical programme and planting was done during the first week of March.

16. **Exploitation of under-utilized root and tuber crops for food and nutritional security**

    The survey on under exploited tuber crops in Thiruvananthapuram district was completed and the collected underutilized root and tuber crops were analyzed for their nutritive values.

Ongoing PG Projects

1. **Weed management in cassava (*Manihot esculenta* Crantz)**

   The crop was planted in May 2015 and has been harvested. Chemical and statistical analyses are in progress

2. **Crop-weather-nutrient relations in cassava under moisture stress**

   Field experiment is in progress

3. **Tillage and nutrition for productivity enhancement in tannia (*Xanthosoma sagittifolium* (L.) Schott.)**

   Field experiments have been completed. Statistical analysis in progress

Faculty – Agricultural Engineering

Name of the Project Coordination Group (01)

Farm Power Machinery & Energy

Project Coordinator: Dr. V. Ramachandran

Concluded PG Projects: 6 Nos

Concluded PG Projects

1. **Development of low cost electrostatic spray-charging system for liquid formulations**

   An electrostatic induction spray charging system as an attachment to powered knapsack mist-blower was developed. A high voltage generator was fabricated on the basis of Cockroft-Walton voltage multiplier principle with input of 6 volt DC battery to provide high voltage required at the developed charging electrode assembly (Model III, Model IV, and Model V) for inducing electrostatic charge on the spray droplets. The three working models were evaluated for charge to mass ratio. The model V with electrode voltage potential at 5 kV and EPP (Electrode Placement Position) at 5 mm showed the maximum CMR (Charge to Mass Ratio) value (1.088 cMc kg^{-1}). The droplets size was observed between 100 and 200 micrometers. The efficiency of the deposition system was observed within the range of 60 to 70 per cent.

2. **Ergonomic investigations on hand arm vibration of brush cutter for the development of a vibration reducing aid**

   The ergonomic aspects and hand transmitted vibrations of brush cutters were studied in six selected subjects who were experienced in operation of brush cutter (3 males and 3 females). A suitable vibration reducing aid for brush cutter was designed and fabricated which could easily be attached and detached from the brush cutter shaft. The ergonomic aspects and hand transmitted vibrations of brush cutters were studied for two types of brush cutters i.e., 4 stroke and 2 stroke engines with four different cutter heads, viz. nylon rope, two blade, three blade, and circular blade. The experiment was conducted for 2-stroke and 4- stroke engine models of brush cutters. It was found that the developed vibration reducing aid, blade and type of internal combustion engine had significant effect on vibration excitation in both right and left handles of brush cutter. The ergonomic analysis of male and female subjects using brush cutter observed that the Oxygen Consumption and Basal Metabolic Rate (BMR) is higher for male workers compared to female workers. Highest value for O_2 consumption and BMR obtained for male worker is 1.3906 L and 1612.980 kcal/day and the minimum value for female worker is 0.6997 L and BMR of 811.499 kcal/day respectively.

3. **Development of seedling uprooting unit for system of rice intensification**

   A seedling uprooting machine for system of rice intensification was developed. The machine consisted of four major components viz. bed cutting tool, conveyor unit, main frame and power unit (4 hp gasoline engine). The field evaluation of the machine was conducted and it was found that the cutting angle of 30ºC with engine speed of 2000 rpm was best for the effective seedling uprooting in terms of bed thickness, time of operation, wheel slip, and plant damage. The theoretical field capacity and field efficiency was found as 163.33 m^2h^{-1} and 81.2% respectively.

4. **Investigations on energy conversion of waste coconut water through an up-flow anaerobic hybrid bioreactor**

   Performance evaluation of a high rate bioreactor viz. up-flow anaerobic hybrid bioreactor (UAHBR) for biomethanation of Waste coconut water (WCW) was undertaken. The performance of experimental UAHBR was evaluated at HRTs of 15, 12, 10, 8 and 6 day. Reactor

was stable in operation during 15, 12, 10, 8 and 6 day and exhibited high process efficiency characterised by good organic reduction and biogas production. The maximum daily biogas production and volumetric biogas production were 114 L and 877 $L.m^{-3}$ for 6 day HRT, respectively. The maximum specific biogas production and productivity were 225.73$Lkg^{-1}TS_{added}$ and 8.7 $L.L^{-1}$ during 15 day HRT.

5. **Investigations on the adaptability of wireless sensor networks (WSN) based technology for harvesting crops**

   Evaluation of mechanical and biometric properties of plants and fruits which influence the mechanical harvesting was done. Investigations were taken up for development of a mechanical harvester working on the principle of linear actuators with components having three degrees of freedom.

6. **Design, Development and Testing of A Tractor Drawn Semi - Automatic Rhizome Planter for Ginger and Turmeric**

   A tractor drawn semi-automatic horizontal disc planter was developed and field tested. The rhizome planter was designed to suit various soil type 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 mean spacing for ginger and turmeric was ranged from 21.66 to 32.63 cm and 20.53 to 31.13 cm respectively. The optimum performance for planting ginger and turmeric were at a forward speed of 0.97 km hr-1 and transmission ratio of 1:1.25. The average field capacity and efficiency was 0.14 ha hr-1 and 78.76%. The savings in cost and time for mechanical planting was about 59.52% and 96.57% compared to manure planting. Based on the performance evaluation results, it is concluded that the developed rhizome planter is economical and efficient for rhizome planting.

Name of the Project Coordination Group (02)

Soil and Water Engineering (SWE)

Project Coordinator: Dr. Visalakshi K.P

Concluded Projects: 2 Nos
Ongoing Projects: 4 Nos

Concluded PG Projects: 6 Nos

Concluded Projects

1. **Comparative evaluation on the yield performance of salad cucumber under Naturally Ventilated Poly House (NVPH), rains helter and open field**.
   The experiment started in January 2015.Salad cucumber showed better yield in polyhouse than rainshelter and open field. The yield obtained from polyhouse was 8.32 kg/$m^2$with average fruit length of 20.5 cm and 6.23 cm average fruit diameter.



2. **Standardization of irrigation and fertigation requirement for Tomato under rain shelter.**
   The newly released KAU variety of Akshaya was used for trial. The experiment was started in November 2014. Seeds were sown in portrays and seedlings were transplanted to the rain shelter. Irrigation treatment with 70% of the ETc and fertigation with 110% of KAU adhoc recommendation (N:P:K = 82.5:44:27.5 kg/ha) showed better yield performance.

Ongoing Projects

1. **Study on structural design and management for Hi-Tech Horticulture in Kerala**

   In this project, detailed studies are progressing at hi-tech research and training unit, IF, Vellanikkara with various crops in different shape of greenhouse, different combination of sheet, different colour of shade net, different types of structures etc .

   In each greenhouse, studies are going on for comparing the soil and soilless media and standardizing the nutritional aspects in soilless cultivation. Observations on variation of pH & EC of soil and soilless media are being taken on weekly interval. Studies are progressing to determine EC level required for various crops like tomato, salad cucumber, chilly and capsicum and leafy vegetables at different stages in substrate cultivation. Influence of colored shade nets on spectral management and its influence on crop growth and yield were carried out by automatically recording the quality and intensity of light using computerized monitoring system. Studies are progressing to determine the influence of various cooling system like exhaust fan, furnace fan, circulating fan, foggers inside and outside the greenhouse on microclimate and growth and yield of crops. An attempt to develop pollinators (hand held and trolly mounted) and its testing and fine tuning is progressing. Studies are also going on for the selection of suitable variety of various vegetable crops under polyhouse. We have raised the crops like salad

cucumber, yard long bean, bitter gaurd, chilly and capsicum etc in soil and soilless media. Observations of various climatic parameters are being taken automatically in all greenhouses covered with different covering materials and shade net and effect of microclimatic parameters on growth and yield of vegetables are also being observed. Provisions have also been made to provide automatic irrigation and fertigation for various crops.

Studies were conducted to select the crops suitable in media bed and raft bed Aquaponics system in a commercial basis. Researches to find out the best media and fish suitable in Aquaponics system for maximum crop and fish yield is in progress. A detailed study to determine the optimum value of each water quality parameters to get best growth and yield of crop and fish are going on. Studies were also conducted to find suitable variety of lettuce, salad cucumber, Gherkins, chilly etc. in aquaponics and also to find crops suitable for media bed and deep water culture.

Steps has been taken to develop better quality multitier grow bag, multitier grow bag with composting facility and to study the low cost, quick fixing and portable type greenhouse structure suited for roof top/ backyard vegetable production.

Study revealed that gable shaped greenhouse structure is giving better results compared to Quonset and Mansard shape. Among all the combination of sheets tested, Anti dust, UV stabilized, diffused, IR cooling, anti mist- anti drip sheet gave better climatic conditions and good growth and yield of crops compared to other sheets. It was found that red colored shade net is giving better growth and yield of crop compared to other colours tested. Study revealed that yield of salad cucumber, chilly and yard long bean in greenhouse is 3.2, 20 & 3.4 times more than polyhouse. EC level at different stages to be maintained for salad cucumber, capsicum and chilly in substrate cultivation were standardized. A suitable design of multitier grow bag of used plastic drum (utilizing one and half drums) was developed to grow 35 to 50 plants. A multitier grow bag with composting facility has successfully developed. A model of poly kitchen garden has developed and more and more improvements were introduced on this aspect. A nutrient solution suitable for hydroponics system was developed and tests were going on. Among 12 variety of lettuce tested, 3 to 5 variety found to give good results in NFT under Kerala condition. Fruiting plants like tomato, chilly and brinjal found to give good results in dutch bucket hydroponics system compared to NFT. Optimum level of EC at various stages of chilly, salad cucumber and lettuce in hydroponic system were standardized. Safe level of various water quality parameters in hydroponics and Aquaponics were found out and studies on this aspect are progressing at the centre.

2. Pot culture study for analyzing quality of organic filtrates and evaluating their effects on soil properties and plant growth.

It is possible to grow crop (Bhindi) by applying filtrates of organic manures alone through fertigation. Yield produced under organic fertigation was comparable with the application of organic manures as such. While integrated application of fertilizers and vermicompost filtrate

through fertigation produced significantly higher yield. Microbial count and nutrient status of the soil were tested before and after the experiment. Result showed that microbial count in soil increases after the application of various treatments. Organic carbon content increased uniformly irrespective of method of application of organic manure. The experiment will be continued to confirm the results and planting of the crop was done in December 2015.

3. **Development and testing of Organic Fertigation unit with power operated agitator**

Organic fertigation unit with hand operated agitator was developed and tested for its performance. Hand operated agitator was found effective in agitating the organic manures. Nutrient analysis of agitated manure solution, filtrate, residue etc is going on. Fabrication of power operated agitator is in progress. Study was conducted using bhindi as test crop with the cow dung filtrate. The result showed that bhindi could be raised by organic fertigation using filtrate of organic manures like cow dung and vermicompost. This organic fertigation is found equally effective as that of integrated application of organic filtrate along with 50% of the recommended dose of fertilizer for bhindi through fertigation.

4. **Development of a suitable filter for reusing household wastewater for irrigation**.

Survey was conducted in and around 20 km from the station. Waste water, both kitchen and laundry waste water were collected. 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 analyses for other parameters such as sodium, calcium, magnesium, SAR, RSC are in progress.

Concluded PG Projects

1. **Groundwater Resources Modelling of a watershed using MODFLOW**

A study on 'Ground water resources flow modelling and mapping of a watershed using MODFLOW', was carried out for Kadalundi river basin of Malappuram District in Kerala. From the pre and post monsoon water table and piezometric water level variations, it was observed that the water table fluctuations in low land, mid land and high land area were correlated with rainfall except at some locations. Vertical Electrical Sounding (VES) method was carried and the apparent resistivity values obtained from the resistivity meter were interpreted with the help of 'IPI2WIN' software to obtain the layer parameters. Visual MODFLOW software version 2.8.1 was used for the flow modelling of the study area and it was used to predict the flow head for the next 15 years assuming five per cent decrease in recharge every year and also to predict the ground water condition by increasing the pumping rate by 10, 25 and 50 percent. From the modelling studies, it can be concluded that the Kadalundi river basin will remain safe for next five years from the point of view of future ground water development and subsequently the water table may reach the bed rock. This necessitates artificial ground water recharge techniques to supplement the recharge of rainfall to the ground water.

2. **Studies on the effect of alternate growing systems and irrigation schedules for soilless culture of Salad Cucumber**

   Field study to evaluate the effect of alternate growing systems and irrigation schedules for soilless culture of salad cucumber under drip irrigation was conducted inside the naturally ventilated poly house in the Precision Farming research plot, in the instructional farm of KCAET, Tavanur. Coir pith was used as alternate growing medium. The experiment was laid out in a factorial RBD with two factors and three replications. First factor was type of poly bag and second factor was irrigation frequency. Fertigation was applied as water soluble fertilizers. Data were analyzed statistically and it was found that, vertical type grow bag filled coir pith showed better performance compared to lay flat type grow bag. Maximum water use efficiency was obtained from vertical growbags with irrigation once in three days. From the study it was recommended that irrigation once in three days during initial stages followed by irrigation once in two days during mid and late stages is better for salad cucumber grown in vertical grow bags containing coirpith in a naturally ventilated poly house.

3. **Suitability of Drip automation systems for optimal irrigation scheduling under rain shelter**

   The study evaluated the suitability of drip automation systems for optimal irrigation scheduling. The experiment was done for tomato grown in rain shelter with four irrigation level treatments. The experiment was laid out in CRD with three replications. Irrigation levels of 40 percent, 50per cent, and 60 per cent Moisture Depletion Levels were compared with a control treatment of 2l/plant/day. 50 per cent MDL showed significantly better plant height and yield compared to other treatments. 50 and 60 per cent MDL gave on par values for water use efficiency (WUE).50 per cent MDL showed uniform soil moisture distribution and gave highest B:C ratio. Hence it can be concluded that for tomato (Akshaya) grown in rain shelter, 50 per cent MDL can be fixed as the optimum level for irrigation. As 60 per cent MDL gave good yield and WUE on par with50 per cent level, it can be also be recommended in water scarce areas.

4. **Modification and Evaluation of Automated Drip Irrigation System**

   Field study was carried out with Hilton FI variety of salad cucumber under different irrigation and fertigation levels using solenoid valves and GSM modem technique. The automated drip irrigation system consists of two capacitor type and two conductive type soil moisture sensors, solenoid valves and water flow sensors. Total yield and crop growth parameters showed better performance under 100 per cent fertigation when compared with 70 per cent fertigation. Combination of 100 per cent fertigation with 70 per cent irrigation also showed good results, whereas production was less in the case of 70 per cent fertigation with 70 per cent irrigation. The modified automated drip irrigation system is cost effective, portable and durable and it shows better performance.

5. **Coastal erosion study of Ponnani region using multispectral images**

   A study of coastal erosion along the Ponnani coast using multispectral imageries and GIS was undertaken to assess the temporal changes in coastal erosion, its extent, magnitude and trends in

the region under study. The study also aimed to evaluate the impact of the existing coastal erosion control structures with a view to assess its efficacy and to identify priority areas for coastal erosion prevention along the study area. The study utilized medium resolution LANDSAT imageries for the mapping and monitoring of the coastline erosion. The digital image processing software used for calculating the erosion rate was TNTmips 2014 professional version (**M**ap and **I**mage **P**rocessing **S**ystem - MIPS) by MicroImages, Inc. The study revealed the usability of multispectral satellite imageries like that obtained from LANDSAT, IRS etc. satellites in assessing the temporal changes along the coastline by the combined application of remote sensing and GIS techniques.

Both long-term and short-term erosion assessment showed that many places along the Ponnani shoreline are under severe erosion. Short-term erosion assessment revealed that many places were having coastal erosion rates more than -4 m/year. The impact of these shoreline protection structures and coastal processes on erosion process was also taken in to account in this study. The study revealed that Ponnani is an actively eroding coast with fluctuating erosion rates. The erosion rates were found to be high with a rate more than -4 m/year for about 35 km of the coastline considered. The areas with accelerated erosion along the coast of Ponnani need sustainable management and protective measures.

6. Comparative Evaluation of Naturally Ventilated Poly House and Rainshelter on the Performance of Cowpea.

A study was conducted in the Instructional Farm of KCAET, Tavanur, Kerala, during the period from August to December 2014 to compare the performance of cowpea grown under polyhouse and rainshelter in relation to open field cultivation. Cowpea variety Vellayani Jyothika, a trailing type legume released by KAU, was used for the trial. Mean monthly values of temperature, relative humidity and soil temperature inside the polyhouse was higher than that in rainshelter and open field in all the four months. During all growth stages, the plant height and intermodal length were significantly higher inside the polyhouse followed by rainshelter and open field. Among the different treatments, early flower initiation (39 days) was recorded in the polyhouse. The number of pods per plant was significantly high in open field. Average length of pods inside polyhouse and inside rainshelter was superior over open field. There was no significant difference in total yield of cowpea harvested from the observation plants from all the three treatments. The maximum benefit cost ratio of 1.73 was noted in open field cultivation. Benefit cost ratio of polyhouse and rainshelter were 1.06 and 1.34 respectively. Incidence of pests and diseases were also comparatively low inside the rainshelter and higher incidence of pests and diseases were noticed in the open field. From the results of the study it was evident that growing cowpea (Vellayani Jyothika) inside the rainshelter is more profitable than growing it inside naturally ventilated polyhouse.

Name of the Project Coordination Group (03)

Food & Agricultural Process Engineering

Project Coordinator : Dr. K. P. Sudheer

Concluded Projects: 2 Nos

Concluded PG Projects: 2 Nos

Concluded Projects

1. 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.

2. Development and quality evaluation of microencapsulated banana pseudostem juice powder

Banana pseudostem, often discarded after the harvest of bunch is very good for health. Its disposal in the field lead to unhygienic surroundings and environmental pollution. Juice from banana stem is a well-known remedy for urinary disorders. But the major problem associated with the pseudostem juice is its perishability and immediate browning reactions which lead to reduction of its acceptability by consumers. Considering these facts, a study was undertaken to obtain powdered products from pseudostem juice. The intention of the study was to develop a process protocol for microencapsulated banana pseudostem juice powder, standardisation of the spray drying parameters, and quality analysis of developed product. Three powder based products were developed from banana pseudostem juice by spray drying technology. Product-I comprised of pseudostem juice-sugar combination with ginger as flavourant. Product-II consists of a blend of banana pseudostem and horse gram with ginger extract. However, the third product from banana pseudostem juice was fortified with milk, horse gram extract and cardamom flavour. The process parameters were optimised as inlet temperature of 180ºC and outlet temperature of 65-68ºC for product-I & II, whereas inlet air temperature of 185°C and outlet temperature of 74-92°C were chosen for Product-III. The feed pump rpm of 15 and main blower rpm of 1800 were kept constant for developing all three products. The physicochemical characteristics, reconstitution and flow properties were determined. Standardised products were stored in aluminium pouches and quality parameters of product-I and II were analysed up to six months at an interval of two months and Product-III was stored up to three months for verifying its stability during storage. Based on quality analysis and sensory evaluation, the best samples were selected from product-I, II and III *i.e.,* T6-180°C (15% sugar + 25% maltodextrin + 56% pseudostem juice), T6-180°C (25% maltodextrin+ 30% horse gram extract + 43% pseudostem juice), and T12-185°C (50% milk + 30% horse gram extract + 20% pseudostem juice), respectively. Cost analysis of the products was done and cost of production of one kilo gram was estimated as Rs.195/-, Rs.208/- and Rs.243/- for product I, II and III, respectively.

Concluded PG Projects

1. Development of microwave assisted fluidised bed dryer for nutmeg mace

Dried mace possesses great importance in international trade and is used in the preparation of extractives and volatile oils. Combining microwave radiation with hot air fluidization provides an effective means of overcoming the non-uniform heating problems in conventional microwave heating. At 5.1 m/s the fresh mace sample attained the fluidization condition. The developed microwave assisted fluidized bed drying system consists of a fluidized bed dryer and a microwave oven unit. The microwave oven unit consists of control panel where cooking time, power indicators and clock time are displayed and controlled. The main components of a fluidized bed dryer are drying chamber, plenum chamber, heating chamber, blower with power source and an air flow control valve. In order to evaluate the developed microwave assisted fluidized bed dryer for nutmeg mace, the process parameters such as microwave powers of 480, 640 and 800W and drying air temperatures of 40, 45 and 50°C were chosen as independent variables. The process parameters would influence drying rate, drying temperature, energy consumption and physico-chemical parameters such as colour, moisture content, bulk density and essential oil yield. The optimized conditions of drying temperature and microwave power for microwave assisted fluidized bed dryer were found to be 47.76 °C and 681.73W.

2. Optimization of process parameters for cryogenic grinding of dried ginger

The processing of spices requires additional care because they are sensitive to atmospheric parameters like temperature and light. The exposure to temperature during any of the processing stage may lead to their quality deterioration in terms of colour, volatile oil, volatile oil constituents, oleoresin content etc. The grinding of spices at cryogenic temperatures helps in retaining the heat sensitive components in the spices. This study envisages on the cryogenic grinding of dried ginger in order to optimize the grinding conditions, considering the important quality characteristics and compared the cryoground powder with the conventionally ground ginger. The physical properties which affect the grinding process directly or indirectly were also determined. The experiments on cryogenic grinding have been carried out for different feed rates and grinding temperature and the best combination was determined in terms of product quality as well as grinding characteristics. The optimized feed rate and temperature were 35 kg/h and -130±5^{o}C. The lower temperature in the grinding zone solidifies the moisture and oil components in the raw material and makes it brittle, which facilitates the grinding easy and faster thus leads to less energy consumption. The extreme cold condition prevents the volatile oil loss and lead to their higher retention. The comparison of cryoground powder with the powder obtained by conventional method has shown that cryogenic grinding prevented the essential oil and oleoresin loss of ginger considerably and retained its constituents. The colour of cryoground ginger powder was superior and the particle size was finer. The time of grinding and specific energy consumption was found lower in cryogenic grinding. The packaging studies on ginger powder showed that laminated aluminum foil is suitable for long term storage.

Faculty –Forestry

Name of the Project Coordination Group (01)

Natural Forests & Biodiversity

Project Coordinator: Dr. Santhoshkumar A.V

Concluded Projects: 3 Nos

Concluded PG Projects: 11 Nos

Concluded Projects

1. **Explorative study and capacity development on human-wildlife conflict management in selected forest tracts of Kerala**

   The study was to assess the extent and nature of human-wildlife conflicts that occur in the selected forest tracts of Kerala with focus on selected wild animals. The aim also was to identify and document best practices and methods adopted by forest department and local communities to avoid and overcome infringement of wild animals into human habitats. It was also envisaged to analyze cause–consequence factors of human-wildlife conflicts in relation to patterns of land use and land cover change. Attempt was also done to understand awareness and attitude about the laws and rules of protection and conservation of forest, biodiversity and wild life among victims of human-wildlife conflicts. Organizing capacity development programmes for human-wildlife conflict mitigation among stake holders through awareness campaigns was also one of the objectives. The project commenced on 28.03.2015 and ended on 30.09.2017. The wildlife involved in the conflicts as well as the preferred mitigation options against such conflicts were identified for each conflict locations in the six districts. Based on these onformation location specific action plans can be designed. A 22 minute documentary "Athijeevanam" in Malayalam and English featuring human-wildlife conflicts was shot and screened in the select schools and community halls in the six districts as a part of capacity building efforts of this project. Concurrently eleven (11) leaflets describing the different wild animals like elephant, wildboar, tiger, leopard, peacock etc which are involved in the conflicts and two leaflets featuring WPA 1972 and its schedules were drafted in Malayalam and was printed and distributed among the public in the project area spanning the six northern districts, viz., Palakkaad, Malappuram, Kozhikode, Wayanad, Kannur and Kasargode. 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, which is being field tested.

2. **Functional diversity of an evergreen forest ecosystem in Vazhachal Forest Division, Kerala**

   The study was undertaken with the principal objective to enumerate the species and functional diversity of selected aboveground and belowground biological components. The study also aimed at understanding the links between diversity, soil aspects and functioning of this forest ecosystem. Eighty four tree species were recorded from the 0.5 ha area with basal area of 85.43m^2. *Aglaia barberi, Culleniaexarillata, Mesuaferrea*and *Palaquiumellipticum*are dominant trees in the top canopy. *Euphorbiaceae, Dipterocarpaceae* and *Meliaceae* were the dominant tree families. The diameter frequency as well as height frequency distribution showed an inverse J shaped curve which reflects a healthy plant population structure. Rényi's diversity profiling and Principal Component Analysis returned only minor variation vis-à-vis vegetation characteristics across the five sampled sites. The dominating plant functional traits like evergreen plant (70.2%), simple leaf (72.6%), glabrous textured leaf (78.57%), smooth textured bark (47.2%), medium

thick bark (53.5%), capsule fruit (32.1%) and zoochorous dispersal (55.95%) are the typical plant functional traits expected in a tropical evergreen forest ecosystem. The functional diversity indices are FRic (17.11), FEve (0.76), FDiv (0.84) and FDis (2.27). There were 28 different orders of soil invertebrates in the 0.5 ha area. *Isoptera, Hymenoptera* and *Coleoptera* are the dominant orders. The species diversity index of the soil invertebrates were Shannon-Wiener Index (2.40), Simpson Index of diversity (0.14) and Pielou's evenness Index (0.51). The resident soil microbial population includes Bacteria (44.4 x 10^6cfu g^{-1}), Fungi (26.3 x 10^3cfu g^{-1}), Fluorescent pseudomonads (18.3 x10^4cfu g^{-1}), Nitrogen fixers (14.4 x 10^4cfu g^{-1}), Actinomycetes (16.4 x 10^4cfu g^{-1}) and Phosphate solubilizers (20 x 10^3cfu g^{-1}). The various edaphic properties observed were also typical of an evergreen forest [Soil temperature (19.82°C),Bulk density (1.28g cm^{-3}), moisture content (29.06%), organic carbon (4.19%), soil acidity (5.25), Soil electrical conductivity (0.07dSm^{-1}) and Sandy loam soil (Sand- 78.15%, Silt- 16.04%, and Clay- 5.82%)]. The study could also observe several linkages between functional traits and ecosystem functioning.

3. **Taxonomic inventory and ecology of the bats of Silent Valley National Park, Kerala.**
The objective of the study was to assess the species diversity, distribution pattern, and habitat preferences of bats in Silent Valley National Park. 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 *Latidenssalimalii, Myotismontivagus* and *Cynopterus sphinx* are new reports from Silent Valley. The Salimalii's fruit bat (*Latidenssalimalii*) is the first report from Kerala.Four frugivorous bats from the family Pteropodidae were recorded which includes *Latidenssalimalii, Cynopterus sphinx, C. brachyotis* and *Rousettusleschenaulti*. Two species from family Rhinolophidae were recorded and it includes *Rhinolopuslepidus* and *Rhinolophusrouxirouxi*. Two species from family Vespertilionidae were also recorded and it includes *Myotismontivagus* and *Myotishorsfieldii peshwa.*

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3. **Status, distribution and habitat preferences of small carnivores in Silent Valley National Park, Kerala**

To study the status of small carnivores such as felids (lesser cats), herpestids (mongooses), viverrids (civets) and mustelids (otters and martens) of the Silent Valley National Park. Also proposed to study the distribution pattern and habitat preferences of small carnivores. In addition to the above, the conservation challenges faced by the small carnivores of Silent Valley National Park also would be studied. 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. The most common species recorded was Small Indian Civet *Viverriculaindica* (45.57%) followed by Brown Palm Civet *Paradoxurusjerdoni*(20.89%), Stripe-necked Mongoose *Herpestesvitticollis* (17.09%), Brown Mongoose *Herpestesfuscus*(6.33%), Leopard Cat *Prionailurusbengalensis*(6.33%) and Asian Small Clawed Otter *Aonyxcinereus* (3.16%) . The Nilgiri Marten *Martesgwatkinsii* was captured only once (5.5%) in the camera traps during the study period. The overall small carnivore

success rate has been generally high at SVNP (10.90%). 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.

4. **Taxonomic inventory and ecology of the rodents and insectivores of Silent Valley National Park, Kerala**

   To study the status and distribution of the rodents and insectivores of the Silent Valley National Park. It was also proposed to study the distribution pattern and habitat preferences of rodents and insectivores. Six species of rodents and one species of insectivore were recorded from Silent Valley National Park. The rodents recorded were members of Muridae, Sciuridae and Hystricidae families. These includes *Rattuswroughtoni, Golundaellioti, Ratufaindica, Funambulustristriatus, Funambulussublineatus* and *Hystrixindica*. The insectivore observed at SVNP was *Suncusmurinus* of the family Soricidae. Though the rodent and insectivore abundance were more during the monsoon season, there was no significant difference. Similarly, though the rodent abundance was more at the evergreen forests, this was also insignificant. Among the microhabitat parameters studied, the climber density has found to be significantly influencing the rodents at Silent Valley. *Rattuswroughtoni* was the most abundant species of rodent at Silent Valley. Among the rodents of Silent Valley, *Ratufaindica* is endemic to peninsular India while *Funambulustristriatus, Funambulussublineatus* are endemic to Western Ghats. The *Funambulussublineatus* is a threatened species of squirrel seen at Silent Valley and the IUCN Redlist category of this is Vulnerable.

5. **Efficacy of arbuscular mycorrhizal fungi for drought tolerance in Swieteniamacrophylla King. Seedlings**

   Study was carried out to analyze the influence of four different levels of water stress (IW/ET=1, 0.8, 0.6 and 0.4 per cent of cumulative evapotranspiration) and three different species of arbuscular mycorrhizal fungi (AMF), viz; Funneliformismossae, Glomus etunicatum, and Rhizophagusintraradices on the growth and development of Swieteniamacrophylla seedlings in nursery. Drought stress was found to affect thegrowth and physiology of mahogany seedlings significantly. Colonization with AMF, especially with G. etunicatum significantly improved the biometric as well as the physiological attributes of the seedlings. 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. 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.

6. **Geographical Indications status for Nilambur Teak (*Tectonagrandis*L.f.).**

The study was carried out in teak plantations of Nilambur and in Central Kerala (Thrissur, Palakkad and Ernakulam) during 2014-2016. The investigation focused on analyzing the potential of securing Geographical indications status for Nilambur teak by exploring the historical importance of Nilambur teak with the help of PRA tool timeline, comparing its wood quality with other National and International provenances and analysing the soil properties and climatic factors that are responsible for the uniqueness of Nilambur teak and to assess the popularity of Nilambur teak among the timber traders. 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.

7. **Feasibility of forest certification in Marayoor Sandal Division, Kerala.**

The 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. **Cause-consequence analysis of human-wildlife conflict in Wayanad district, Kerala**

The main objective is to describe the nature, frequency, distribution and intensity of human wildlife conflicts in Wayanad and to understand the causative factors involved in the conflicts by identifying and mapping hotspots of conflicts using vulnerability mapping and GIS methods. This study also intends to suggest mitigatory measures and enhance human-wildlife co-existence in Wayanad District. The study noticed a definite shift in the farming practices in Wayanad. The respondents believed that the shortage of resources in their natural habitats is pushing the wild animals to the farmlands. Proper habitat enrichment programs, they believe, can reduce the

conflicts. According to them, the forest department and the local people are working hand-in-hand to reduce the conflicts. There was no significant difference between any of the social demographic variables such as age, educational status to attitude towards human-wildlife conflicts and wildlife conservation in Wayanad district which indicates that the attitude of the population is not affected by any of these factors. The major conflict causing animals reported by the respondents in all the study areas are elephant *(Elephas maximus)*, wild boar (*Susscrofa)*, bonnet macaque (*Macacaradiata*), leopard (*Pantherapardus*), giant squirrel (*Ratufaindica)*, spotted dear (*Axis axis*), tiger (*Pantheratigris*), peafowl (*Pavocristatus)* and porcupine (*Hystrixindica*). The five best mitigation measures suggested by the respondents (in decreasing order of priority) were improving the food resources inside the forests, facilitating access to water for wild animals, fencing of farmlands, providing insurance coverage for crops and livestock and adequate and immediate compensation.

9. Species diversity and community structure of reptiles of selected agroecosystems in Thrissur, Kerala

To study the species diversity and the reptilian community structure of various agroecosystems in Thrissur, Kerala. It is also proposed to assess the spatial variation of reptile distribution using Geographic Information System (GIS) tools. A 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. More reptiles were recorded during the night hours. Habitats variables were found to be influencing only certain species. Occurrence of Russell's Kukri Snake *Oligodontaeniolatus* 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 *Boigabeddomei*, Termite Hill Gecko*Hemidactylustriedrus*, Spotted House Gecko *Hemidactylusbrookii*, Common Wolf Snake *Lycodonaulicus*, Common Trinket Snake *Coelognathusesche* and Checkered Keelback *Xenochrophispiscator* was found to be influenced by relative humidity. Occurrence of Common Krait *Bungaruscaeruleus*, Dussumier's Litter Skink *Sphenomorphusdussumieri*and Bark Gecko*Hemidactyluseschenaultia*was found tobe influenced by maximum temperature. 31 reptiles reported from Kerala Agricultural University Main campus

10. Status, distribution and habitat preference of small carnivores in Wayanad Wildlife Sanctuary, Kerala

The objectives of the study were to understand diversity, status, distributionand habitat preference of the small carnivores of Wayanad WLS. 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. Small Indian Civet Viverriculaindica found as most common species followed by Stripe-necked Mongoose Herpestesvitticollis, Common Palm Civet Paradoxurushermaphroditus, Brown Palm Civet Paradoxurusjerdoni, Ruddy Mongoose Herpestessmithii, Indian Grey Mongoose Herpestesedwardsi, Leopard Cat Prionailurusbengalensis, Asian Small-clawed Otter Aonyxcinereus and Jungle Cat Felischaus. 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.

11. Species diversity and community structure of amphibians of selected agroecosystems in Thrissur, Kerala

The objective of the study was to assess the species diversity and communitystructure of amphibians of selected agroecosystems in Thrissur and its association with various habitat parameters. The study also assessed the spatial variation of amphibian distribution using Geographic Information System (GIS) tools. 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 *Pseudophilautuswynaadensis*. *Pseudophilautuswynaadensis*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 *Pseudophilautuswynaadensis*were soil moisture, soil pH, litter depth, maximum airtemperature, minimum air temperature, shrub density, soil temperature at 5 cm depth and evaporation.

Name of the Project Coordination Group (02)

Planted Forests & Utilisation

Project Coordinator: Dr. Anoop E.V

Concluded Projects: 1 No
Ongoing Projects: 3 Nos

Concluded PG Projects: 8 Nos
Ongoing PG Projects: 2 Nos

Concluded Projects

1. **Standardization of methodologies for improving wood quality of coconut (*Cocos nucifera*, L.) for structural uses and pulping – wood property profiling of coconut palms**

The objective is to study the anatomical, physical and mechanical properties of coconut wood and to analyze variation in these properties in coconut palms of different age classes and varieties grown in different agro-climatic zones of Thrissur district. 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.

Ongoing Projects

1. **Short and long-term strategies for income generation from teak, matti and silver oak plantation areas at Panchavadi hills in KAU main campus**

The objective of the study is to establish profitable short term and long term plantation forestry models at KAU campus and establishing demonstration facility for the promotion of tree farming for small and medium farmers of Kerala. 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 Project in progress.

2. **Establishing bamboosetum for KAU**

Establishment of bamboosetum of commercially and ecologically important tropical bamboos species. Development of interpretation centre on the prospects of profitable cultivation of bamboo for small and medium farmers of Kerala. 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. The project is in progress.

3. **Training and Technology Demonstration Project for Making Value Added Products from Coconut Wood**

Set up a modern Coconut Wood Technology Demonstration Centre (CWTDC), installing advanced machineries for sawing, seasoning and preservation and manufacture of utility items such as furniture, interior decorative items, building materials, handicraft items etc. based on coconut wood so as to popularize the use of cocowood for additional income to farmers. To develop a value chain model of cocowood extraction, conversion, design, manufacture and sale of cocowood furniture and other value added products in collaboration with Furniture Consortium Private Ltd. and the Kodungallur Coconut Producer Company Ltd. (KCPL). Two training programmes on "Processing, Value Addition and Product Manufacture from Coconut Wood" were organized at the Coconut Wood Technology Demonstration Centre (CWTDC), at the College of Forestry, Vellanikkara where machineries for making furnitures and fixtures from coconut wood including a Portable Saw Mill were installed. As part of the training, The trainees mainly from KCPCL were given training in the manufacture of furniture items out of coconut wood by the Master Trainer. The project is in progress.

Concluded PG Projects

1. **Quality evaluation and value addition of fruits of *Elaeocarpus serratus* L.(Ceylon olive tree)**

The objective of the study was to ascertain the physico-chemical and sensory characters of *Elaeocarpus serratus* fruits, to develop value added products such as Ceylon olive pickle and candy and to study the organoleptic and chemical qualities of the product developed.

The physical characteristics of the fruits revealed that the mean fruit weight, volume, length, diameter for the fruit were 3.55 g, 5.97 cm3, 23.07 mm and 15.58 mm respectively. Correlation matrix revealed a significant and positive relation among all the studied physical parameters. The nutritional composition of the fruits was found to be in par with other tropical fruits like tamarind, passion fruit, jack fruit etc. Organoleptic evaluation of the fruit showed the mean scores for appearance, colour, flavor, texture, odour and taste. The organoleptic scores for the pickle and candy shower high values for all the parameters with the overall acceptability mean score of 8.4 and 7.7 respectively.

2. **Performance of selected medicinal herbs under rubber and cashew planations**

The objective of the study was to assess the understory productivity of two prominent land management systems in Kerala viz Para rubber and cashew through intercropping with shade

tolerant herbaceous medicinal crops. To study the biochemical changes in these medicinal crops and the bio-physical attributes influencing the productivity of both of these land management systems. Also, to assess the soil carbon sequestration in these two land management systems. The biophysical attributes influencing the productivity of the land management systems and the biochemical changes in the products of understorey crops were studied. Additionally, soil carbon sequestration in both the given land use systems and the treeless open plot was estimated. In terms of yield attributes, the selected understorey crops have better prospects in wooded land use system in general and the specific advantage of cashew over rubber was also obvious. This may be attributed to relatively better PAR transmission, higher nutrient accumulation and lesser root competition in cashew. Further, the better quality of rhizomes under comparably higher shade levels suggests their performance in tree-based land use systems.

3. Autoallelopathy of selected multipurpose tree species and the effect of their leachates on agricultural test crop

The study aimed to identify the allelochemicals present in the leachates of five selected MPTs and also to understand the possible effects of leachates of these MPTs on germination, seedling growth and dry matter production of seedlings of the same tree species and the agricultural test crop. 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 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.

4. Provenance evaluation of *Acacia mangium* Wild

A provenance evaluation of *A. mangium* was conducted in 14 year old plantation at Livestock Research Station, Thiruvazhamkunnu, to understand the variation in growth and wood traits among the provenances. Ten provenances and one local seed source was used for the trial.

The provenances had high survival percentage (77.44%), but did not differ significantly between provenances. Significant differences between provenances were found in tree height, while they were on par for DBH, volume, tree form and branching habit. The provenances of Kuranda, Arufi Village, Upper Aramia, Oriomo, Balimo and Binaturi were taller than the rest. Heritability of growth attributes was highest for height (63%). Morphometric traits of seeds were found to be significantly different between the provenances. Arufi Village provenance was found to be better than the other provenances for the traits. Lake Murray provenances showed the best performance

in most of the parameters studied for germination. No significant differences between provenances were observed for germination capacity. Germination parameters are under moderate to high genetic control. The provenances differed significantly in physical properties of wood, but not in mechanical properties. The provenances differed significantly for heartwood only at the base, while basic density was significantly different at all the height levels. Wood properties of the provenances were under strong genetic control. Based on the study, Tully-Mission Beach, Arufi Village, Kuranda, Upper Aramia, Lake Murray and Binaturi provenances can be recommended for growing under Kerala condition.

5. **Performance of selected medicinal herbs under prominent land management system in Kerala viz. homegarden and coconut garden**

   The study intended to assess the relative performance of selected herbaceous medicinal crops viz. ginger (*Zingiber officinale* Roscoe), turmeric (*Curcuma longa* L.) and kacholam (*Kaempferia galanga* L.) when grown under two major tree based cropping systems in Kerala viz. homegarden and pure coconut garden. Further, the study will probe into the biophysical and biochemical changes affecting productivity and product quality of the medicinal crops when grown under two systems. Result converges to the generalisation that despite better soil physico-chemical attributes, understory productivity in the homegarden is by and large decided by the PAR availability. Hence there is need to develop stand structure that optimize the productivity in homegarden through judicious stand density regulation and tree management practices

6. **Comparative performance of mulberry (*Morus alba* Linn) and subabul (*Leucanea leucocephala* Lam) under diverse management regimes in a coconut based fodder production system**

   The study aims to assess the influence of planting density and pruning frequency on forage yield and nutritional qualities of mulberry and subabul intercropped in coconut gardens. The study will also explore the soil fertility changes associated with intercropping these fodder trees in coconut plantations. Management of mulberry and subabul fodder banks for optimizing forage yield and nutritive value in coconut garden has been standardized. The technology provides an alternate protein source to livestock against costly concentrate feeds.

7. **Genetic diversity and population structure of two distinct natural populations of *Syzygium travancoricum* Gamble**

   The objective of the study is to compare the genetic variation between two populations of *Syzygium travancoricum* Gamble growing in geographical isolation at two different natural habitats. The study further will investigate the population structure and variation in reproductive biology occurring within the species, to determine if constraints to seed production may explain the rarity of the species. The study revealed that, flowering occurred in *S. travancoricum* after a dry period and the fruiting occurred just before the onset of rain. The inflorescence of the species was axillary cymose with white, calyptrate flowers. Mass flowering was observed in S.

travancoricum, but, when compared to other syzygium species, number of flowers produced per tree was less. The species associated with S. travancoricum was different in Kalasamala and Kattilappara. The relative density of the species was different in the two populations. The two populations showed significant variations in the case of wood anatomical characters. The seed banks too differed significantly between the two sites. The study concluded that the constraints such as, lesser flower production, poor fruit set, lower seed germination, poor seed viability could be the main causes of the rarity of *S. travancoricum*. The study further showed that the two populations have considerable differences between them, either environmental or genetic.

8. **Morpho-physiological diversity assessment of *Garcinia gummiguta* (L.) Robs. germplasm collection**

The objective of the study is to explore the variability, physiological and biochemical characters in the trees of Garcinia gummi-gutta collection maintained at NBPGR, Vellanikara. The present investigation related to variation in morphological and biochemical parameters in G. gummi-gutta indicated considerable variation among the accessions. Trees could be grouped into five clusters based on these characters using cluster analysis. Thus, there is a possibility of taking up hybridisation work using the present germplasm for improving the yield and nutritional value of this important tree crop of Kerala.

Ongoing PG Projects

1. **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. The project is in progress.

2. **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). The project is in progress.