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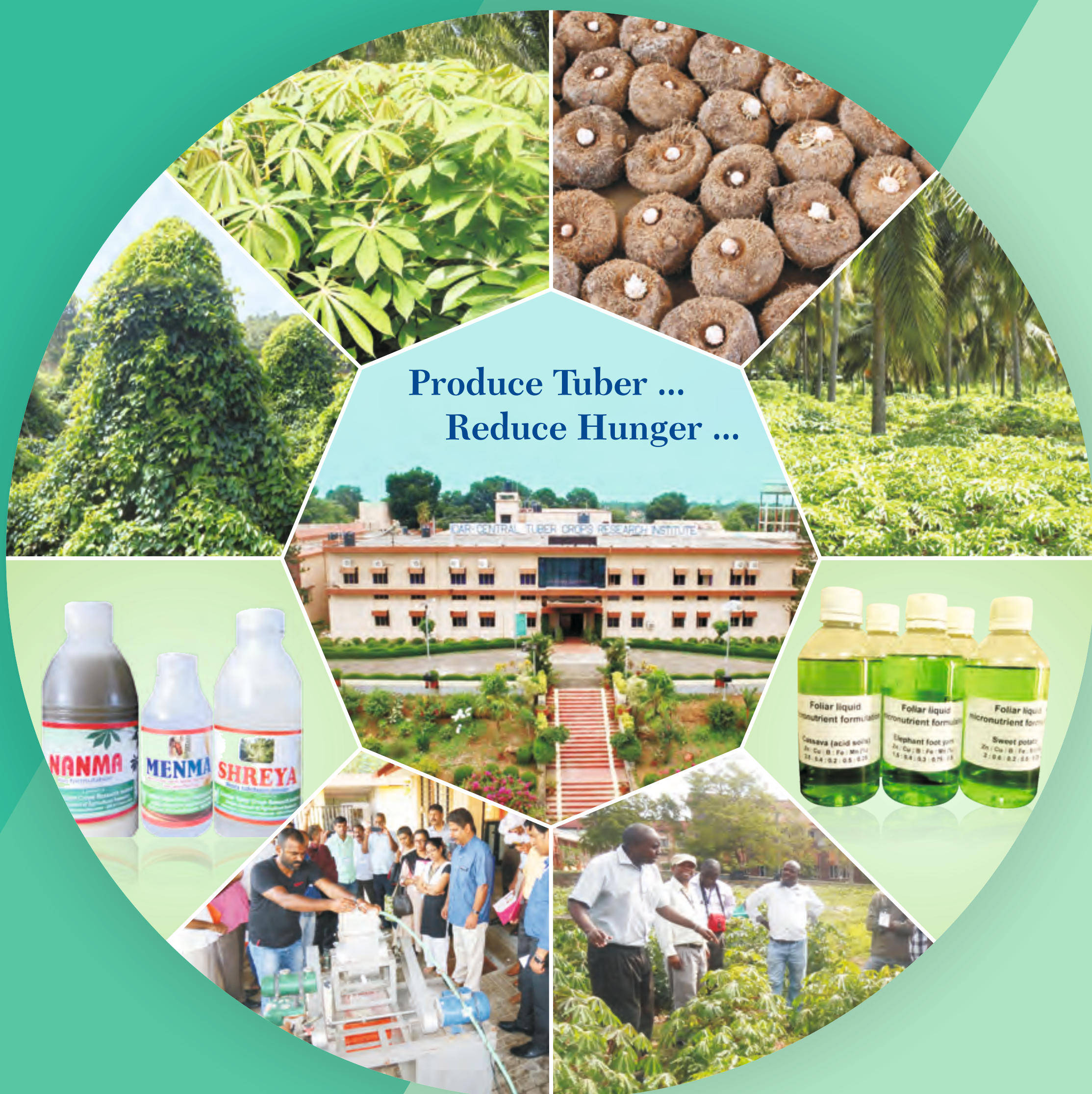

भा.कृ.अनु.प.-केन्द्रीय कंद फसल अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
श्रीकारियम, तिरूवनंतपुरम - 695 017, केरल, भारत

ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
Sreekariyam, Thiruvananthapuram - 695 017, Kerala, India

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PREFACE

The ICAR-Central Tuber Crops Research Institute is stepping ahead towards fulfilling its vision of tuber crops based inclusive growth. The Institute in Thiruvananthapuram along with its Regional Centre at Bhubaneswar is shouldering the responsibility with its mission to integrate root and tuber crops as a component of sustainable agriculture for food, nutrition and livelihood improvement of rural population. Tuber crops, the third most important food crops, world-wide, provide 5.4% dietary energy and also a source for animal feed and processing industries.

In the present global scenario of climate change, tuber crops are gaining visibility as 'Future Smart Crops' for climate resilience, low input cost and also for being rich in calorie, dietary fibres, minerals, vitamins and anti-oxidants.

The ICAR-CTCRI is addressing the research, development and promotion of root and tuber crops by serving mankind with user and eco friendly production, protection, value addition and dissemination of technologies for over 55 years including the commendable and eventful year of 2017-18.

During the reporting period, research programme were focused to address the current demand of climate smart crop, sustainable resource management, production, protection, processing technologies and their dissemination. Accordingly, the Institute has released five tuber crops varieties with valued traits and resilient to diseases. Diagnostic kit against dasheen mosaic virus disease was also released. The Institute has licensed 10 technologies of which one for production and the rest for processing. Fifteen methodologies were developed for production, protection, processing and value addition including cassava commodity model. Developed 3 farmers' friendly digital agro advisories and tools *viz.*, variety identification tool, "*Tuber Guru*" and *Sree Poshini* apps. One patent was filed and DUS guidelines were developed for Greater yam and Yam bean. Published 63 research papers in peer reviewed journals and submitted 28 research proposals for external funding of which 6 already got approved with a total budget of ₹12.57 Crores.

The Institute witnessed an eventful year by organizing 2 Technology Conclaves – one at HQ and one at Regional Centre. Other events organised by the Institute include workshops, brainstorming and stakeholders interface meet. A live telecast of the Hon'ble Prime Minister's address on the event of Krishi Unnati was also arranged for the stakeholders on 17 March, 2018 at the Institute.

As suggested by Dr. T. Mohapatra, Hon'ble Director General, ICAR & Secretary, DARE, our Institute takes pride in organizing Centre-State meet 'On enhancing productivity of rice and horticultural crops' for the first time at ICAR-CTCRI on 28 October 2017.

To reach the un-reached and to empower the farming community, we organized 3 Entrepreneurship development programmes, Agricultural science day, World soil day, National science day, Women farmer's day and 21 exhibitions across the nation. As a part of capacity building, 3 International and 8 National training programmes were conducted. To enhance the income generation of farmers, fifty farmer friendly demonstrations were conducted in Kerala, Tamil Nadu and Karnataka Value chain analysis of sweet potato in Belagavi, Karnataka indicated the benefit cost ratio of 2.42:1 and the rural livelihood sustainable index of sweet potato farmers (56.02) was similar with the index of paddy growers (57.9).

International linkage with CGIAR Institution 'CIAT' has been strengthened with the guidance and support from Dr. T. Mohapatra, Hon'ble Director General, ICAR & Secretary, DARE and Dr. Anand Kumar Singh, Hon'ble Deputy Director General (HS), ICAR. Our linkages are continuing with CIP, European Commission and Swiss Agency for Development & Co- operation. Working in association with PPV& FRA, RKVY- Govt. of Odisha, Kerala, KSCSTE, Kerala State Planning Board, Coconut Development Board, MANAGE, KVKs, sister concerns & other R & D Institutions for tuber crops based sustainable growth.

We are privileged to apprise the R & D progress of the Institute to Hon'ble Union Minister of Agriculture and Farmers' Welfare 'Shri Radha Mohan Singh' on 17 February, 2018 and Hon'ble Minister of State 'Shri Sudarshan Bhagat' on 24 August, 2017 during their visits to Thiruvananthapuram. The Institute bagged 'Panjabrao Deshmukh Outstanding Woman Scientist Award 2016', International IZA-FAI Award and various prizes in exhibitions, Hindi and sports competitions.

The Institute is moving forward with various National programme *viz.,* TSP, NEH, *MGMG* and Swatcch Bharat Mission with full spirit and enthusiasm.

I express my deep sense of gratitude to Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his invaluable guidance, support and inspirational speeches during his visits to the Institute. I place on record my gratitude to Dr. A. K. Singh, Deputy Director General (HS) for his encouragement and timely guidance in every sphere of activities including 'Performance Review of the Institute'. I sincerely thank Dr. T. Janakiram, Dr. W.S. Dhillon, ADGs (HS), Dr. V. Pandey, Dr. B.K. Pandey, Dr. R.Singh, Dr. M. Das and all other staff of SMD for their co-operation and timely help. I express my sincere thanks to Dr. James George, Project Coordinator, AICRP TC and Heads of divisions for their wholehearted cooperation for enhancing the visibility of this Institute. I am thankful to the scientific, technical, administrative and skilled supporting staff for their steadfast commitment. I also appreciate and congratulate the editorial team for their involvement in bringing out this publication on time.

16 June 2018

Archana Mukherjee
Director

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EXECUTIVE SUMMARY

Crop Improvement

A total of 5570 accessions comprising 1211 cassava, 1124 sweet potato, 1110 yams, 683 edible aroids, 200 minor tuber crops and 1242 collections from regional centre were maintained and conserved in the field gene bank. New collections were added to the existing germplasm from various sources in sweet potato (20); yams (3); edible aroids (1) and minor tuber crops (15).

A total of 1211 accessions of cassava comprising the indigenous, exotic, landraces and breeding lines were maintained in the field gene bank. Three hundred and seventy five indigenous accessions of cassava were characterized for 34 above ground vegetative plant characteristics (24 qualitative and 10 quantitative) and 20 tuber traits and yield (12 qualitative and 8 quantitative) using a combination of IPGRI/NBPGR/IITA descriptors along with digitization. The accessions, CI-332 (54.59%), CI-363 (52.46%), CI-485A (52.43%) and CI-690 (5.83 to 50.41% on fresh weight basis) had drymatter (DM) greater than 50%. The total starch content ranged from 50.2 to 78.2%, sugar from 1.0 to 5.0%, crude fibre content from 0.8 to 1.5% and ash from 0.8 to 3.0%.

Twenty seven indigenous accessions of cassava were subjected to genetic variability study using 30 morphological plant and tuber traits (20 qualitative and 10 quantitative traits) and using molecular markers (10 SSR primers). Dendrogram generated using UPGMA showed no duplicates present in the set. A comparison of the morphological and molecular clusters showed that six cassava accessions were common in both methods *viz*., TCR-5, TCR-10, TCR-15, TCR-45, TCR-79 and TCR-69. Ten accessions of cassava germplasm were maintained under *in vitro* conservation and DNA of 27 accessions was maintained in the DNA bank.

A method for cryo-preservation of pollen of cassava variety, Sree Padmanabha (MNga) was standardized. From the pollens preserved in liquid nitrogen for 16 months, 56.64% pollens stained, while 36.34% pollens germinated in the laboratory conditions. Further, hand pollination was done using this cryo-stored pollen with the profusely flowering and fruit setting variety, Sree Jaya, where, fruit set to the tune of 43.68% was observed.

A CMD resistant cassava variety "Sree Reksha" (IC625792) has been released by the Kerala State Seed Sub Committee. It has a duration of 8-9 months and is completely resistant to cassava mosaic disease and also tolerant to post-harvest physiological deterioration. The recorded average tuber yield was 40-50 t ha^{-1}. It has medium starch (27-32%), low cyanogen (35.01 ppm) and low sugar (1.10%) content. It is suitable for planting under rainfed and irrigated conditions, especially in regions with high incidence of cassava mosaic disease.

In the trial on early bulking cassava lines with CMD resistance, of the 10 lines tested, three were found to be completely resistant to cassava mosaic disease (16S-1, 9S-174 and 16S-374). The highest tuber yield was recorded in 16S-143 (39.09 t ha^{-1}) at sixth month after planting followed by 16S-36 (31.68 t ha^{-1}) and 9S-174 (30.04 t ha^{-1}). The individual tuber weight was maximum (570 g) in the line 16S-143 followed by 16S-48 (540 g) as compared to 233 g per tuber in the check variety (Vellayani Hraswa).

In the replicated yield trial for development of cassava mosaic resistant varieties for industrial use, 15S-135 produced the maximum tuber yield (64.19 t ha^{-1}) followed by 15S-409 (62.95 t ha^{-1}). In the advanced yield trial for development of CMD resistant varieties with good culinary quality, 15S-406 produced the maximum tuber yield of 55.0 t ha^{-1} with a dry matter content of 48.4%.

Among the yellow-fleshed cassava, 15S-139 produced the maximum yield (48.53 t ha^{-1}) with low dry matter content (22.8%). Two sweet cassava lines were identified of which, 15S-113 had the maximum tuber dry matter (43.0%).

Identification of molecular markers associated with post-harvest physiological deterioration (PPD) in cassava revealed that among 75 cassava genotypes tested, Kalpaka, Black Thailand, Sree Vijaya, CI-848, Burma, H-165, Sree Prabha and Sree Reksha were free of PPD symptoms whereas, Vellayani Hraswa, CR-43-11, 8S-501-2, 9S-127, 9S-132, CO-4, White Thailand and 8W-5 were highly susceptible to PPD. Two consecutive years data showed that Kalpaka and Sree Reksha were free of PPD symptoms whereas, Vellayani Hraswa, CR-43-11, 9S-127 and 9S-132 were highly susceptible to PPD in both the years. Parental polymorphism survey with the identified PPD tolerant and susceptible parents was conducted with 60 SSR primers including PPD specific primers and other cassava primers. The RT-PCR study on the identified tolerant and susceptible parents for few genes which contribute to PPD clearly showed that transcripts for those genes involved in the metabolism of cyanogenic glycosides, with roles in cell wall remodelling and repair, enzymes involved in the inter-conversion and detoxification of ROS and programmed cell death (PCD) were induced.

In the experiment on identification of drought tolerant lines in cassava, 15 cassava lines were tested in the polyhouse. At 5 months after planting, a reduction of 47.40% in plant height; 80.72% in leaf weight, 79.53% in stem weight, and 82.87% in total biomass was observed in water deficit stressed (WDS) plants. Total carbohydrate content in the leaf significantly decreased under WDS conditions (1.38 g $100g^{-1}$ DW) when compared to the control/irrigated conditions (4.073 g $100g^{-1}$ DW). There was no significant difference between control and stressed plants for carbohydrate content of inner cambium including pith of the middle portion of the stem, but the density of central pith was low in the WD plants. The leaf HCN content was reduced under water deficit conditions (42.60 ppm DW) in comparison with control conditions (166.80 ppm DW). Chlorophyll content of the leaf was not found significantly different when the leaves were sampled from mid-canopy, but significant difference was observed when leaves were sampled from lower canopy.

In the experiment on pyramiding of genes for cassava mosaic disease (CMD) resistance, 150 hybrid seedlings having both *cmd-1* and *cmd-2* genes were evaluated under field conditions and all had 100% field resistance to CMD disease. Among the 150 progenies, 50 progenies with high yield, high starch and good plant types were selected for evaluation and further improvement.

For identification of markers linked to high starch, a total of 150 hybrid seedling progenies between high starch line 9S-127 and Sree Padmanabha (MNga-1) were established along with parents in the field. The parental screening was done with 40 SSR markers and 31 of them showed polymorphism between parents (78%). Among the 31 polymorphic SSR primers, 10 primers were used for screening the seedling progenies and genotypic data was scored.

In the experiment on genetic modifications for quality improvement in cassava, *in vitro* micropropagation of CMD resistant, 9S-127 and CR-43-11 was done along with the susceptible variety, H-226. Somatic embryogenesis was achieved in 9S-127 and CR-43-11 using immature leaf lobes. Compared to these accessions, cassava varieties, H-226, Sree Padmanabha, Sree Prakash and Sree Swarna produced lesser number of somatic embryos. The nodes, internodal segments and immature leaf lobes of cassava accession, 9S-127 was transformed with EHA having *glgC* gene for enhanced starch content.

For alleles mining responsible for abiotic stress in cassava, genome-wide HMM based-analysis led to the identification of 67 small *heat shock proteins* (*MeHSP20*) and 41 *SNF-related serine/threonine-protein kinase* (*MeSnRK*) family genes in cassava. The *MeHSP20* family genes are distributed in all the chromosomes, except on chromosome no. 5, whereas, the *MeSnRK* family genes are distributed in all the chromosomes except on chromosome no. 4. Promoter analysis of 67 *MeHSP20* and 41

MeSnRK family genes of cassava revealed the presence of tissue-specific, biotic, abiotic, light-responsive, circadian and cell cycle-responsive *cis*-regulatory elements. Phylogenetic/evolutionary analysis of cassava *MeHSP20* family genes with *HSP20* family of Malpighiales genomes grouped the members into 22 sub-groups (CI sHsp, CII sHSP, CIII sHSP, ER sHSP, MTI sHSP, MTII sHSP, P sHSP, P-Like sHSP, PXI sHSP, PXII sHSP, TF, UAP I, UAP II, UAP IV, UAP V, UAP VI, UAP VII, UAP VIII, UAP IX, UAP X, UAP XI and NaLi). Phylogenetic/evolutionary analysis of cassava *MeSnRK* family genes with *SnRK* family of Malpighiales genomes grouped the members into 3 sub-groups (SnRK1, SnRK2 and SnRK3).

Starch biosynthesis pathway in cassava was reconstructed using the sequences available at Phytozome, TAIR, Gramene, Rice Genome Annotation Project, Sol Genomics Network and KEGG for cassava, *Arabidopsis*, maize, rice, potato and castor bean respectively. The template plants were selected as they are starchy crops and also having evolutionary and physiological resemblance with cassava. Based on the literature review and comparative analysis in one of the template plant, *Oryza*, five genes were prioritised in cassava, which were identified as candidate genes in starch biosynthesis pathway.

In silico analysis of carotenoid biosynthesis pathway in cassava (*Manihot esculenta* Crantz) was carried out for identification and functional annotation of the genes involved in the carotenoid biosynthesis pathways in cassava using templates of *Arabidopsis*, tomato, potato and sweet potato. Based on the classification of precursor pathway, core pathway and degradative pathway, the 39 genes were classified into different pathways, seven genes were classified into MEP pathway, 21 genes to the core carotenoid pathway and 11 genes belonged to the carotenoid degradative pathway. Locations of these genes in chromosomes were also identified.

At the Regional Centre (RC), Bhubaneswar 1242 accessions of tropical tuber crops were maintained in the field gene bank. A total of 1124 sweet potato accessions were maintained in the field gene bank. Twenty accessions were added to the germplasm this year. Preliminary yield evaluation of 45 accessions of sweet potato was done for two seasons. Accession, S-1609 was the highest yielder in both the seasons with a yield of 0.85 kg plant^{-1} and 1.15 kg plant^{-1} in the first and second seasons, respectively.

Forty five accessions of sweet potato were evaluated for cooking quality as well as tuber flesh colour. Of these, seven were orange-fleshed, two purple-fleshed and remaining were yellow or cream/ white-fleshed. Cooking quality based on IPGRI descriptors revealed that tubers of the accessions, S-1636, S-1709, S-1653, S-1657, S-27, S-1610, S-1707, S-1656, S-1712, S-1401 and S-1655 tasted good. The tubers of the accessions, S-1628, S-1636 and S-1656 were very sweet with starchy tubers and no fibre. Accessions, JAS-9-white and JAS-10-pink had starchy tubers with low sugar.

Characterization of 76 accessions of sweet potato based on morphological descriptors (CIP, 1991) (17 vegetative characters) and molecular markers (11 ISSR markers) could identify three sets of duplicates *viz*., S-203 and S-295; S-236 and S-256 as well as S-747 and S-772 using morphological markers of which only one set of duplicate *viz*., S-236 and S-256 was identified using 11 IISR markers.

At the RC, Bhubaneswar 50 sweet potato accessions were characterized for 12 morphological characters as per the descriptor.

In the sweet potato improvement program, progressive evaluation of germplasm resulted in the selection of four lines No.15, S-30/16, Baster-45 and accesion No. 527, with high yield (18-19.5 t ha^{-1}), crop duration of 75 to 80 days and which responded well to half doses of N and K (37.5 : 37.5).

Evaluation of OP generated breeding lines revealed 75 days maturity in seven lines, of which two were orange-fleshed, two white-fleshed and three purple-fleshed. Another set of seven purple-fleshed, six white-fleshed and nine orange-fleshed sweet potato were observed to have 90 days maturity. The yield of these breeding lines ranged between 18.0 and 22.0 t ha^{-1} and between 20.6 to 31.2 t ha^{-1} for 75 days and 90 days maturity lines, respectively.

The evaluation of clonal generations of reciprocal cross products of 2014-15 resulted in identifying 15 sweet potato lines (white-5, orange-4 and purple-6), of which 75 days maturity was observed in two white, two orange and three purple-fleshed lines. The remaining were of 90 days maturity. The crossed products of 2015-16 showed high yield ranging from 20.5 to 28.8 t ha^{-1} in 11 lines; 75 days maturity was recorded in three white-fleshed and two orange-fleshed lines, whereas, 90 days maturity was recorded in three white, two orange and one purple-fleshed lines. The clonal generation of 2016-17 revealed seven lines (white-4, orange-2, purple-1) with targeted traits. Of which 75 days maturity was recorded in two white and two orange-fleshed lines with a yield range of 16.8 to 20.8 t ha^{-1} and the rest with 90 days maturity showed an yield range of 19.2 to 26.8 t ha^{-1}. All the early maturing (75 days duration) lines showed no weevil infestation. Starch content ranged from 15.5 to 19.2%; β-carotene ranged from 9.5 to 15.2 mg 100 g^{-1} and anthocyanin 60 to 98.8 mg 100 g^{-1}.

In the field gene bank of yams, 1110 yam accessions comprising greater yam (591), white yam (158), lesser yam (220), potato yam (6) and wild yams (135) were conserved. Two accessions of lesser yam and one accession of potato yam were added to the existing germplasm. Eight greater yam accessions (Da-110, Da-198, Da-200, Da-210, Da-251, TCR-308, TCR-311 and Da-374) exhibited high field tolerance/resistance to anthracnose disease. Characterization of 22 greater yam accessions for biochemical traits resulted in the identification of one accession, Da-341 with high anthocyanin content (40.33 mg 100 g^{-1}). Molecular characterization of 30 accessions of greater yam with 15 ISSR and 10 SSR primers revealed no duplicates.

In white yam, many high yielding accessions were identified under various evaluation trials. Under germplasm evaluation, Dr-350 was the highest yielder (6.8 kg plant^{-1}). In other advanced trials, accessions Dr-353 (46.3 t ha^{-1}) and Dr-40 (45.3 t ha^{-1}) produced high yield. Dr-44 recorded high yield (35.0 t ha^{-1}) coupled with compact tuber shape.

In general, white yam accessions had higher dry matter content (28.0 to 39.8%) than the greater yam accessions (22.0 to 32.8%). White yam accession, Dr-319 had the highest dry matter (39.8%) followed by Dr-208 (38.2%). *Dioscorea bulbifera* (CTDb-2) recorded the highest crude protein content (5.62%) on fresh weight basis.

In lesser yam many high yielding accessions were identified under germplasm evaluation *viz*., CTDE-85 (5.8 kg plant^{-1}), De-104 (4.4 kg plant^{-1}) and De-53 (3.5 kg plant^{-1}). The greatest number of tubers (39) was observed in CTDE-116, followed by CTDE-174 (37) and CTDE-148 (36).

Three varieties of yams *viz*., one greater yam, one dwarf white yam and one trailing white yam were recommended by the Kerala State Seed Sub Committee for Varietal Release. Sree Nidhi (IC625797) is a greater yam variety, which produces medium cylindrical tubers with pinkish cortex and white flesh colour, with no browning when cooked. It produced an average yield of 35 t ha^{-1} with optimum tuber size, good culinary quality, white flesh colour without any undesirable coloration, very little apical portion and less wastage. It is tolerant to anthracnose disease and has medium dry matter (32.0%), starch (23.2% FW) and crude protein (2.5% FW).

Sree Swetha is a high yielding (34.0 t ha^{-1}) dwarf white yam variety with good culinary quality, which was released for cultivation in Kerala under non trailing condition. It has medium dry matter (32.98%), starch (22.0% FW) and crude protein (3.8% FW).

Sree Haritha is a high yielding (46 t ha^{-1}) white yam variety with compact tuber shape, which was released for cultivation in Kerala. It is a trailing type with medium dry matter (37.6%), starch (26.0% FW) and crude protein (3.22% FW).

Screening of pre-breeding lines of greater yam for resistance to anthracnose indicated that three hybrids *viz*., DaH-9/196, DaH-22-2-3 and DaH-58FG had high field tolerance/resistance to anthracnose disease. In the advanced yield trial of greater yam hybrids, DaH-10-1-4 produced the highest tuber yield (49.38 t ha^{-1}), followed by DaH-15 (46.91 t ha^{-1}), DaH-10-403 (45.42 t ha^{-1}) and DaH-8-174 (43.20 t ha^{-1}).

Among the yellow-fleshed greater yam hybrids, DaH-99/24 produced the highest tuber yield (53.08 t ha^{-1}) followed by DaH-24-1-1 (39.50 t ha^{-1}). Three profusely flowering fertile female clones were identified for use in future greater yam breeding programmes. A novel interspecific hybrid having dark yellow flesh with outer purple ring was also identified.

Among the dwarf white yam lines, three hybrids *viz*., Drd-1095, Drd-1142 and Drd-1148 produced yields more than 35.0 t ha^{-1}. In the on-farm trial of non trailing white yam, SD-15, having broader leaves and thicker vines as compared to other dwarf white yam varieties, produced significantly higher yields than Sree Dhanya (dwarf) and Sree Priya (trailing) with medium dry matter (34.0%), starch (17.0% FW) and crude protein (2.51% FW).

In the field gene bank, 683 edible aroid germplasm comprising 429 taro, 203 elephant foot yam, 48 tannia and 3 *Alocasia* were maintained to which one *Amorphophallus* sp. from Kallar, Kerala was added. In the DNA bank, DNA from 69 *Colocasia*, 13 *Xanthosoma* and 1 *Alocasia* lines were stored.

Molecular characterization of 36 taro accessions using 10 SSR markers showed that all the selected primers gave high polymorphism as explained by average number of alleles per locus, which ranged from 1.81 to 2.67; Shannon's diversity index, which ranged from 0.88 to 2.10 and Polymorphism Information Content (PIC), which ranged from 0.58 to 0.80. The 36 accessions showed diversity as indicated by the heterozygosity values, which ranged from 0.65 to 0.82. Dendrogram showed that no duplicates were present in this set.

At RC Bhubaneswar, 50 accessions of taro were characterized for 15 morphological characters. These were evaluated for their acridity level in the leaf and petiole, of which, 30 had very high acridity level, 10 had medium acridity and 10 had low acridity. Flowering was observed in eight accessions.

Field screening of 129 taro accessions for resistance against taro leaf blight (TLB) showed that, 89 were susceptible and the remaining 40 had field tolerance. In the activity for introgression of TLB resistance in taro, seven accessions showing tolerance to taro leaf blight for four consecutive seasons were identified.

Seeds from last year's cross in taro between C-157 or C-688 (female parents) with TLB tolerant lines-Muktakeshi, C-565 or C-203 (male parents) were raised along with OP seeds from TLB tolerant line (C-690-V) and susceptible parent C-157. OP seeds had more vigour as compared to the hybrids. In the activity on breeding for quality improvement in taro, 50 high yielding lines of taro were evaluated for various micronutrient contents in corms and leaves *viz*., crude protein, phosphorous, potassium, iron, copper, zinc and manganese. On the basis of biochemical and micronutrient profile, 15 nutritionally rich lines were selected and planted in crossing block for hybridization. Seven single crosses, 2×39, 5×36, 6×39, 6×43, 6×46, 39×43 and 52×36 were made and F_1 seeds were collected for further evaluation.

In elephant foot yam, the hybrid seedlings from the previous year crosses were harvested upon maturity and observations on corm and cormel characters showed that the corm weight of hybrid seedlings ranged from 10 g to 250 g. Twenty accessions of elephant foot yam were screened for collar rot resistance, and none had tolerance/resistance.

PYT II in tannia with seven accessions showed that the accession Xa-AD/2014-15 produced the highest cormel (5.98 t ha^{-1}) and total (8.68 t ha^{-1}) yield.

Using ISSR markers, the identity of the tannia accession, BCT (DK)-1 from Kalyani, which produced long unmarketable cormels and large corms, unlike typical tubers of tannia, was assessed along with other tannia accessions and an *Alocasia* accession. The dendrogram revealed that, the *Alocasia* existed as an outlier while, BCT (DK)-1 grouped in between the tannia and *Alocasia,* indicating a possible intermediate type.

In the AYT II of arrowroot, M2 produced highest rhizome yield (21.03 t ha^{-1}) and a single rhizome weight of 171.11g. The number of rhizomes per plant was highest in the genotypes M2 and M6 (22). The total starch content ranged from 18.0% (M1) to 19.87% (M4) while, the total sugar content ranged from 0.76% (M1) to 0.91% (M7). Total moisture content ranged from 63.57% (M2) to 68.17% (M1) while, the total ash content was highest in the genotype M7 (1.19%) and lowest in M1 and M2 (1.03%). The total crude fibre content was lowest in the accession M4 (0.66%) and highest in the accession M6 (0.89%).

Molecular characterization of 23 accessions of Chinese potato germplasm done using 10 ISSR markers, showed the absence of duplicates in this set. Variability was seen in this crop as indicated by the average percentage polymorphism of 84.27%. The similarity coefficient ranged from 0.52 to 0.94. The accessions TCR-137 and AKI/2015-2 remained as outliers in the dendrogram generated.

Under the *in vitro* conservation of germplasm of tuber crops, accessions of sweet potato and yams received from NBPGR and other accessions of cassava, sweet potato and yam were subcultured and maintained in the *in vitro* gene bank. Cultures of ten cassava, seven arrowroot and five Chinese potato accessions have been initiated and maintained. At the RC, Bhubaneswar, 10 accessions of cassava, 11 accessions of sweet potato, five accessions of taro, four accessions of yam, two accessions of elephant foot yam and four accessions of Chinese potato were maintained under IVAG. An *in vitro* conservation protocol was standardized in taro using sprouts from tubers with an intermediary shoot multiplication step.

Under bio-prospecting for angiogenic effects in tuber crops, ethanol extracts from *D. alata*, *D.bulbifera* and arrowroot tubers as well as *Coleus aromaticus* leaf and stem were tested for its effect in wound migration. Wound was created in a monolayer of HepG2, hepatocellular carcinoma cells and the cells were treated with the ethanol extracts prepared. Observations were recorded at the 0 hour of treatment and after 24 hours and 36 hours. It was observed that wound healing as evidenced through migration of HepG2 was seen as early as after 24 hours of treatment in the extract prepared from *C. aromaticus* leaf.

Evaluation of yield and other yield contributing traits in F_3 generation of five best F_1 hybrids along with check variety (RM-1) of yam bean revealed that tuber yield in F_3 generation of best F_1 hybrids ranged from 29.28 t ha^{-1} (3x9) to 32.44 t ha^{-1} (3x10) as compared to 22.44 t ha^{-1} in RM-1, the check variety. Starch content ranged from 8.22 to 14.56% and sugar content (3.55 to 7.84%). Cu content ranged from 120.4 to 149.5 ppm, Mn content from 15.22 to 43.22 ppm, Zn content from 33.3 to 39.5 ppm and Fe content from 130.2 to 203.4 ppm. F_3 generation seeds were raised for production of F_4 generation for evaluation of successive generation.

Two hundred accessions of minor tuber crops comprising Chinese potato, yam bean, arrowroot, *Curcuma* spp., *Canna* sp., *Costus* spp., *Tacca* sp., *Arisaema* sp. and *Coleus aromaticus* were maintained in the field gene bank.

Fifteen accessions of different minor tuber crops comprising 14 in seven species of *Curcuma* *viz.*,*Curcuma aromatica* (1), *Curcuma aeruginosa* (3), *Curcuma amada* (2), *Curcuma caesia* (1), *Curcuma decipiens* (2), *Curcuma zedoaria* (4) and *Curcuma longa* (1) and one of *Maranta arundinaceae* were collected from Idukki and Thrissur districts of Kerala and maintained for characterization.

Crop Production

Planting material of cassava stems soaked in hot water resulted in zero cassava mosaic virus infection for two months and it was 4, 6, 8 and 10% at 3rd month and 35, 38, 43 and 40% at 8th month of planting in cassava varieties Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Swarna respectively.

There was yield reduction (28%) in cassava under intercropping (24.16 t ha^{-1}) with pulses in rice based system over sole cassava (33.53 t ha^{-1}) in the second year. Rice var. Kanchana followed by short-duration cassava var. Sree Vijaya + black gram was productive (tuber equivalent yield of 40.19 t ha^{-1} and production efficiency of 111.64 kg ha^{-1} day^{-1}), energy efficient (191.11 x 10^3 MJha^{-1}) and profitable (added profit of ₹ 61,736 ha^{-1} over sole cassava), besides nutrient saving to the extent of half FYM and N and full P was possible (FYM @ 6.25 t ha^{-1}, NPK @ 50:0:100 kg ha^{-1}).

In Organic Farming, of the management practices, 100% organic or 75% organic was the most profitable when computed with premium price in cassava-groundnut, cassava-vegetable cowpea and taro-black gram.

Among the 12 cassava varieties tested under organic mode, H-226 produced the highest yield (46.70 t ha^{-1}) on par with CR-24-4 (Sree Reksha) (45.81 t ha^{-1}), Sree Athulya (36.29 t ha^{-1}) and Sree Pavithra (33.43 t ha^{-1}). H-226 and CR-24-4 (Sree Reksha) also generated higher profit (₹ 5,32,229 ha^{-1} and ₹ 5,18,855 ha^{-1}, respectively) and B: C ratio (4.16 and 4.08) under organic mode.

After 13 years of continuous cultivation in the same field, cassava was confirmed as a sustainable crop with a tuber yield of 8.0 t ha^{-1} and sustainable yield index (SYI) of 0.37 under absolute control, whereas the recommended PoP had a tuber yield of 11. 43 t ha^{-1} and SYI of 0.68.

Among the different organic manures *viz.*, green manuring *in situ* with cowpea (13.99 t ha^{-1}), coir pith compost (12.35 t ha^{-1}), and vermicompost

(12.62 t ha^{-1}) were suitable alternatives to FYM (11.43 t ha^{-1}) in cassava production.

The results of continuous cultivation of cassava in the same field for the 13th year among the different combinations of secondary and micronutrients applied based on soil test, Mg alone resulted in a significantly higher yield (16.40 t ha^{-1}) than PoP (11.43 t ha^{-1}) in cassava, where the soil available Mg status was 0.538 meq 100 g^{-1} (below the soil critical level). Soil test based application of NPK @ 71:0:71 kg ha^{-1} along with FYM @ 5 t ha^{-1} with complete omission of P and reduced levels of N, K and FYM had a tuber yield of 11.50 t ha^{-1} on par with PoP (NPK @ 100:50:100 + FYM @12.5 t ha^{-1}).

After conducting field experiments continuously for three seasons with NPK efficient cassava genotypes *viz*., Sree Pavithra, CI-905, CI-906 and 7 III E3-5 at four levels of NPK (25, 50, 75, 100% NPK), these genotypes were significantly different with respect to tuber yield (32.89, 38.48, 36.46 and 30.98 t ha^{-1} respectively for Sree Pavithra, 7 III E3-5, CI-905 and CI-906) with 7III E3-5 having the highest yield on par with Sree Pavithra and CI-905. Tuber yield of these genotypes with 25, 50, 75 and 100% NPK were on par during three seasons including the pooled mean (32.03, 33.02, 34.29, 36.17 t ha^{-1} respectively at the above NPK levels) indicating that by using these NPK efficient genotypes, NPK fertilizers can be saved upto 75%.

Among the four genotypes, Sree Pavithra (36.43 ppm) had the lowest HCN and CI-906 had the highest starch (21.9%) and were tolerant to CMD, with good plant architecture, tubers were low in cyanogen and medium in starch and had excellent cooking quality. Among the three CFs tried in cassava under intercropping in coconut, CF1 and CF2 with grades as N:P_2O_5:K_2O:Mg:Zn:B @ 8:11:21:3.5:1:0.3 (CF1), 7:12:24:2.5:1.25:0.4 (CF2) @ 500 kg ha^{-1} performed best with tuber yields of 53.76 and 53.46 t ha^{-1} respectively.

The cassava tuber yield of 31.8, 33.4 and 28.6 t ha^{-1} was obtained in the third year of study (2016-17) under conventional (CT), deep (DT) and minimum tillage (MT) practices, respectively. The influence of different types of mulches on the yield was in the order of porous ground cover (GC) > crop residue (CR) > no mulch (NM). Maximum bulk density (1.62 Mg m^{-3}) was recorded in soils under minimum tillage whereas the values under CT and DT were on par (1.46-1.52 Mg m^{-3}).

Studies using ensembled multi-model prediction of change in climate and climate suitability of cassava by 2030 and 2050 in major cassava growing regions of India based for 4.5 and 8.5 representative concentration pathways (RCP) showed that average climate suitability change in major cassava growing regions is 4 and 4.78% under RCPs 4.5 and 8.5 by 2030 and 8.36 and 7.6% under RCPs 4.5 and 8.5 by 2050. Detailed studies showed that there is no considerable change in the climate suitability of cassava in major growing areas by 2030 and 2050, which shows that cassava is resilient to climate change.

In cassava field under minimum tillage soil hydraulic properties *viz.*, field saturated hydraulic conductivity (HC), matric potential (MP), and sorptivity (SS) estimated under different treatments had shown that HC and SS of CT was 16 and 20% higher as compared to minimum tillage. Minimum tilled soils were not having improved soil transmission properties in the third year.

Among the ten cassava varieties tested for their performance under normal and water deficit stress (WDS) conditions, Sree Athulya was the best performing variety under WDS free conditions while, under WDS conditions, Sree Reksha outperformed other varieties in terms of growth and physiological parameters.

In control and WDS conditions, cassava genotypes had the average net photosynthetic rate (*Pn*) of 28.2 and 18.4 µmol CO_2 m^{-2} s^{-1} (34% reduction in stressed plants over control), respectively, while, in control and WDS conditions, cassava genotypes had the average stomatal conductance (g_s) of 0.3 and 0.18 mol H_2O m^{-2} s^{-1} (39% reduction in stressed plants over control), respectively.

On-farm validation experiments of customised fertilizers developed for cassava based on SSNM technology were completed in 35 farmers' fields spread across five agro-ecological unit (AEU) zonations of Kerala (Malappuram, Palakkad, Idukki, Alappuzha and Pathanamthitta). In Pathanamthitta and Alappuzha districts, the SSNM resulted in significantly higher tuber yield (42.00 and 38.00 t ha^{-1} respectively) than farmers' fertilizer practice (FFP) (36.50 and 31.00 t ha^{-1} respectively). On an average, the customized fertilizer treatment resulted in 22% higher tuber yield over FFP across the five agro-ecological units studied. *Sree Poshini*, a mobile app for SSNM of tropical tuber crops was developed. Five foliar solid and liquid micronutrient formulations developed for SSNM of cassava (2 products), sweet potato, elephant foot yam and yams are being commercialized through AGRINNOVATE for ₹ 2.5 lakhs. Five foliar solid micronutrient formulations were also developed for SSNM of cassava (2 products), sweet potato, elephant foot yam and yams.

The results of three seasons trials conducted during 2017-18 to standardise the INM package comprising of major, secondary and micronutrients revealed that in the case of major nutrients, among the different levels of N, P, K tried independently, N @ 50, P @ 50 and K @ 100 kg ha^{-1} resulted in maximum tuber yield in sweet potato (Variety: Sree Arun). Gypsum, dolomite and calcium nitrate @ 2 t ha^{-1} were good liming materials for sweet potato. Foliar application of either Mg (1%) or B (0.01%) or soil application of $ZnSO_4$ (20 kg ha^{-1}) was found best.

Application of NPK @ 50:25:50 kg ha^{-1} was optimum to realize higher tuber yields of sweet potato with good quality tubers in the natural saline soils under island ecosystem of Andaman.

In greater yam + maize intercropping system, maize produced higher yield under fertigation in 30 splits at 2 days interval. Maize yield decreased with increasing fertigation frequency intervals and number of split doses. Fertigation in 60 splits at 3 days interval resulted in higher greater yam equivalent yield of 37.9 t ha^{-1}. Fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} in 60 splits at 3 days interval resulted in maximum gross (₹ 5,68,500 ha^{-1}) and net returns (₹ 3,58,500 ha^{-1}) as well as B: C ratio (2.71).

The yield of taro under intercropping with pulses (6.01 t ha^{-1}) was on par (+6.0%) with sole cropping (5.68 t ha^{-1}), during the first year. Of the two varieties, Sree Kiran proved superior and resulted in an yield increase of 14.56%, whereas Sree Rashmi could not withstand competition and the cormel yield was lowered by 4.20%. Both green gram and black gram under reduced fertility level (FYM @ 6.25 t ha^{-1}, NPK@ 40:0:100 kg ha^{-1}) produced significantly higher cormel yield in taro.

For upland taro, water requirement was critical from planting to 24 weeks after planting, coinciding with sprouting, tuber initiation and tuber bulking phases. Based on a preliminary experiment, drip irrigation @ 75% of the cumulative pan evaporation (CPE) from planting upto 24 weeks was ideal for producing optimum cormel yield in taro.

The maximum *Pn* of nine taro genotypes increased due to short-term (ten minutes) exposure at eCO_2 concentrations between 400 ppm and 1000 ppm in nine taro genotypes. The average *Pn* of nine taro genotypes was 24.4, 33.79, 40.60 and 45.12 µmol CO_2 m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. The nine taro genotypes had 61.80 – 113.3% hike in *Pn* at eCO_2 (1000 ppm) as compared to ambient CO_2 (400 ppm). However, the per cent of increment in *Pn* at eCO_2 for every 200 ppm between 400-1000 ppm significantly declined (4.4-18.4%) at 1000 ppm CO_2. The difference in *Pn* were statistically significant across nine taro genotypes, CO_2 concentrations and the interaction effect of genotypes and CO_2 concentrations on *Pn* was significant.

Elephant foot yam corms fumigated with carbon disulphide @ 80 ml 100 kg^{-1} resulted in maximum uniform sprouting of 99% at 30 days after planting (DAP) and produced significantly higher corm yield (24.50 t ha^{-1}).

The yield of elephant foot yam under intercropping with pulses (51.49 t ha^{-1}) was on par (- 8.5%) with sole cropping (56.27 t ha^{-1}), during the second year. Among the treatment combinations, elephant foot yam var. Gajendra + soybean under full fertility level (FYM @ 25 t ha^{-1}, NPK@ 100:50:150 kg ha^{-1}) resulted in higher yield (66.40 t ha^{-1}), equivalent energy (239.91 x 10^3 MJ ha^{-1}), production efficiency (247.30 kg ha^{-1} day^{-1}) and tuber equivalent yield (66.77 t ha^{-1}) over sole cropping of elephant foot yam var. Gajendra (46.48 t ha^{-1}, 167.33 x 10^3 MJ ha^{-1}, 172.45 kg ha^{-1} day^{-1}, 46.48 t ha^{-1}).

Comparison of conservation vs. conventional vs. organic practices in banana + elephant foot yam system indicated that conservation chemical treatment proved to be the most productive (+13% over PoP) and profitable (+32% over PoP) as revealed from the highest total tuber equivalent yield (45.34 t ha^{-1}), production efficiency (151.13 kg ha^{-1} day^{-1}), gross income (₹ 13,60,170 ha^{-1}), net income (₹ 8,66,421 ha^{-1}) and B:C ratio (2.75). Weed control ground cover resulted in higher weed control efficiency (95.3%), which led to higher elephant foot yam corm yield (32.4 t ha^{-1}) compared to the other treatments. The next best treatment was four rounds of manual weeding (30, 60, 90 and 120 DAP; 32.1 t ha^{-1}) followed by 2 rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP; 30.4 t ha^{-1}).

Among the new generation herbicides tested for the management of weeds in elephant foot yam, higher corm yield (38.47 t ha^{-1}) and benefit cost ratio (5.15) was obtained with T_7 Pendimethalin (PE) + Glyphosate at 45 DAP + Glyphosate at 90 DAP.

Use of plastic ground cover mulches (weed mat) and application of super absorbent polymers like Pusa hydrogel could reduce the water requirement of elephant foot yam to 50% without adversely affecting the corm yield.

In elephant foot yam, soil and foliar application of Mg (1%) independently and soluble NPK (19:19:19) @ 5 kg ha^{-1}along with Zn EDTA (0.1%) as foliar was the best.

The three customized fertilizer (CF) formulations developed for elephant foot yam under intercropping in coconut gardens of AEU 3 and AEU 9 with grades as $N:P_2O_5:K_2O$:Mg:Zn:B @ 8:11:21:3.5:1:0.3 (CF1), 7:12:24:2.5:1.25:0.4 (CF2), 7:3:25:3:1.25:0.4% (CF3), @ 625 kg ha^{-1} were found best after experimentation in five districts of Kerala with an average yield of 62.62 t ha^{-1} and BC ratio of 8.49.

Significantly highest corm yield (26.34 t ha^{-1}) was obtained due to integrated application of lime + FYM + NPK + $MgSO_4$ with highest yield response of 159% over control in elephant foot yam. The increase in tuber yields was 37, 65 and 107% due to application of 50, 100 and 150% NPK based on soil test values over control. Significantly highest dry matter, starch and sugar were observed due to integrated application of lime + FYM + NPK + B.

To induce tolerance to high temperature stress through chemical treatments in elephant foot yam under field conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 35.59%, 22.44% and 1.23% respectively as compared to control plants under ~30-32°C day temperature. Under humidified polychamber conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 33.98%, 19.41% and 30.09% respectively under 32-40°C day temperature and >80% RH (10am – 4pm) as compared to control plants. Under polychamber conditions without humidification, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 28.81%, 21.9% and 27.39% respectively under 32-40°C day temperature and ~54% RH (10am - 4pm) as compared to control plants. Compared to field conditions, the corm yield was significantly reduced by 31.27% to 64.0% under polychamber conditions in control as well as under $CaCl_2$, Salicylic acid and BA treatments.

The three elephant foot yam genotypes had the average *Pn* of 17.97, 25.07, 29.44 and 30.06 µmol CO_2 m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. The three elephant foot yam genotypes had 56.71-82.51% hike in *Pn* at eCO_2 (1000 ppm) as compared to ambient CO_2 (400 ppm). However, the per cent of increment in *Pn* at eCO_2 for every 200 ppm between 400-1000 ppm significantly declined (- 4.81-9.03%) at 1000 ppm CO_2. The differences in *Pn* were statistically significant across three elephant foot yam genotypes and CO_2 concentrations. However, the interaction effect of genotypes and CO_2 concentrations on *Pn* was insignificant, whereas the *Pn* had a quadratic relation with the increase in CO_2 concentration.

A total number of 210 micro plants of different cassava varieties against cassava mosaic virus and 140 numbers of elephant foot yam variety Gajendra were indexed. Quality planting materials of tuber crops *viz.*, 70, 000 cassava stems, 6 tonnes of elephant foot yam, 14 tonnes of greater yam, 4.5 tonnes of taro and 2.35 lakh vine cuttings of sweet potato and 300 kg of yam bean seeds were produced.

Though maximum gross return (₹ 4,85,500 ha^{-1}) was observed in weed control ground cover treatment, higher benefit cost ratio (2.22) was obtained in 2 rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) treatment due to low cost of cultivation.

The soils adjacent to industrial areas of Bhadrak, Balasore, Mayurbhanj, Cuttack and Ganjam districts of Odisha contain toxic levels of Fe, Mn, Cr, Ni and Pb with low biological activities. It was also noticed that the available Cu and Zn in the polluted soils were higher than the critical limits.

Soil health hoarding of 10 X 6 ft dimension in trilingual (Hindi, English, Malayalam) was prepared and installed at the entrance of ICAR-CTCRI which is on the main public road side that can be seen very prominently to the public.

A total of 223 soil health cards were issued to the beneficiaries of MGMG programme of the Institute belonging to eight panchayats of the Kazhakuttom Block, Thiruvananthapuram.

Crop Protection

Analysis of cassava mosaic diseased samples from different locations showed the variability among the SLCMV and more particularly in the common region of the genome. Using Rolling circle amplification strategy, full genome of both DNA-A and B components of SLCMV were cloned and the infectious clone was prepared with bitmer preparations. Different bioinformatics tools and biological databases were used for predicting homology of coat protein of SLCMV like GenBank-NCBI, UniProt and PDB (Protein Data Bank). Capsid protein sequence of SLCMV, in FASTA format was mined from GenBank-NCBI database (*Sri Lankan cassava mosaic virus* isolate coat protein (AV1) gene, complete cds GenBank: KX343908.1) and UniProt database (Q7T6F2) for homology modeling and docking study. Three-dimensional structure of the SLCMV capsid/coat protein was predicted by homology modelling. The homology model of SLCMV was constructed by SWISS-PROT. Three-dimensional structure of SLCMV consists of the N-terminal domain (*red*) and C-terminal arm (*blue*) was predicted. The result of homology modelling revealed partial similarity between NCBI database and Uniprot Database and completely non-significant to the control (*Tomato leaf curl virus* coat protein).

A preliminary *in silico* analysis was performed for the identification of miRNAs targeting SLCMV. Overall 153 miRNAs previously reported from *Manihot esculenta* was analysed *in silico* for their RNAi effects on SLCMV. Among the conserved miRNAs, 10 miRNA candidates that belonged to three miRNA families such as MIR399, MIR 159, and MIR172 were predicted to target the AC1 and BC1 protein coding regions of SLCMV. Two selected miRNAs such as miR408a and a novel miR1, that were predicted to have a role in stress response were cloned from small RNA isolated from the susceptible variety H-226, by stem-loop RT-PCR. The sequencing confirmed the mature miRNAs. Differentially expressed gene candidates that were reported to be involved in the stress response during SLCMV infection in the model plant *N. benthamiana* were analysed for their expression. Among the seven selected genes, PCR amplification profiles were standardised for sucrose synthase, cytochrome p450 monoxygenase, WRKY 30 and βeta-1, 3-glucanase. These genes were identified from the susceptible plant, H-226 on infection. A detailed *in silico* analysis was also attempted for the identification of gene regulatory effects of virus-encoded siRNAs /miRNAs on the host genome. Several potential gene targeting sites on the host genome were identified.

Genome-wide HMM based-analysis led to the identification of 123 *MeNAC* family genes in cassava. The *MeNAC* family members were distributed in all the 18 chromosomes of cassava genome. Promoter analysis of 123 *MeNAC* family genes of cassava revealed the presence of tissue-specific, biotic, abiotic, light-responsive, circadian and cell cycle-responsive *cis*-regulatory elements. Phylogenetic/evolutionary analysis of cassava *MeNAC* family genes with *Arabidopsis* genome grouped the members into 2 large groups and 18 sub-groups.

Metagenomic DNA of *Bemisia tabaci* was isolated by SDS based metagenomic DNA extraction procedure and used the Illumina Next Generation Sequencing platform to reveal total bacterial community present. Analysis of hypervarible V3 region of 16S rRNA fragment resulted in 1, 321, 906, 690 and 661 high quality paired end sequences with mean length of 150 base pairs. Highly diverse bacterial communities were present in the sample containing approximately 3, 513 operational taxonomic units (OTUs). Downstream analysis using QIIME and MG-RAST programmes showed a marked difference in the abundance of bacteria in different populations of whitefly. Mining out of functional diversity of bacterial community present in whitefly, revealed their role in making *B. tabaci* a successful vector and polyphagous pest of global importance. Analysis also showed the presence of specific endosymbionts like *Asenophonus,* which was found only in high CMD infested area. Insecticidal toxin producing opportunistic bacteria like *B. thuringiensis*, *B. cereus etc*. were also reported in *B. tabaci*.

Ten cassava hybrids with high yield (>50 t ha^{-1}), CMD resistance and good plant type were selected and planted in replicated evaluation trial for identifying CMD resistant varieties suitable for industrial use. All the varieties remained symptom free throughout the growth period. The CMD resistance of all these hybrids to *Sri Lankan cassava mosaic virus* (SLCMV) and *Indian cassava mosaic virus* (ICMV) was confirmed through artificial screening through grafting and multiplexed PCR. The resistance of these hybrids was linked to the marker SSRY28. The dry matter content of the resistant hybrids ranged from 22.8% to 55.4%. Among the hybrids, 15S433 produced the maximum dry matter (55.4%) followed by 15S256 (49.8%), 15S 436 (48.8%) and 15S 142 (48.4%). The maximum tuber yield was recorded in 15S256 (69.10 t ha^{-1}). Eight hybrids with high yield and cooking quality were selected and planted in replicated evaluation trial for identifying CMD resistant varieties suitable for culinary purpose. Among the hybrids selected with good cooking quality, 15S 409 (66.6 t ha^{-1}) produced the maximum tuber yield followed by 15S59 (64.2 t ha^{-1}). Based on Advanced Yield Trial (AYT), six CMD resistant hybrids that produced high yield (>50 t ha^{-1}) *viz*., 9S 73, 9S 132, 9S 164, 9S 172, 9S 174 and 9S286 were multiplied for conducting agronomic trial.

A study was initiated with the highly CMD susceptible variety, H-165, by planting in pots by applying nutrients *viz*., Si, Ca, B, Zn, P, Mg, K, both soil and foliar to determine the effect of nutrients on management of CMD. There was a reduction in CMD intensity from 96.02% at one month after planting (MAP) to 70.12, 44.86 and 32.39% respectively at 2, 3, 4 MAP with application of nutrients *viz*., Ca, Zn, K and P individually.

For CMD management through nutrient application, Si, Ca, B, Zn, P, Devirus, ginger mixture and biogas slurry were applied under field conditions. The maximum reduction in CMD intensity as compared to control was observed with application of B (54%) followed by Si (41%), Ca (24%) and P (16%) at four months after planting.

Cassava mosaic virus free planting materials of cassava varieties, Sree Vijaya (5000 stems) and Sree Jaya (4000 stems) were produced and indexed for virus. The rate of re infection was nil upto two months and it was 6 and 8% at 3rd month and 12 and 18% at 4th month and 38 and 41% at 8th month of planting the virus free cassava respectively. Planting of virus infected cassava material showed the virus symptoms at first month itself and the virus incidence was 15 and 12% at 2nd month, 19 and 21% at 3rd month and 33 and 29% at 4th month and at 8th month it was 67 and 78% in the varieties Sree Vijaya and Sree Jaya respectively.

Virus free cultures of cassava variety, H-226 was maintained *in vitro* and mass multiplied for the production of synthetic seed. Nodal explants and shoot tips from *in vitro* cultures were encapsulated with 3% sodium alginate and polymerized in 100 mM calcium chloride. Sodium alginate and calcium chloride solutions were supplemented with 0%, 3%, 6% and 9% sucrose to study the *ex vitro* germination potential of cassava synthetic seed. Different cytokinin and auxins like 6-Benzylaminopurine (BAP), kinetin and Indole-3-butyric acid (IBA) respectively, were added in different concentrations and combinations to the encapsulation solutions to study the *ex vitro* germination. Different potting mixtures *viz.,* cocopeat, vermiculite and sandy soils were used for *ex vitro* germination studies.

Survey on insect pests of sweet potato in Andhra Pradesh, Kerala and Odisha showed that sweet potato weevil, *Cylas formicarius* is the single and most serious pest causing damage upto 90% if management practices are not adopted.

The insecticides, Imidacloprid and Dimethoate at 0.05% were very effective against spiralling white fly (SWF). Imidacloprid and Dimethoate @ 0.01% resulted in 82.2 and 84.2% reduction in the population of SWF, whereas it was 96.5 and 91.2% at 0.05%.

The mortality of sweet potato weevil was 91.5 and 85.0% respectively when fed with Imidacloprid and Chlorpyrifos (at 0.001 and 0.01%), treated leaves. But its mortality increased to 100% with Imidacloprid at 0.05%. Malathion at all the three concentrations showed the least mortality. Leaf sprayed with all the test insecticides and when fed on third day after treatment, mortality of weevil due to Imidacloprid at 0.05 and 0.01% was 86%, whereas treatment with rest of the test insecticides, the mortality was less than 50%. Leaf fed on five days after treatment, the mortality was less than 15% in all the five insecticides treated, whereas it was 75% in the case of Imidacloprid, (both at 0.01 and 0.05%). On the 7th day, the mortality of weevil was 50% with Imidacloprid at 0.05%.

Rooted sweet potato cuttings were dipped into each concentration of insecticides upto one day and subsequently they were transferred into tap water. The leaf and stem cuttings were fed to male and female sweet potato weevil separately in 1, 3, 5, 7, 9 and 12 days after treatment, and their mortality was studied. One day after treatment the mortality was 71 and 80% respectively in the treatments with 0.01 and 0.05% of Imidacloprid, and on 5th day after treated leaf and stem when fed to the weevil, the mortality declined to 73% in 0.01% treatments.

The gene specific primers for the proteinase inhibitor and cysteine protease genes of sweet potato were designed and validated in 41 genotypes including released varieties and germplasm accessions by sequencing. All the sequences showed 99% similarity to sweet potato proteinase inhibitor SPLTI-1 gene (AF330701.1), SPLTI-a mRNA(AF330700.1), SPLTI-b mRNA (AF404833.1), SPLTI-2 gene (AF330702.1) and cysteine protease mRNA (AF260827.1). The expression of proteinase inhibitor genes in 15 sweet potato genotypes were studied by Reverse Transcriptase PCR (RT-PCR). Out of 15 genotypes four released varieties Kanhangad, Bhu Sona, Bhu Krishna, Sree Arun, and one germplasm accession S-1401, the proteinase inhibitor gene of 122 bp was amplified by RT-PCR. The real time quantitative PCR (RT-qPCR) analysis for the quantification of relative expression of the proteinase inhibitor gene in these sweet potato genotypes was standardised with cytochrome c oxidase subunit Vc (COX) (159bp) as reference gene. The gene expression of the sweet potato genotypes was calculated by $2^{-\Delta\Delta C_T}$ method and the expression of proteinase inhibitor gene was high in Kanhangad followed by Bhu Sona, S-1401, Sree Arun and Bhu Krishna.

Cloning and sequence analysis of *Sweet potato feathery mottle virus* from infected samples showed that among eight clones, five were closely related to SPFMV-Argentina isolate, two were Korea isolate and one was China isolate.

For developing decision support system to advise the farmers for managing anthracnose in greater yam based on weather parameters, three released varieties of greater yam, *viz*., Orissa Elite (highly susceptible), Sree Karthika and Sree Keerthi (tolerant) were used and the disease severity was observed at weekly intervals till 9th month of planting, i.e. upto December 2017. The maximum disease intensity was observed in Orissa Elite (OE) (75%) followed by Sree Karthika and Sree Keerthi. Generally the disease intensity will advance in August after rainfall followed by high temperature and will be static in September and shoots up in October and peak during November first week. But, during 2017-2018, the disease was high only at the end of November and December. AUDPC of Sree Keerthi, Sree Karthika and Orissa Elite is 1960, 1305.5 and 5085.5 respectively and the score was 1.9, 1.3 and 5.0 respectively.

The commonly used fungicide *viz.*, mancozeb, carbendazim and ICAR-CTCRI developed biopesticide, *Nanma* were evaluated for their efficacy to inhibit *Colletotrichum gloeosporioides* causing greater yam anthracnose *in vitro* through dual culture technique. Carbendazim (7.5 ppm), mancozeb (500 ppm) and *Nanma* @ 1% showed maximum effect individually. The disease intensity was significantly low in the recommended package (0.05% carbendazim), which was on par with the combination of 0.025% carbendazim and 0.5% *Nanma* in a pot trial. The fungicide dosage was 50% less than the present recommendation. The stability of the mixture was also tested weekly for the first month and then monthly. It was stable for nine months and the stability test will be continued.

In the field trial on management of anthracnose in greater yam with combination of bio-rationals and fungicide, carbendazim (0.05%), there was reduction in intensity and increase in the yield in all the treatments compared to control. The maximum decrease in disease intensity over control was observed in soil application and tuber treatment (S+T) with *Nanma* along with carbendazim spray (7 times) (64%) and S+T (*Trichoderma*) and carbendazim spray (3 times) (64%). Soil application and tuber treatment (S+T) with *Menma* and spraying *Nanma* (weekly) (34.71) resulted in highest increase in yield over control, which was closely followed by S+T (*Nanma*) along with spraying carbendazim (7 times) (34.41%).

To refine management strategies for taro leaf blight (TLB) incidence, cormel treatment with *Bacillus amyloliquefaciens*/*Trichoderma asperellum* along with the soil application of vermicompost amended with *B. amyloliquefaciens / T. asperellum* at the time of planting reduced the percent disease intensity (PDI) from 52.08 to 25.0 and 31.67 respectively.

Onset of TLB infection and its spread was studied in taro varieties, Sree Kiran, Sree Rashmi (highly susceptible) and Muktakeshi (resistant), with an objective to develop decision support system (DSS) for TLB. The first appearance of leaf blight symptom was noticed in the month of May. The disease incidence showed an increase with time and the highest PDI of 55.25 was noted in Sree Kiran in November. AUDPC score was calculated based on the PDI calculated for different months. The score clearly showed that Muktakeshi was resistant to taro leaf blight.

The presence of *Taro bacilliform CH virus* was noticed in taro samples that showed viral symptoms. Sequence analysis of the virus showed 100% similarity with Taro bacilliform China isolates.

Analysis of soil samples collected from elephant foot yam fields of different areas showed that *Pratylenchus coffeae* and *Meloidogyne incognita* were in maximum frequency and abundance in ICAR-CTCRI, whereas *Hoplolaimus* sp. and *M. incognita* were the predominant species in Omaloor and Pathanamthitta of Kerala with prominence values of 47.25 and 19.65, respectively. In Appakoodal and Erode of Tamil Nadu. *M. incognita* and *Pratylenchus* sp. were the most predominant nematodes with prominence values of 29.36 and 20.74, respectively and in Kollegal, Karnataka, *M. incognita, Pratylenchus* sp., and *Rotylenchulus reniformis* were observed, but their population density was less than a nematode per gram of soil.

In elephant foot yam, corm treatment with *Trichoderma asperellum* along with the conjoint application of carbendazim and mancozeb (Saaf) reduced the collar rot incidence from 22.67 to 8% followed by tuber treatment with *Trichoderma asperellum/B. amyloliquefaciens* along with soil application of vermicompost amended with *Trichoderma asperellum/B. amyloliquefaciens*. Highest yield (32.92 t ha^{-1}) was also obtained in tuber treatment with *T. asperellum* along with combination of mancozeb and carbendazim (0.2%) as against 21.23 t ha^{-1} in control.

To study the etiology of post-harvest rot in elephant foot yam, 61 diseased corms were collected from 13 different storage yards and 16 organisms were isolated. Koch's postulates were proved with 12 organisms. Apart from the already reported organisms, *Colletotrichum* spp., *Rhizoctonia* spp., *Aspergillus* spp., *Penicillium* spp. and *Pythium* spp. were found associated with post-harvest rot in EFY.

Tuber treatment with a fungicide containing a combination of mancozeb and carbendazim (0.2%), *Nanma* (0.7%) and combination of fungicide and *Nanma* prior to storage was effective in checking post-harvest rot in elephant foot yam. Compatibility test revealed that mancozeb and carbendazim with *Nanma* had synergistic effect.

The healthy elephant foot yam tubers indexed for DsMV through DAS-ELISA planted in farmer's field at Thiruvananthapuram were symptom free throughout the crop period. DAS-ELISA of all the samples performed twice with leaf samples at 3 months after planting and tuber at the time of harvest did not show positive. The second generation elephant yam tubers from tissue cultured plants were planted in Anchal, Kollam district, Kerala also did not exhibit viral symptoms. Since vectors were not observed in elephant foot yam, the disease free planting material production may be the acceptable strategy for managing viral diseases in the crop.

Thermotheraphy of DsMV positive EFY tubers was performed with steam treatment at 45-50^{o}C for 60 min and 90 min, hot water treatment at 45 to 50^{o}C for 60 min and direct sunlight for 180 min (38-40^{o}C) along with positive and negative control. DAS-ELISA has been performed after three months of planting. The per cent of negative sample was 15, 0, 75, 50, 56 and 87 respectively in the above samples. However, the germination percentage in hot water at 45 to 50^{o}C for one hour and direct sunlight for three hours 38-40^{o}C was only 57%. The germination was 100% in the other treatments.

The biopesticide *Nanma* at 3 and 5% were effective against rugose spiralling white fly

(RSWF) [*Aleurodicus rugioperculatus* Martin] in arrowroot and coconut, respectively.

The root knot nematodes recovery was significantly lower in the solarized soil as compared to control. Cell free culture filtrate of four bio-agents significantly inhibited the egg hatching and caused juvenile (J2) mortality of *M. incognita*. Maximum suppression in egg hatching was recorded in *Bacillus amyloliquefaciens* (99.9%). GC-MS analysis of purified secondary metabolites of the bacteria showed the presence of Octadecanoic acid 2, 3-dihydroxy propyl ester and Hexadecanoic acid, methyl esters, which are known to possess nematicidal properties.

Sixty organisms were isolated from soil samples collected from different parts of the country. Ten bacterial isolates were selected based on mycelial suppression of *Phytophthora Colocasiae* and *Sclerotium rolfsii* under *in vitro* condition. IAA production by the potential isolates was analysed and it varied from 5.06 µg ml^{-1} to 8.07 µg ml^{-1}. Three most efficient isolates were identified as *Pseudomonas aeruginosa, P. alkylphenolica* and *Myroides odoratimimus* based on 16s r DNA amplification and sequencing.

Sixty one endophytes, including 31 fungal endophytes and 30 bacterial endophytes were isolated from leaves, stem and roots of greater yam, taro, coleus, and arrowroot. Bacterial endophytes showed more inhibitory activity (70%) against *Colletotrichum* compared to fungal endophytes (60-65%). Among them 3 bacterial endophytes and 4 fungal endophytes were potential. The bacterial isolates were identified as *Bacillus* SPP by 16S rDNA sequencing.

Multiplication of *Trichoderma* was attempted on ten substrates including dolomite, cassava rind, bio-pesticide waste, cassava powder and cassava tuber extract. The highest population of 1.33 $x10^{40}$ cfu g^{-1} was obtained with vermicompost. The population in substrates of cassava origin were very high (6.0 $x10^{26}$ to 1.0 $x10^{36}$ cfu g^{-1}**)** compared to dolomite (6.3 $x10^{14}$ cfu g^{-1}). Growth promotion by *Trichoderma* (21 isolates) was studied using cowpea seeds. Out of the best isolates, five were *Trichoderma asperellum* and two were *T. virens* as per tef and ITS region amplification.

Loop mediated isothermal amplification (LAMP) was employed for rapid and effective detection of fungal pathogens. LAMP primer was designed using *Phytophthora colocasiae* (Accession KY432681), *Colletotrichum gloeosporioides* (Accession KJ632430) and *Sclerotium rolfsii* (Accession KC894861). Three sets of primers were designed based on the following 6 distinct regions of the ITS target gene: the F3c, F2c and F1c regions at the 3' side and the B1, B2 and B3 regions at the 5' side after considering the length, base composition, GC contents and the formation of secondary structures. Final verification of primer regions was done by using the Primer Explore (special software to design LAMP primers). Using this technique, fungal DNA of *P. Colocasiae* and *C. gloeosporioides* was amplified from the fungal mycelium under isothermal condition of 63^{o}C for one hour in PCR, which could detect the pathogen by visual evaluation of the reaction mixture by adding different nucleic acid dyes like ethidium bromide, calcein and HNB in LAMP reaction mixture. The products of LAMP reaction could also be detected by electrophoresis on 2% agarose gels, and showed ladder-like patterns. Given its specificity, sensitivity, easy handling and cost-efficiency, the LAMP assay is recommended for rapid diagnosis of fungal pathogens infecting tuber crops.

Crop Utilization

Cassava papads were made from the dough of cassava tuber mash and sago polish powder and also from the dough of cassava flour-sago powder with steaming as pretreatment. The biochemical and physical properties of the papads were analyzed. Among all the treatments, the papad with highest overall acceptability was obtained from the dough of 6 h fermented cassava tubers with sago powder.

Noodles were prepared from the composite flour containing cassava flour, soya flour or Bengal gram flour, maida and gelatinised cassava starch using cold extrusion method followed by steaming for one minute.

The TNAU model cassava harvester was modified by increasing the shank height from 30 cm to 38 cm and the width of the digging blade from 16.5 cm to 22.5 cm. The improved harvester with optimized spacing of 65 cm showed a maximum tuber damage of 9.05% for the cultivar Mulluvadi, planted on mounds and with a minimum tuber loss of 4.42% for the variety H-165, planted on ridges made by the tractor.

The soaking time and concentration of reconstituted dry starch was optimized for sago production. Twelve hour of soaking of dry starch in water at 30% starch concentration was found to be optimum. Sago produced from the combination of reconstituted dry starch and wet starch in the ratio of 75:25 was better among various treatments. The globulation time (15 min), frequency (3.5 Hz), roasting time (3 min) and temperature (170°C) were optimized for good quality sago production.

Particle boards were prepared using cassava starch modified with sodium hypochlorite (oxidized starch) and octenyl succinic anhydride (starch succinate) as binder and glycerol and water as plasticizers.

The optimum conditions for the production of cassava stem based particle board with oxidised cassava starch as the binder were: starch-12.9%, pressure-55.36 bar and glycerol-5%. The particle boards have the following characteristics: Density-851 kg m^{-3}, moisture content-8.2%, total colour difference-39.7, maximum water absorption-11.9% and 96.5%, respectively after 2 h and 24 h of soaking, and thickness swelling after 2 h soaking-24%.

Cassava stem based particle boards were produced using starch succinate as the binder under the optimum conditions of starch-9.99%, pressure-80 bar and glycerol-8.7%.

The cost of production of three cassava starch based corrugating adhesives *viz*., caustic free corrugating adhesive mix, moisture resistant corrugating adhesive and single phase corrugating adhesive was worked out and were ₹ 42.15, ₹ 39.23 and ₹ 44 per kg, respectively. These formulations are free of dextrins and use only chemically modified starches and the cost were on par with the cost of corrugating adhesives available in the market.

Thermoplastic starch sheets were prepared from cassava starch modified with cross-linked cassava starch and starch octenyl succinate. Under optimized conditions of temperature (130°C), pressure (34.74 bar) and concentration of glycerol (41.46%), sheets with density 1301 kg m^{-3}, total colour difference-34.45, net expansion index-51.38%, solubility-8.65% and hygroscopicity at 9.90 g g^{-1} at 75% relative humidity, were obtained with octenyl succinate starch.

Thermoplastic starch sheets made with cross linked cassava starch at 140°C, 130 bar pressure and 40% glycerol had a density of 1619 kg m^{-3}, total colour difference of 34.32, expansion index of 21.05%, solubility of 1.58%, and hygroscopicity of 13.65 g g^{-1} at 75% relative humidity.

Wax coating technology along with suitable pre-treatment has been standardized for increasing the shelf-life of fresh cassava roots to four to six weeks.

Single barrel and double barrel kilns were designed and tested for the production of biochar from agricultural wastes and crop residues. Among the two, double barrels kiln was more efficient for the biochar production. Standardized the biochar production conditions using selected biomass such as cassava stems, yam vines, arrowroot leaves and wood wastes. Co-composting with mineral fertilizers and crop residues is being studied for nutrient enrichment of biochar.

Urea fertilizer coated with cross-linked cassava starch phosphate as well as urea double coated with starch phosphate and wax to attain sustained release of nitrogen in soil, have been synthesised and characterized. Coated urea exhibited high swelling potential and sustained release of nitrogen in soil.

Cassava starch-Montmorillonite clay (MMT)-Urea composites with sustained release of nitrogen, have been synthesized and characterised.

Graft-copolymerization reaction of cassava bagasse (thippi), the solid lignocellulosic bio-waste from cassava starch industries, has been standardized for its functionalization and could be effectively utilized as a coating material for urea to develop controlled release of fertilizer.

Purple-fleshed sweet potato flour extrudates were prepared, which had an expansion ratio ranging between 80.53 and 140.89%, solubility in water between 10.25 and 30.64%, water absorption capacity between 5.28 and 8.39 g g^{-1} and anthocyanin content between 10 and 30 mg 100 g^{-1}.

Resistant starches of potato, cassava, sweet potato, raw banana and lentil were synthesized by the esterification of respective native starches with octenyl succinic anhydride. The products were in the medium glycemic index range (GI = 55-70).

De-branching of cassava and sweet potato starches with the enzyme, pullulanase and subsequent treatment with glyceryl monostearate (GMS) was adopted to synthesize RS5 type resistant starches with medium glycemic index.

Co-pigmentation of purple yam and purple sweet potato tuber anthocyanins with various natural extracts have shown that there was an increase in antioxidant activity of the anthocyanins on interaction with beet root and pomegranate extracts, but the activity decreased with ginger, garlic, turmeric and red onion extracts.

Co-pigmentation of anthocyanins from purple yam and purple sweet potato tuber with selected phenolic acids has been performed to reinforce the anthocyanins. Synergistic interaction of anthocyanins was observed with structurally similar ferulic and caffeic acids, which lead to an increase in antioxidant activity, but with P-coumaric acid, anthocyanins exhibited antagonistic effect. Base hydrolysed anthocyanins showed significantly higher antioxidant activity than unhydrolysed anthocyanins.

Elephant foot yam papad was prepared with 30% elephant foot yam flour, 30% green gram flour and 60% black gram flour and characterized. It contained moisture in the range of 13.10 to 14.75%, crude protein 16.50 to 18.22%, crude fat 0.98 to1.73%, total ash 6.96 to 8.82% and total carbohydrates 55.87 to 58.13%.

Response surface methodology was used for the formulation of ready-to-cook pasta from elephant foot yam flour, suji and finger millet flour. The cooking time of pasta varied from 4.45 to 5.40 min, rehydration ratio from 1.50 to 2.85 and solid loss from 7.57 to 8.85.

The major compound identified in Chinese potato tubers was linoleic acid by column chromatography and spectroscopic techniques such as FT-IR, Mass spectroscopy, ^{1}HNMR, ^{13}CNMR, COSEY, DEPT, HMBC and HSQC analyses.

The free radical scavenging activity (DPPH and ABTS assays) of the Chinese potato tuber extract could be enhanced by combining the extract with Lekshmi taru (*Simarouba glauca)* leaf extract and orange (*Citrus reticulate*) peel extract. However, the glucose inhibition capacity of the combined extracts was antagonistic.

Extension and Social Sciences

Ten front line demonstrations of improved varieties of cassava were conducted at Kanyakumari district of Tamil Nadu. Sree Pavithra produced the maximum yield (36 t ha^{-1}) followed by Sree Jaya (35 t ha^{-1}), Sree Swarna (33 t ha^{-1}) and Sree Vijaya (32.5 t ha^{-1}). Average productivity of cassava from improved varieties was found to be 34.12 t ha^{-1} which was greater (17.7%) than that of local varieties (29 t ha^{-1}). Gross income realized from improved varieties and local varieties of cassava were ₹ 2.73 lakhs ha^{-1} and 2.32 lakhs ha^{-1} respectively.

Time series data using autoregressive integrated moving average (ARIMA), popularly known as the Box–Jenkins methodology was used to forecast the variables for cassava commodity model. The total volume of consumption of cassava tubers is expected to reach 1.45 million tons by 2021 from 0.94 million tons in 2016, growing at a compound annual growth rate (CAGR) of 9% during 2016-2021. Similarly, demand for cassava starches and starch products in India are expected to increase 1.7% by 2021 from 1.5% in 2016. Adoption of improved varieties of cassava had a positive impact on cassava yields. This is evidenced by the increase in average yield of cassava from 23.6 t ha^{-1} in 1990-91 to 1994-95 to 33.6 t ha^{-1} in 2005-06 to 2009-10. Area of cassava and its price were negatively related and were significant, which indicated that more area will increase production, which will reduce the market price.

Mapping of quantitative trait loci (QTL) in cassava using Markov chain Monte Carlo (MCMC) method was applied in SAS, which draws variables using adaptive block random walk Metropolis algorithm. The parents were MNga and CI-732 which are highly contrasting in the trait of interest. Out of one hundred and fourteen seedlings studied for the CMD resistance, sixty five seedlings were symptom less, 8 seedlings had severe symptom with score of 5. To apply the Bayesian method of QTL mapping, the disease score was modelled as following Poisson distribution and the expectation is connected to QTL effects through a log link function. The Normal prior distributions were assumed and inverse chi square prior distribution was assumed for variance. Under single marker analysis, thirteen marker alleles (SSRY28a, SSRY28b, SSRY324d, SSRY59a, SSRY59b, SSRY43d, SSRY32c, SSRY32d, SSRY10b, SSRY30c, NS97c, NS185a and NS185b) have been found to be significantly associated with CMD resistance. Interval mapping identified two QTLs in chromosome 7 and chromosome 22 at LOD score above 8.0. QTL on chromosome 7 was flanked by NS97a and SSR38a, both marker alleles were contributed by the male resistant parent MNga-1. QTL on chromosome 22 was flanked by NS97c and SSRY30c, alleles contributed by the female parent. Composite interval mapping identified the same two QTLs as identified by SIM at LOD score above 8.0. The first QTL was associated with marker NS97a and SSR38a with positive additive effect of 0.38 but the phenotypic variance explained by the QTL was very low. The second QTL was strongly associated with NS97c flanked by SSRY30c. R2 value of 0.15 explained that this QTL on chromosome 22 was a major QTL, which was responsible for the phenotypic variation for CMD. With multiple interval mapping, three QTLs were identified by MIM, one in chromosome 6 at a position 6cM and other two QTLs in chromosome 7 at 0.1cM and 60.4cM position. From these QTLs, main QTLs were identified by refine model and identified two main QTLs, which were found in chromosome 7 at two different positions. First QTL was located at position 0.1cM with an additive effect of 0.56 and dominant effect of-2.61. The second QTL was located at position 60.4 with an additive effect of-0.0628 and dominant effect of 0.34.

Twenty demonstrations on improved varieties of sweet potato *viz.,* Sree Arun, Sree Nandhini and Sree Bhadra were conducted in Belagavi district of Karnataka. Sree Arun produced the maximum yield (27 t ha^{-1}), followed by Sree Bhadra (20 t ha^{-1}) and Sree Nandhini (19 t ha^{-1}). The average yield of improved varieties of sweet potato was found to be 21.3 t ha^{-1} which was (9.2%) greater than the yield of local varieties (19.5 t ha^{-1}). Gross income realized from improved and local varieties of sweet potato were ₹ 1.38 and 1.17 lakhs ha^{-1} respectively.

Value chain analysis of sweet potato was conducted in Belagavi district of Karnataka. A total of 112 sweet potato growers, 10 commission agents and 10 retailers constituted the sample for the analysis. The average age of sweet potato growers was 51 years with household size of 6.60. Seventy eight per cent of the sweet potato growers were literate. Over 97% of the farmers had farming as primary occupation, while 21% had worked as wage labourers. Sweet potato farmers had an average landholding size of 2.49 ha in total, of which about 40% area was grown with sweet potato. The average production of sweet potato was 9.83 tons during *Kharif* season. It was found that more than 90% of the sweet potato produced was sold immediately after harvesting, while only 10% was retained for home consumption.

The total cost for cultivating sweet potato was estimated to be ₹ 24, 262 ha^{-1} and the cost of production was ₹ 246 per quintal of tubers. The human labour and chemical fertilizers + farm yard manure were the major expenditure accounting to 32% and 26% respectively. On an average, net income of ₹ 34, 585 was obtained from one hectare of sweet potato cultivation. The benefit cost ratio of sweet potato was estimated to be 2.42:1, which further reinforced in support of increasing of sweet potato acreage in order to enhance farmer's income.

Farmers have a well organized market namely Agricultural Produce Market Committee (APMC) to sell their produce of sweet potato in Belagavi district of Karnataka. The method of sale of sweet potato in APMC market was open auction method as prescribed by the Govt. of India Act. The maximum transaction was observed in December (about 58%), while the peak period of demand was during September, October and first week of November which led to good return to farmers as prices were much greater compared to other months.

The wholesalers had an average experience of 17 years in sweet potato trade and considered it as the best business commodity than other agricultural commodities. The average quantity purchased by wholesalers during the *Kharif* season was 400 tonnes. The sweet potato procured from APMC, Belagavi was transported to wholesale markets in Delhi, Maharashtra, Punjab and Gujarat through trucks. The respondents reported over 10% of transportation and other post-harvest losses of sweet potato at the wholesale level.

All the retailer respondents sold sweet potato through unorganised retailing *i.e.kirana shops* and vegetable *mandis*. The retailers procured sweet potato from APMC market/wholesaler and sometimes directly from producers and sold it directly to the consumers. The average quantity sold during the season was 39 tons at the rate of ₹ 2, 000 per quintal.

The major problem faced by the sweet potato farmers was incidence of pests and diseases during production, besides unforeseen weather due to erratic rainfall, which affects the production. Farmers reported low price for their produce and high commission fee charged by the commission agents at APMC market, where farmers have to pay commission of around 7-8% of the total value of produce to commission agents. Many of the farmers opined that high marketing cost, long distance to the APMC market and lack of access to processing units as important constraints for marketing their produce. The major constraints faced by commission agents are; lack of cold storage facility, price fluctuation, delay in receiving the payment from buyers and lack of processing units of sweet potato. Whereas, the constraints faced by the wholesalers and retailers were price fluctuation, high cost of transportation, lack of cold storage facility and post-harvest loss due to weight loss and weevil infestation in tubers.

Sustainable livelihood analysis of tuber crops farmers was conducted in Belagavi district of Karnataka. The average age of sweet potato and paddy farmers was almost same (47 years). The average size of land holding for sweet potato and paddy growers differ significantly at 5% level. The average yield of sweet potato was greater than the paddy. The sweet potato farmers realized 39% greater net profits than the paddy growers. With respect to human capital index, training index was more for paddy growers (49.44), when compared to sweet potato growers (22.77). The overall human index was 45.98 for sweet potato growers and 52.17 for paddy growers. Under the physical capital index regarding type of house, the index for sweet potato growers was 65.41, whereas it was 54.16 for paddy growers. The overall physical capital index was more for sweet potato growers (72.05) as compared to paddy growers (69.99). Social capital index was similar to both the farmers; in the case of sweet potato growers it was 63.32 and for paddy growers it was 63.43. The overall financial index was 39.81 for paddy growers and 35.80 for sweet potato growers. The overall natural capital index was 62.98 for sweet potato growers and 64.47 for paddy growers.The rural livelihood sustainable index was marginally more for paddy growers (57.97) than sweet potato growers (56.02). Major sources of livelihood as reported by both the farmers were, agriculture, employment in government/private sector and small business. The vulnerability factors were rampant inflation, price fluctuation, crop failure and labour cost. The trends observed were, price rise (input cost), drought and climate change.

An Android app ‘Tuber Guru app’was developed, which is an information system on tropical tuber crops, which provides information on cassava, sweetpotato, elephant foot yam, yams and taro in English and Malayalam. Algorithm for VIT app (Variety Identification Tool) to identify the varieties of cassava, sweet potato, yams and taro based on their morphological attributes like colour and shape of stem, leaf, petiole, tuber etc., was developed.

Under Tribal Sub-Plan (TSP), two tribal villages were selected, one each from Odisha and Jharkhand states. In Dadrisahi village, 24 tribal households and in Burahkocha village, 57 tribal households were adopted for conducting tuber crops demonstrations. About 50,000 vine cuttings of sweet potato, 3000 stems of cassava, 52.5 kg of yam bean, 900 kg of greater yam and 5.6 kg of vegetable seeds were distributed to the farmers. Four on-farm trainings were conducted for capacity building of tribal farmers on tuber crops cultivation. Income generation through tuber crops intervention was ₹ 23,000/-per household. Regular availability of roots and tubers for household consumption for improving their nutritional security was 400 kg per household. Eighty one tribal households were adopted and tuber crop demonstrations were conducted.

Assessment of roles and performance of agricultural enterprises of Agri Clinic & Agri-Business Clinics Scheme was conducted among AC&ABC ventures in Maharashtra, Kerala and Tamil Nadu. A total of 20,503 persons were trained in Maharashtra, Kerala and Tamil Nadu states, of which 9,826 established ventures indicating 47.92% success rate. The proportion of trainees creating a new venture was maximum in Tamil Nadu (51.59%), followed by Maharashtra (46.49%) and Kerala (25.63%). The sub-component wise analysis of enterprising tendency revealed that Kerala entrepreneurs had high level of enterprising components, which was significantly different from the other states. The Maharashtra and Tamil Nadu entrepreneurs had similar creative tendencies, but significantly different in other components. The analysis had revealed six latent factors such as favourable govt policy, entrepreneurial culture, availability of technical and business support, availability and access to funds, willingness to take risk and access to business mentoring.

Six technologies including fried snacks and protein enriched pasta were commercialised to entrepreneurs from Kerala, Karnataka and Tamil Nadu and one contract research proposal for developing jackfruit based pasta was signed. A total of ₹ 17,32,324 was generated as revenue through technology commercialisation and other professional service functions.

INTRODUCTION

ICAR-CTCRI, Headquarters, Thiruvananthapuram

ICAR-CTCRI, Regional Centre, Bhubaneswar

ICAR-CTCRI (1963-2018)

The ICAR-Central Tuber Crops Research Institute (ICAR – CTCRI) was established during the Third Five Year Plan for intensification of research on tuber crops (other than potato). The Institute started functioning in July 1963 with its headquarters (HQ) at Sreekariyam, Thiruvananthapuram, Kerala in an area of 21.50 ha. Later, an area of 26.69 ha was added. It has one Regional Centre (RC) at Bhubaneswar with a farm area of 20 ha. The All India Co –ordinated Research Project on Tuber Crops (AICRP-TC) was started at ICAR – CTCRI in 1968 for testing and popularizing the location specific tuber crop technologies in various parts of India. It has presently 22 centres including ICAR-CTCRI HQ and Regional Centre. The Institute is also one of the centres of the All India Co-ordinated Research Project on Pre and Post-Harvest Technology. The ICAR-CTCRI is conducting basic and applied research on various edible tropical tuber crops.

Vision

Root and tubers for ensuring better health, wealth generation and inclusive growth.

Mission

To integrate root and tuber crops as sustainable farming system components to ensure food and nutritional security of the nation and livelihood improvement of rural population.

Mandate

The Institute has a broad mandate of generating information on research of tropical tuber crops that will help to enhance productivity and improve the utilization potential.

Basic, strategic and applied research on genetic resource management, crop improvement, sustainable production and utilization of tropical tuber crops.

Co-ordinate research and validation of technologies through AICRP on Tuber Crops.

General Achievements

The ICAR-CTCRI is a premier research organisation in the world dedicated solely to the research on tropical tuber crops. The Institute celebrated its golden jubilee during 2013 and 55 years of concerted research have led to the development of several production and processing technologies for tuber crops, besides release of 66 improved varieties. The target group of most of the technologies being marginal and resource poor farmers, adequate emphasis is also given for on-farm evaluation and popularisation of the technologies. In addition, several industrial Hi–tech technologies were also developed in the recent past enabling resource generation through consultancies. ICAR-CTCRI has a wealth of germplasm of tuber crops, totalling 5570. This has formed the basis of all the genetic improvement and variety development programme. Earlier the improvement work was exclusively based on conventional breeding programmes. In fact, the pioneering role of ICAR-CTCRI in the area of classical breeding of tropical tuber crops attracted international collaborations in the breeding and genetic improvement of these crops. Now, work on molecular based improvement has also been initiated. The ICAR-CTCRI has released 66 varieties in eight unique traits and preferences. The cassava starch and sago production in the country is mostly dependent on two major industrial varieties of cassava released from ICAR-CTCRI, *viz.*, H-165 and H-226. Two triploid cassava varieties, *viz.*, Sree Athulya and Sree Apoorva are promising and acceptable to farmers as well as industries. Sree Reksha and PDP CMR 1 were released which are resistant to CMD and are high yielding. The β carotene rich sweet potato varieties, Bhu Sona, Bhu Kanti and Bhu Ja and anthocyanin rich Bhu Krishna, mid season drought tolerant Bhu Swami were released recently. Three varieties in yams *viz.,* Sree Nidhi, Sree Haritha, Sree Swetha were also released. The domestic and international training received in the use of biotechnology in conservation, characterisation and genetic improvement of tuber crops has contributed to a great extent in development of facilities and formulation of programmes using this advanced technology for the improvement of tuber crops. The Institute presently has very strong programmes on biotechnology which includes the development of diagnostic tools for viral and fungal diseases and transgenic plants for conferring resistance to cassava mosaic disease and to enhance the starch content and waxy starch.

Agro-techniques are available for tuber crops in the different production systems of the country. Besides, technologies for quality planting material production, sustainable nutrient (INM, SSNM and organic management), water (micro irrigation, drip fertigation) and weed management, which help in enhancing the yield, soil fertility, employment opportunities and farm income are also developed. Integrated crop protection technologies developed for cassava mosaic disease, taro leaf blight, collar rot of elephant foot yam, greater yam anthracnose and sweet potato weevil would help the farming community in extreme eventualities. Management of banana pseudostem weevil through cassava based biopesticides, *viz., Nanma* and *Menma* was a grand success in the farmers' fields.

Efforts in crop utilization have paid rich dividends in terms of value addition and diversified technologies suitable for big, small and cottage industries. Many of these technologies are capable of ensuring food and nutritional security to the people of India. Technologies for the industrial sector include the latest products like superabsorbent polymers, graft copolymerized starches, cold water miscible starch, solid adhesives, bioethanol, pasta products etc. Cassava starch composite based biodegradable films and adhesive formulations for corrugation and paper industries are successfully developed recently. Development of functional food products from cassava, yam and elephant foot yam and enhancement of anthocyanin recovery from yam and sweet potato are the recent contributions. Aroids especially elephant foot yam is gradually gaining importance in Odisha, Bihar, Uttar Pradesh, Gujarat and north-eastern states. Supply of quality planting material is ensured to farmers of all regions through revolving fund scheme, mega seed project and tuber crops development scheme from state department.

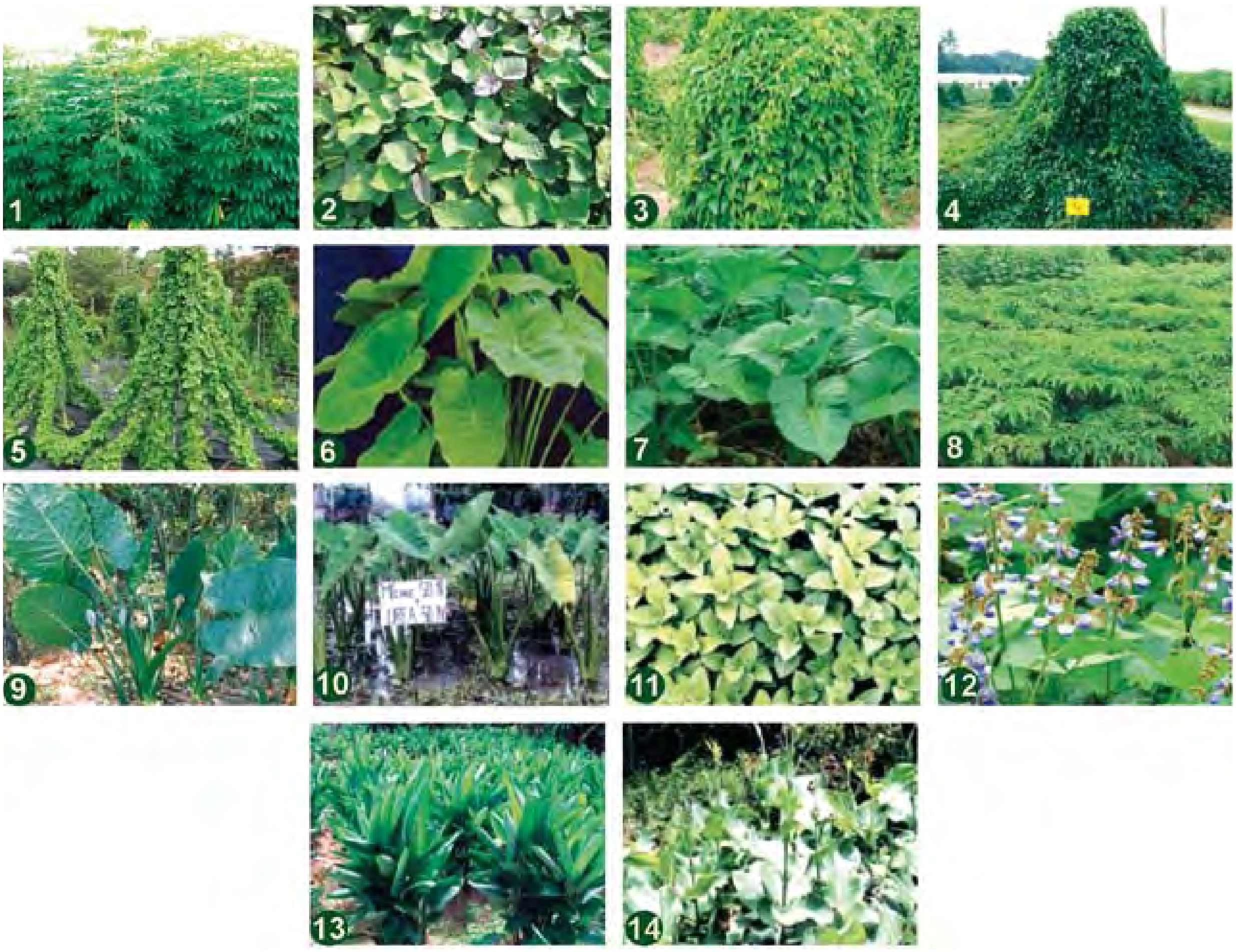
There exists a good research base in the country to sustain root and tuber crops research and development with ICAR-CTCRI giving the leadership and ICAR-AICRP TC to plan and coordinate region specific research and testing of technologies on these crops. Technology generation and transfer are being closely interlinked with the utilization by the clientele system. The ICAR-CTCRI bagged the Sardar Patel Outstanding Institution Award for the year 2005, Instituted by the ICAR for outstanding contributions made in the improvement of tropical tuber crops and development of low cost production technologies. The Institute also bagged many national and international recognitions in the past that include J. Chinoy Gold Medal (1970), three ICAR Team Research Awards (1985, 1996, 1998, 2014), D. L. Plucknett Award for Tropical Root Crops, Hari Om Ashram Trust Award (1993), Jawaharlal Nehru Award (1975, 1995, 1998, 2000 and 2003), Young Scientist Award Instituted by

Deseeya Sasthra Vedi (1996), NRDC cash reward for biodegradable plastics (2000), Pat Coursey Award (2000, 2006), Vasantharao Naik Memorial Gold Medal (2002), Samantha Chandrasekhar Award (2013), International Potash Institute (IPI)-Fertilizer Association of India (FAI) Award (2014) and Shri. L. C. Sikka Endowment Award (2014), International Plant Nutrition Institute (2016), IZA (International Zinc Association)-FAI (Fertilizer Association of India) (2017) and Panjabrao Deshmuk Woman Scientist Award (2017). In recognition of its contribution to cassava growers and consumers worldwide, ICAR-CTCRI has been rewarded at the First International Meeting on Cassava Plant Breeding, Biotechnology and Ecology organized at Brasilia, Brazil during 11 to 15 November, 2006. The Institute bagged first prize in the Agricultural Exhibition 2017 organised by VFPCK, Kollam and won second prize in the National Banana Festival 2018 conducted at Kalliyoor, Thiruvananthapuram. The best annual report award (1997-98) among the category of small Institutes was conferred to ICAR-Central Tuber Crops Research Institute for succinctly presenting the research results.

The Institute has conducted more than 18 national and international symposia/seminars/workshops. The infrastructural facilities of the Institute have been tremendously increased during the X and XII Plan periods. Laboratories like Food Extrusion Laboratory, Transgenic Glass House, Bioinformatics Laboratory, Biodiversity Sheds, Modernised Computer Cell, Seed Storage Laboratories and Net Houses etc. exist in the institute. The Institute Museum has been renovated, giving a totally new look. Crop museum with the display of all mandatory crops is also being maintained for the visitors. A number of sophisticated state-of-the-art equipments like the food extruder, texture analyzer, differential scanning calorimeter, FTIR, HPLC, HPTLC, atomic absorption spectrophotometer, auto-analyser, gel documentation system, real time quantitative PCR, nitrogen analyser, fibre analyser, genetic analyser etc. Plant growth chamber, two gel documentation systems, Total Station, Leica Zeno 20 GPS, 75 HP Tractor (John Deere, Model5975E), Bakery oven are available in the Institute. The infrastructural facilities of the Regional Centre have also been considerably improved through the creation of additional laboratory space and purchase of several new equipments.

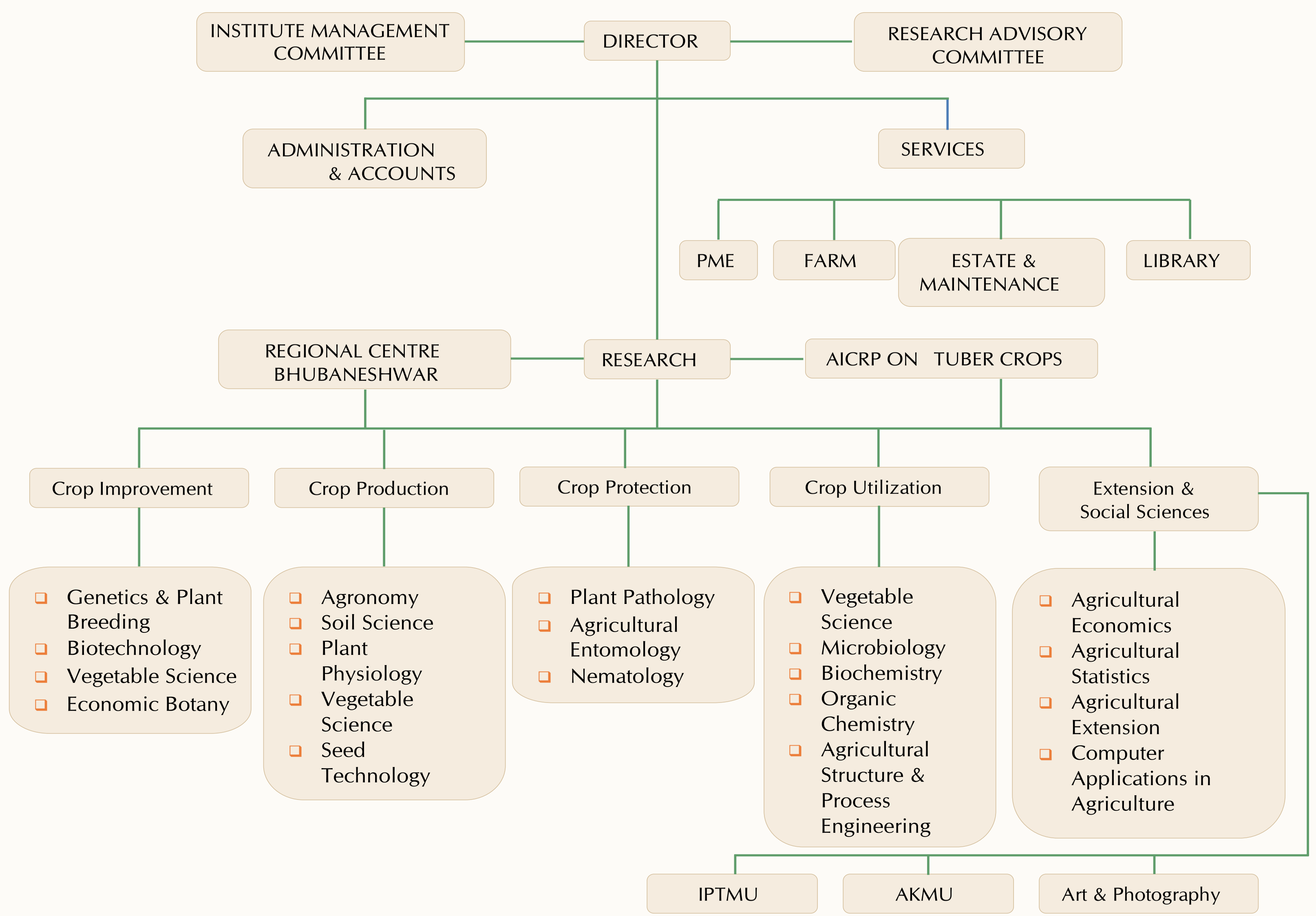
Extramural support by way of research schemes from both international (like CIAT, CIP, CIRAD, European union, IFAD, Indo–Swiss etc.) and national agencies like DBT, DIT, DST, DRDO, DSIR, ICAR, JNU, KSCSTE, LSRB, MOEF, DoA, Kerala, KSPB, NABARD, PPIC, RKVY, PPV & FRA, SHM, CDB, UGC were a great boon to the Institute to upgrade the research infrastructure as well as to facilitate detailed studies on frontier areas of research. The Network and Consortia projects of ICAR have helped the Institute to focus research on priority areas. Intellectual Property Management Technology (IPTMU) of the Institute has been active in carrying out IP activities. The unit is engaged with public/private parties for the commercialization of technologies. The IPTMU has taken initiatives in filing patent applications. Various technologies related to value addition have been commercialised through IPTMU under consultancy, licensing and contract research mode. Our Institute has established a full fledged Local Area Network connecting various Divisions, Administration, Accounts, and farm sections of ICAR-CTCRI through a strong fiber optic backbone. The entire network is supported by state of the art equipments such as fiber optic core switches, routers and firewalls. The entire campus is wi-fi enabled through access controlled wi-fi devices and controllers. The servers are powered with Microsoft Windows 2012 operating system. The network consists of Windows 2012 staff server, Windows 2012 student server, storage server, internet proxy server, 204 computers, laser printers, inkjet printers, scanners, DTP and multimedia workstations. VPN connectivity is established for global access to the servers. Legal licensed versions of latest software packages are installed for various types of applications. The ICAR-CTCRI has setup a home page on the internet. This can be accessed at http://www.ctcri.org which provides a comprehensive information about the various activities of the Institute and various online facilities like sales counter, discussion forum etc.

MANDATE CROPS



1.	Cassava: *Manihot esculenta* Crantz, Euphorbiaceae	**8.**	Elephant foot yam: *Amorphophallus paeoniifolius* (Dennst.) Nicolson, Araceae
2.	Sweet potato: *Ipomoea batatas* (L.) Lam., Convolvulaceae	**9.**	Giant taro: *Alocasia macrorrhiza* (L.) Schott., Araceae
3.	Greater yam: *Dioscorea alata* L., Dioscoreaceae	**10.**	Swamp taro: *Cyrtosperma chamissonis* (Schott.) Merr., Araceae
4.	White yam: *Dioscorea rotundata* Poir., Dioscoreaceae	**11.**	Chinese potato: *Plectranthus rotundifolius* (Poir.) J. K. Morton, Labiatae
5.	Lesser yam: *Dioscorea esculenta* (Lour.) Burk., Dioscoreaceae	**12.**	Yam bean: *Pachyrrhizus erosus* (L.) Urban, Leguminaceae
6.	Taro: *Colocasia esculenta* (L.) Schott., Araceae	**13.**	Arrowroot: *Maranta arundinacea* L., Marantaceae
7.	Tannia: *Xanthosoma sagittifolium* (L.) Schott., Araceae	**14.**	Queensland arrowroot: *Canna edulis* (KerGawler), Cannaceae

ORGANISATIONAL SETUP



Staff Position (2017-2018)

Category	Sanctioned	Filled	Vacant
RMP	1	1	0
Scientists	52	51	1
Technical	47	37	10
Administratiion	31	23	8
Skilled support staff	55	41	14
Total	**186**	**153**	**33**

Progressive Expenditure (2017-2018)

Sl. No.	Head	Unified Budget RE 2017 – 18 (₹ in lakhs)	Expenditure 2017 – 18 (₹ in lakhs)
Grant-in-aid-Capital			
1.	**Works**		
	Office Building	**11.00**	**11.00**
2.	Equipments, Information Technology, Library Books and Journals	0.00	0.00
A.	**TOTAL CAPITAL EXPENDITURE**	**11.00**	**11.00**
Revenue			
1.	Establishment Expenses and salaries	-	-
	i. Establishment charges	**1520.00**	**1520.00**
	ii. Overtime Allowance	-	-
	Pension and Other Retirement Benefits	**342.00**	**336.13**
2.	Traveling Expenses		
	A. Domestic TA/Transfer TA	30.00	30.04
	B. Foreign TA	-	-
	Total TA	**30.00**	**30.04**
3.	Research and Operational Expenses		
	A. Research Expenses	35.00	33.68
	B. Operational Expenses		
	i. Institute	60.80	54.21
	ii. TSP	10.00	10.00
	iii. NEH	2.00	1.99
	Total Research and Operational Expenses	**107.80**	**99.88**
4.	Administrative Expenses		
	A. Infrastructure	105.00	98.32
	B. Communication	6.00	5.17
	C. Repairs and Maintenance		
	i. Equipments, Vehicles and Tyres	10.00	10.37
	ii. Office building	73.02	80.28
	iii. Residential building	0.33	0.33
	iv. Minor works	5.50	15.05
	D. Others (excluding TA)	22.15	30.00
	Total Administrative Expenses	**222.00**	**239.52**
	Miscellaneous		
	A. HRD (Domestic)	5.00	4.84
	B. Other items (fellowships, Scholarships etc.)	0.00	0.00
	C. Publicity and Exhibitions	2.00	3.69
	D. Guest House-Maintenance	12.00	2.49
	E. Other Miscellaneous	3.00	1.34
	Total Miscellaneous	**22.00**	**12.36**
B.	**TOTAL (Revenue Expenditure)**	**2243.80**	**2237.93**
	CAPITAL + REVENUE	**2254.80**	**2248.93**
	P. Loans	**10.00**	**10.00**

RESEARCH ACHIEVEMENTS

INSTITUTE PROJECTS

CROP IMPROVEMENT

CONSERVATION AND UTILIZATION OF GERMPLASM OF TUBER CROPS FOR SUSTAINING PRODUCTION

A total of 5570 accessions comprising 1211 cassava, 1124 sweet potato, 1110 yams, 683 edible aroids, 200 minor tuber crops and 1242 collection from regional centre were maintained and conserved in the field gene-bank.

New collections were added to the existing gemplasm from various sources in sweet potato (20); yams (3); edible aroids (1) and minor tuber crops (15).

Cassava

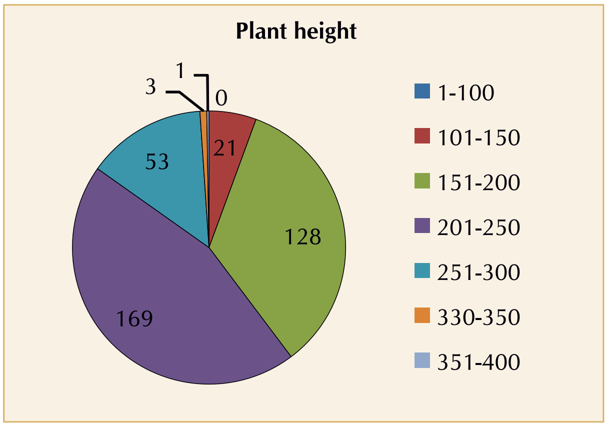
A total of 1211 accessions of cassava comprising indigenous, exotic, landraces and breeding lines are maintained in the field gene bank for evaluation.

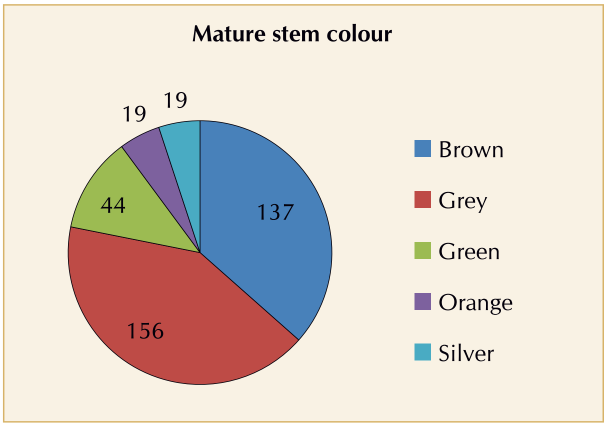
Out of these, 375 indigenous accessions of cassava were characterized for 34 above ground vegetative plant characteristics (24 qualitative + 10 quantitative) *viz.,* plant type, shape of plant, growth habit of young stem, branching habit, levels of branching, young and mature stem colour (Fig. 1), prominence of leaf scar, colour of apical leaves, pubescence on apical leaves, shape of central leaf lobe, mature leaf colour, leaf lobe margin, leaf vein colour, petiole base, middle and top colour, lamina petiole joint colour, orientation of petiole, flowering, fruit set, colour of fruit and CMD susceptibility, plant height, stem perimeter, branching angle, height of first branching, distance between leaf scar, number of leaf lobes, length and width of central leaf lobe, central leaf lobe tip length and petiole length as well as 20 tuber yield and yield attributing traits (12 qualitative + 8 quantitative) *viz.,* tuber growth attitude, tuber shape, tuber surface colour, tuber cortex colour, tuber flesh colour (Fig. 2), texture of tuber rind, ease of removal of tuber rind, ease of removal of tuber cortex, tuber cortex thickness, tuber taste, roots on tuber, tuber constrictions, total fresh weight of tubers per plant, number of tubers per plant, number of marketable tubers per plant, number of rotten tubers per plant, tuber length, tuber diameter, single tuber weight and tuber neck length using a combination of IPGRI/NBPGR/IITA descriptors (Fig. 3) with digitization.

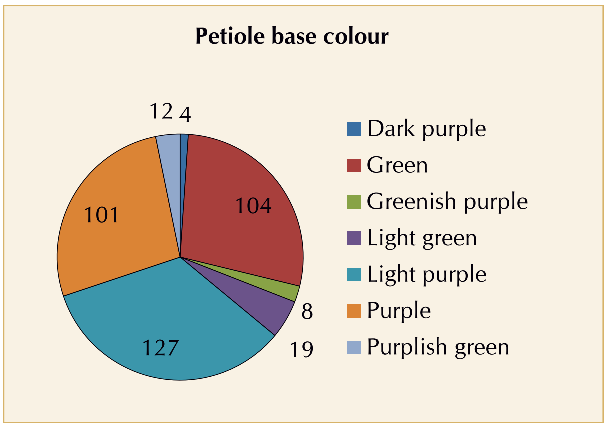
Dry matter content of tubers of these 375 accessions of cassava was also recorded and among these 175 were analysed biochemically. Among the 375 accessions, CI-109A (11.91%) and CI-508 (19.62%) had the lowest dry matter content, while the accessions CI-332 (54.59%), CI-363 (52.46%), CI-485A (52.43%) and CI-690 (50.25%) had dry matter content greater than 50.0%. The total starch content ranged from 5.83 to 50.4% on fresh weight basis, sugars from 1.0% to 5.0%, crude fibre content from 0.8% to 1.5% and ash from 0.8% to 3.0%.

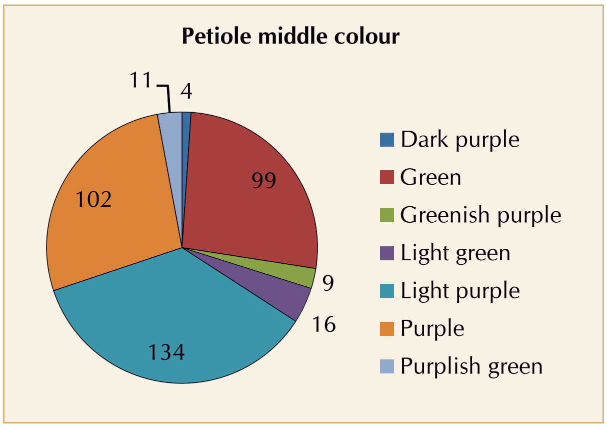
Fig. 1. Stem variability in cassava germplasm

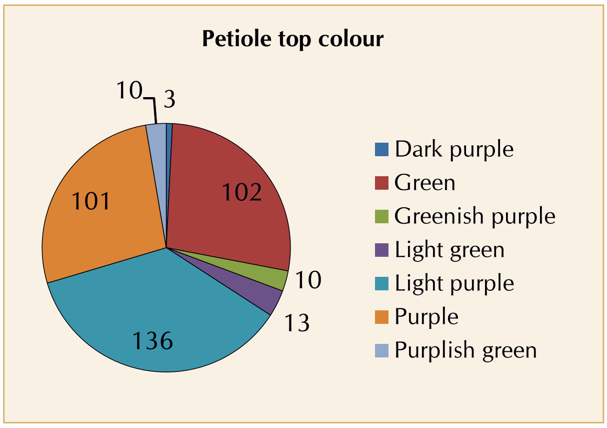
Fig. 2. Tuber flesh variability in cassava germplasm

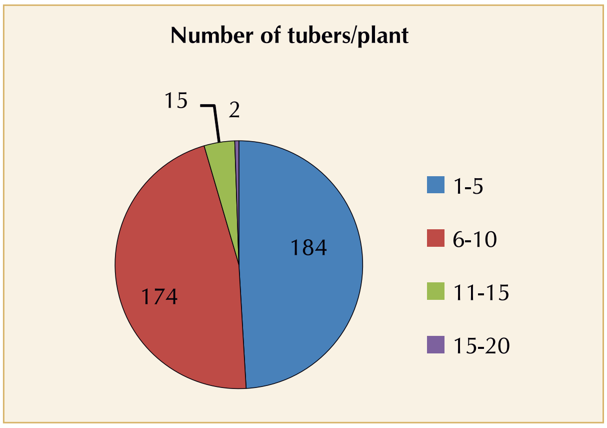












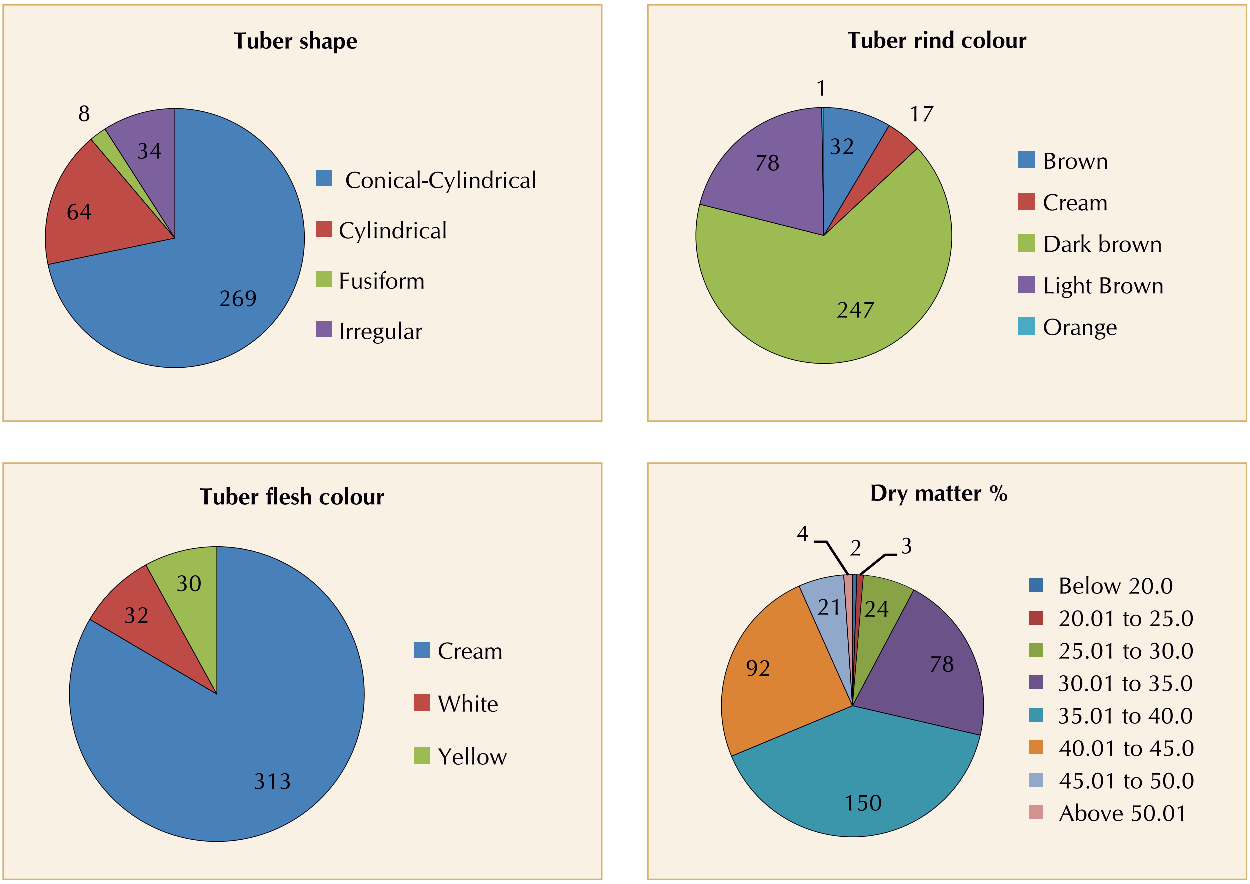


Fig. 3. Frequency distribution of traits in 375 cassava accessions characterized

To assess the amount of variability present in twenty seven indigenous accessions of cassava, 30 morphological traits (20 qualitative and 10 quantitative traits) and 10 SSR markers were used. Dendrogram based on morphological and molecular markers grouped these 27 accessions into 2 major clusters each with 2 sub-clusters. In the morphological clustering, Cluster-I with seven accessions was further subdivided into two sub clusters namely, I A with four accessions and I B with three accessions. The bigger group of Cluster-II with 20 accessions was also further divided into two sub groups namely II A with twelve accessions and II B with eight accessions. Clustering based on SSR marker analysis grouped the accessions into 2 Clusters. Cluster-I with six accessions was further divided into I A and I B with three accessions each. Cluster II with 21 accessions was subdivided into two subgroups namely II A with 13 accessions and II B with eight accessions. By comparing the morphological and molecular clusters, Cluster II of each dendrogram had six similar accessions of cassava namely, TCR-5, TCR-10, TCR-15, TCR-45, TCR-79 and TCR-69. Clustering and Principal Component Analysis of the data validated the variation among the cassava accessions (Fig. 4).

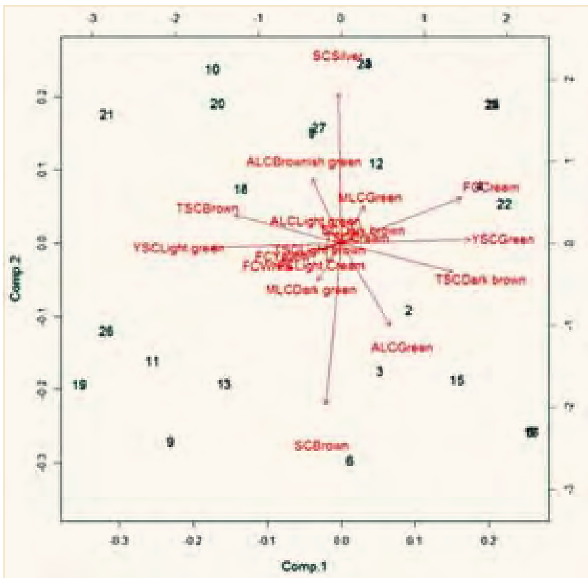


Fig. 4. Principal Component Analysis based on morphological characters

DNA of twenty seven indigenous accessions of cassava was deposited in the DNA bank for long term conservation.

Sweet potato

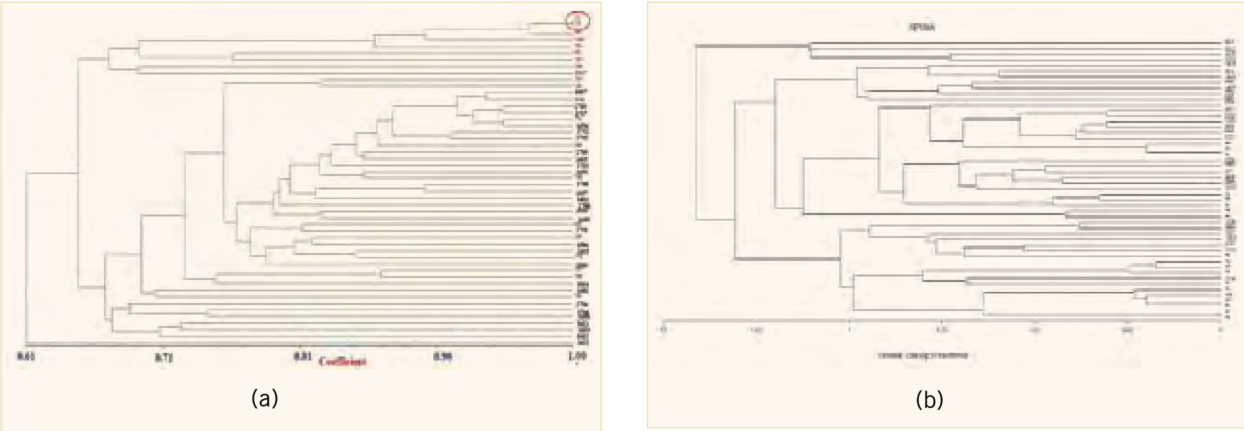
A total of 1124 accessions are being maintained in the field gene bank. Twenty accessions received from AICRPTC Dharwad during 2017 were added to the germplasm. Preliminary yield trial and evaluation of tuber traits were performed for 45 accessions with digitization. In one of the evaluation trials laid in ICAR-CTCRI using 45 accessions in two replications during June-September 2017, the accession S-1609 was the highest yielder with a per plant yield of 0.85 kg plant^{-1} followed by S-1607 (617.50 kg plant^{-1}), S-1636 (0.48 kg plant^{-1}), S-1401 (0.39 kg plant^{-1}), S-1603 (0.38 kg plant^{-1}), S-1656 (0.41 kg plant^{-1}) and S-1615 (0.41 kg plant^{-1}) (Fig. 5). When the trial was conducted in the second season, S-1609 was again the highest yielder with 1.15 kg plant^{-1} followed by S-1636 (0.81 kg plant^{-1}), S-1607 (0.65 kg plant^{-1}) S-1401 (0.51 kg plant^{-1}), S-1603 (0.63 kg plant^{-1}) and S-1653 (0.63 kg plant^{-1}). These 45 accessions were also evaluated for their cooking quality as well as tuber flesh colour. Of these, seven were orange fleshed, two purple fleshed and remaining were yellow or cream/white fleshed. Cooking quality based on IPGRI descriptors revealed that tubers of the accessions S-1636, S-1709, S-1653, S-1657, S-27, S-1610, S-1707, S-1656, S-1712, S-1401 and S-1655 had very good taste. The tubers of the accessions S-1628, S-1636 and S-1656 were very sweet with starchy tubers and no fibre. The accessions JAS-9-white and JAS-10-pink had starchy tubers with low sugar.

S-1609 S-1603

S-1656 S-1636

Fig. 5. Elite accessions of sweet potato

Characterization of sweet potato germplasm based on morphological descriptors (CIP, 1991) (17 vegetative characters) and molecular markers (11 ISSR markers) for 76 accessions was done. Using morphological traits, three sets of duplicates were identified *viz*., S-203 and S-295; S-236 and S-256 as well as S-747 and S-772. However, the same accessions, when assessed using 11 ISSR markers, only one of these sets *viz*., S-236 and S-256 was identified as duplicates (Fig. 6 a,b).



(a) (b)

Fig. 6. Dendrogram of sweet potato accessions based on (a) Morphological descriptors and (b) 11 ISSR markers

Yams

In the field gene bank of yams, 1110 yam accessions comprising greater yam (591), white yam (158), lesser yam (220), potato yam (6) and wild yams (135) are conserved and two accessions of lesser yam and one accession of potato yam were added to the existing germplasm.

Four hundred accessions of greater yam were characterized for 38 traits. Wide variation in tuber characters especially for tuber shape and tuber flesh colour was recorded amongst the 400 accessions (Fig. 7). Twenty two greater yam accessions were evaluated for biochemical traits of which, one accession, Da-341 was identified with high anthocyanin content (40.33 mg $100g^{-1}$). Molecular characterization of 30 accessions of greater yam was carried out using 15 ISSR and 10 SSR primers and no duplicates were identified.

The greater yam accessions were screened for anthracnose disease tolerance and eight accessions were identified (Da-110, Da-198, Da-200, Da-210, Da-251, TCR-308, TCR-311 and Da-374) that exhibited high field tolerance/resistance to anthracnose disease.

In white yam, the maximum tuber yield was recorded in Dr-350 (6.8 kg $plant^{-1}$). In the advanced evaluation of high yielding white yam clones, Dr-353 recorded the highest tuber yield (46.3 t ha^{-1}) followed by Dr-40 (45.3 t ha^{-1}). Dr-44 recorded high yield (35.0 t ha^{-1}) coupled with compact tuber shape. White yam accessions recorded higher dry matter and starch content than the greater yam accessions. In white yam, Dr-319 recorded the highest dry matter (39.8%) followed by Dr-208 (38.2%). *Dioscorea bulbifera* (CTDb-2) recorded the highest crude protein content (5.62%) on fresh weight basis (Fig. 8).

In lesser yam, the maximum tuber yield was recorded in CTDE-85 (5.8 kg $plant^{-1}$) followed by De-104 (4.4 kg $plant^{-1}$) and De-53 (3.5 kg $plant^{-1}$). The highest number of tubers (39) was recorded by CTDE-116 followed by CTDE-174 (37) and CTDE-148 (36). CTDE-115 (Fig. 9) recorded the highest number of marketable tubers per plant (29).

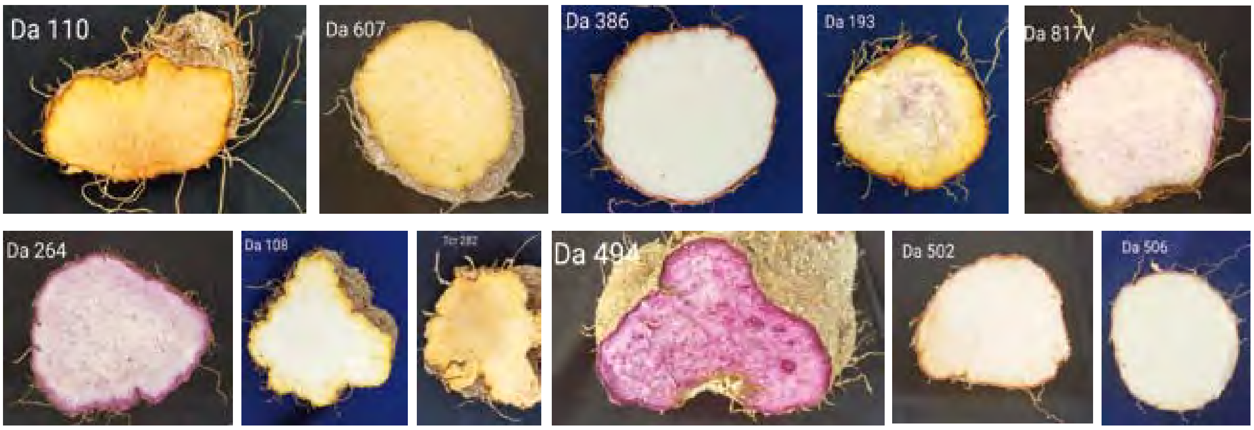


Fig. 7. Variation exhibited in and tuber flesh colour of greater yam

Fig. 8. *D. bulbifera* accession CTDb-2

Fig. 9. *D. esculenta* accession CTDE-115

Edible aroids

One *Amorphophallus* sp. from Kallar, Kerala was collected and added to the existing germplasm. In the field gene bank, 683 edible aroid germplasm comprising 429 taro, 203 elephant foot yam, 48 tannia and 3 *Alocasia* are being maintained. Under *in vitro* active germplasm, 36 taro accessions previously initiated are maintained. In the DNA bank, DNA from 69 *Colocasia*; 13 *Xanthosoma* and 1 *Alocasia* lines are stored. Field screening was done for 129 accessions of taro for resistance against taro leaf blight (TLB). Out of these, 89 were found susceptible and the remaining 40 had field tolerance to TLB.

Using ISSR markers, the identity of the tannia accession, BCT (DK)-1 obtained from Kalyani which produced long unmarketable cormels and large corms (Fig. 10), unlike typical tubers of tannia, was assessed. A dendrogram generated using UPGMA cluster analysis pooling the 13 tannia accessions revealed that, the *Alocasia* existed as an outlier while the tannia in question, BCT(DK)-1 could be a possible intermediate type as it was grouped in between the tannia and *Alocasia* clusters. The intermediate types are often seen among aroids.

Molecular characterization of 36 taro accessions was done using 10 SSR markers. All the selected primers gave high polymorphism as explained by average number of alleles per locus which ranged from 1.81 to 2.67. The Shannon's diversity index, which ranged from 0.88 to 2.10 and Polymorphism Information Content (PIC) ranged from 0.58 to 0.80. All the 36 accessions were found to show diversity which was explained by the heterozygosity value which ranged from 0.65 to 0.82. Dendrogram divided these accessions into 2 main clusters, and no duplicates could be identified in this set.

Minor tuber crops

A total of 200 accessions comprising Chinese potato, yam bean, arrowroot, *Curcuma* spp., *Canna* sp., *Costus* spp., *Tacca* sp., *Arisaema* sp. and *Coleus aromaticus* maintained in the field were harvested and digitization of tubers for variability in wild turmeric, Chinese potato and Canna was made.

Fifteen accessions of different minor tuber crops comprising 14 in seven species of *Curcuma viz.*, *Curcuma aromatica* (1), *Curcuma aeruginosa* (3), *Curcuma amada* (2), *Curcuma caesia* (1), *Curcuma decipiens* (2), *Curcuma zedoaria* (4) and *Curcuma longa* (1) and one of *Maranta arundinaceae* were collected from Idukki and Thrissur districts of Kerala and planted in the pots for characterization (Fig. 11).

Fig. 10. Cormels and corms of BCT (DK)-1.

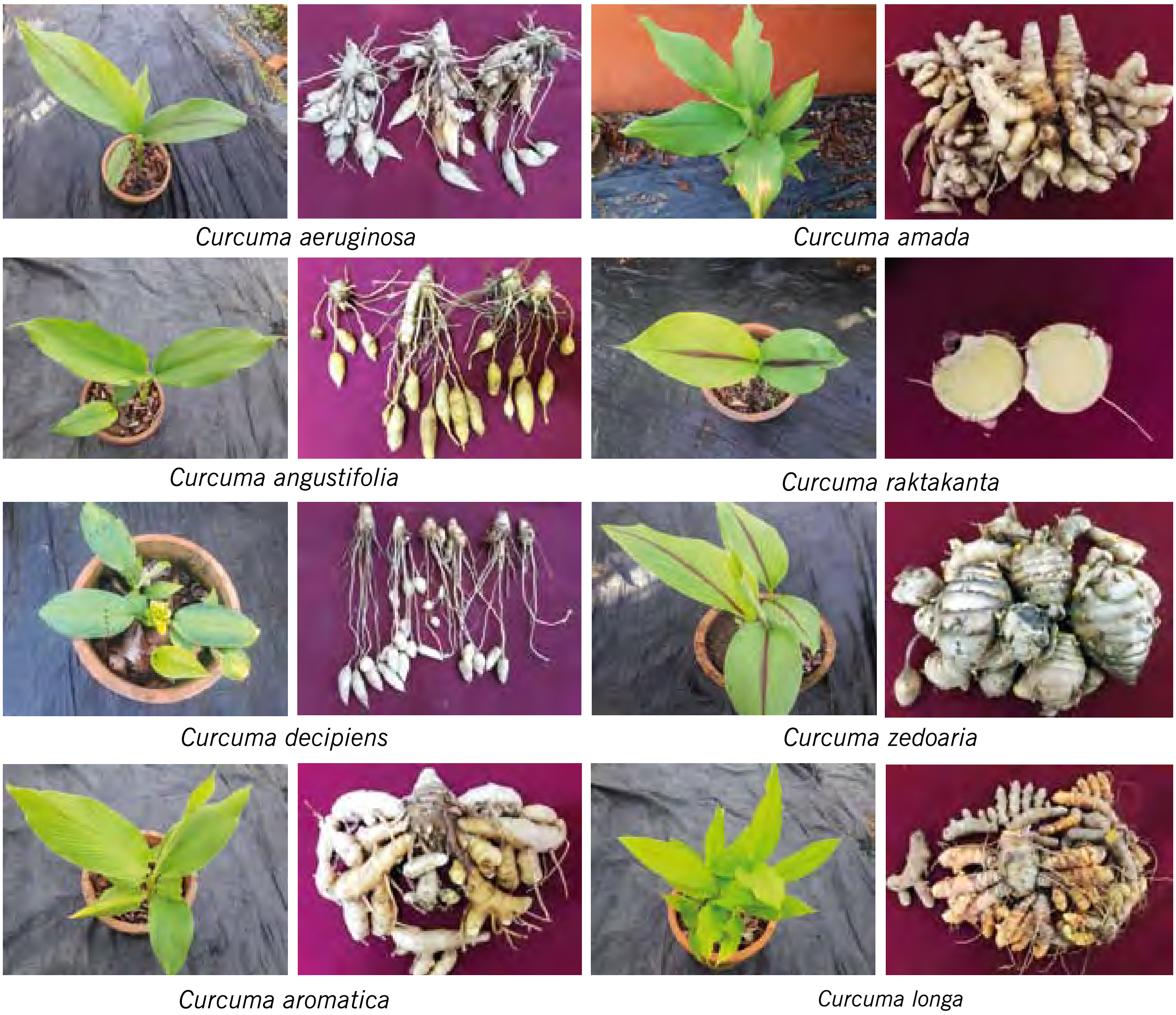


Fig. 11. New collections of *Curcuma* species

Molecular characterization of 23 accessions of Chinese potato germplasm was done using 10 ISSR markers. Of the 86 markers generated across 23 samples, 76 were polymorphic. Among the primers used, UBC 827 produced the maximum number of fragments (18) followed by UBC 810 (15). Average percentage polymorphism was 84.27%. The similarity coefficient based on ISSR markers ranged from 0.52 to 0.94. The dendrogram generated using UPGMA separated the 23 Chinese potato accessions into two major clusters with two outliers (Fig. 12). Cluster-1 consisted of five accessions (JAS-17, TCR-110, TCR-122, TCR-124, TCR-144) with around 72% similarity, while Cluster-2 consisted of 16 accessions (TCR-120, TCR-121, TCR-123, TCR-125, TCR-128, TCR-130, TCR-131, TCR-133, TCR-134, TCR-135, TCR-136, TCR-138, TCR-139, TCR-140, TCR-141 and AKI/2015-1). The accessions TCR-137 and AKI/2015-2 remained as two outliers in the grouping and the results indicated that the primers selected were useful markers for the characterization and genetic diversity studies of Chinese potato germplasm.

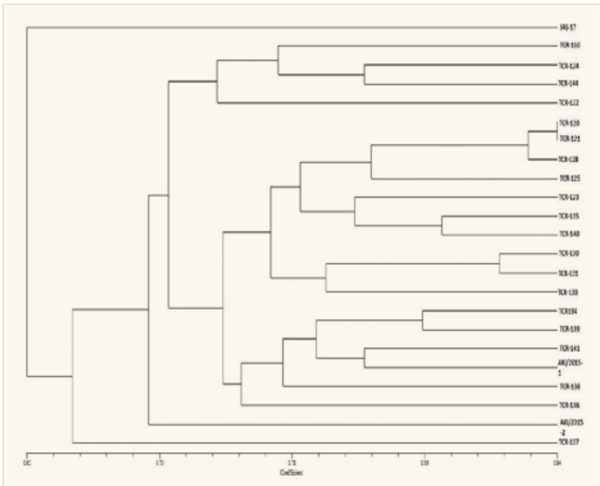


Fig. 12. Clustering pattern of 23 Chinese potato accessions using ISSR markers

Seven accessions of arrowroot and five of Chinese potato were conserved under *in vitro* condition.

Regional Centre

At the Regional Centre, ICAR-CTCRI, Bhubaneswar, a total of 1242 germplasm of tropical tuber crops comprising cassava, sweet potato, taro, elephant foot yam, yam, yam bean and other minor tuber crops are maintained in the field genebank. Fifty accessions of sweet potato germplasm were characterized for 12 morphological characters as per the descriptor. Fifty accessions of taro germplasm were characterized for 15 morphological characters. 50 taro accessions were evaluated for their acridity level in the leaf and petiole. Out of the 50 accessions, 30 had very high acridity level, 10 had medium acridity and 10 had low acridity. Flowering behavior was recorded in these 50 taro accessions and of these, flowering was observed in eight accessions. Micronutrient analysis of 60 accessions of yam bean tuber and 30 accessions of yam bean seed was done. Evaluation of rotenone content was also done for 30 accessions of yam bean seed.

In vitro conservation of tuber crops germplasm

Under *in vitro* Active Germplasm (IVAG), accessions of sweet potato and yams received from NBPGR and other accessions of cassava, sweet potato and yam were subcultured and maintained in the *in vitro* gene bank. Cultures of ten cassava, seven arrow root and five Chinese potato accessions were nitiated and maintained. At the Regional Centre, 10 varieties in cassava, 11 varieties in sweet potato, five varieties in taro, four varieties in yam, two varieties in elephant foot yam and four varieties in Chinese potato are maintained under IVAG.

An *in vitro* conservation protocol was standardised in taro using sprouts from tubers. The explants were sterilized for 25 min in bavistin, 10 min in labolene and 5 min in $HgCl_2$ with intermittent washing in distilled water. The explants were inoculated in basal MS media for establishment of contamination free cultures. Multiple shoots were induced by culturing in shoot multiplication media consisting of MS media fortified with TDZ (0.1 mg l^{-1}) and then transferred to basal MS for a brief period, for establishment. The established shoots were then transferred to the slow growth media consisting of half strength MS medium for medium term conservation.

Conservation of nuclear genetic diversity of cassava by pollen cryo-storage

Male flowers of cassava variety Sree Padmanabha (MNga) were collected during 9.00 to 10.30 am just before anthesis and immediately stored at different temperatures and in liquid nitrogen (-196^{o}C). Viability of the pollen was tested by acetocarmine staining and *in vitro* pollen germination tests (Fig. 13). The results showed that after 16 months of storage in liquid nitrogen, 56.64% pollen stained, while 36.34% pollen germinated in the laboratory conditions. Profusely flowering and fruit setting variety of cassava Sree Jaya was selected as a female parent and hand pollination was done using 16 months old cryo-stored pollen. Fruit set of 43.68% was observed when these pollen were used for pollination (Fig. 14, 15). These findings will form the base information in helping the breeders to plan hybridization programme in cassava and in easy conservation and exchange of male gametes.

Fig.13. Viability of stored cassava pollen assessed by (a) acetocarmine test and (b) *in vitro* germination test

Fig. 14. Fruit set in cassava using the cryo-stored pollen

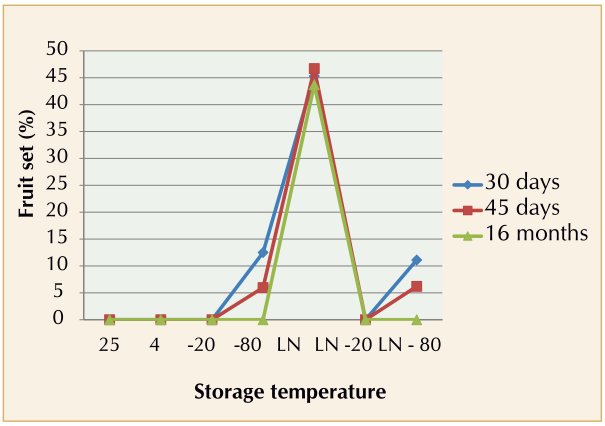


Fig. 15. Viability of cassava pollen stored at different temperatures as evidenced by fruit set in field condition

Gene bio-prospecting for novel traits in tuber crops

Ethanol extracts prepared from *D. alata* tubers, *D. bulbifera* tubers, arrowroot tubers and *Coleus aromaticus* leaf and stem were screened for its effect in wound migration. Wound was created in a monolayer of HepG2, hepatocellular carcinoma cells and the cells were treated with ethanol extracts prepared. Observations were recorded at the 0 hour of treatment and after 24 hours and 36 hours (Fig. 16). Extract prepared from *C.aromaticus* leaf showed wound healing effects as evidenced through migration of HepG2 cells as early as after 24 hours of treatment.

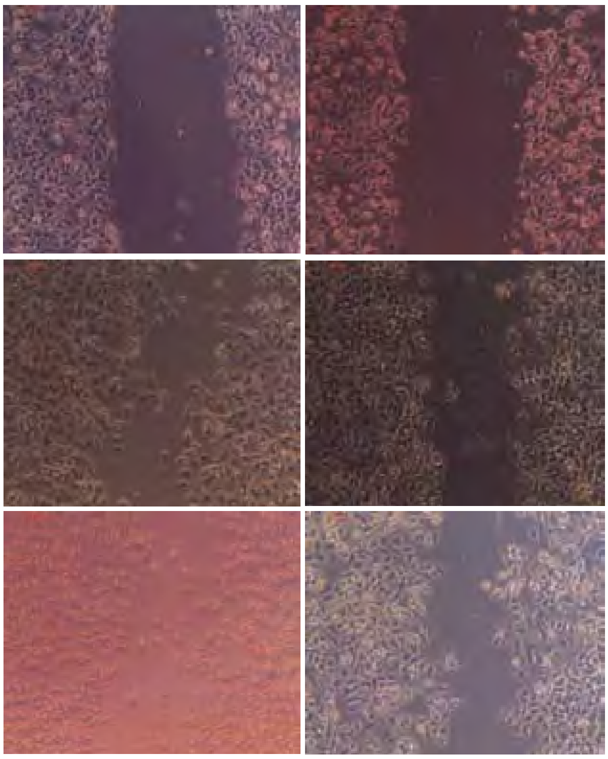


Fig. 16. Wound healing effects of ethanol extract of coleus leaf on HepG2 cells

GENETIC IMPROVEMENT OF TUBER CROPS THROUGH CONVENTIONAL BREEDING AND MOLECULAR APPROACHES

This megaproject is undertaken to address the gaps prevailing with regard to yield, diseases, pest and other quality traits for different crops. The progress made during the year under report is presented crop wise as follows:

Cassava

The cassava mosaic disease resistant variety "Sree Reksha" (IC625792) has been approved for release by the Kerala State Seed Sub Committee for Varietal Release. It is a tall variety (275-325 cm), non branching with brown stem, lanceolate 5-7 lobed leaves with dark purple petioles and light brown emerging leaf. The tubers have brown skin, cream rind and white flesh colour (Fig. 17). It has a duration of 8-9 months and is completely resistant to cassava mosaic disease caused by the North Indian cassava mosaic virus and Sri Lankan cassava mosaic virus. It is also tolerant to post harvest physiological deterioration. The recorded average tuber yield was 40-50 t ha^{-1} and potential yield is 125 t ha^{-1}. It has medium starch (27-32%), low cyanogen (35.01ppm) and low sugar (1.10%) content. It is suitable for planting under rainfed and irrigated conditions especially in regions with high incidence of cassava mosaic disease.

Fig.17. Sree Reksha

Ten early bulking lines were planted in a replicated yield trial with Vellayani Hraswa as the control. Three lines *viz.*, 16S-1, 9S-174 and 16S-374 were found to be completely resistant to cassava mosaic disease while, five were found to be of the recovery type (16S-39, 16S-48, 16S-143, 16S-225 and 16S-247). The highest tuber yield was recorded in 16S-143 (39.09 t ha^{-1}) at sixth months after planting followed by 16S-36 (31.68 t ha^{-1}) and 9S-174 (30.04 t ha^{-1}). 16S-143 produced the highest individual tuber weight (570 g) followed by 16S-48 (540 g) as compared to the check variety Vellayani Hraswa (233 g).

In the replicated yield trial for development of cassava mosaic resistant varieties for industrial use, 15S-135 recorded the highest tuber yield (64.19 t ha^{-1}) followed by 15S-409 (62.95 t ha^{-1}). In the advanced yield trial for development of CMD resistant varieties with good culinary quality, 15S-406 recorded the highest tuber yield of 55.0 t ha^{-1} with a dry matter content of 48.4% followed by 15S-43.

Among the yellow fleshed cassava, 15S-139 recorded the highest yield (48.53 t ha^{-1}) with low dry matter content (22.8%). Two sweet cassava lines were identified of which, 15S-113 (Fig. 18) recorded the highest dry matter (43.0%). In another experiment on induction of polyploids for triploidy breeding, the polyploids induced are being hardened for ploidy assessment.

Fig. 18. 15S-113 a sweet line of cassava

In the activity on identification of molecular markers associated with postharvest physiological deterioration (PPD) in cassava, a total of 75 cassava genotypes including released varieties, advanced breeding lines and germplasm accessions were characterised for PPD tolerance. Visual assessment of PPD symptoms was done randomly in three tubers at 1, 3, 5, 7, 10, 15 and 20 days after harvest (DAH) by taking transverse sections (0.3 cm) at 25, 50 and 75% of the total length of tubers from proximal to distal end. The tubers were categorised based on visual scoring using two different scales. For peripheral symptoms, a scale of 1-5 developed by Wheatley *et al*., (1982) was used (1-no damage; 2-25% of the portion of the tuber cross section has symptoms; 3-26 to 50% of the portion of the tuber cross section has symptoms; 4-51 to 75% of the portion of the tuber cross section has symptoms and 5-100% damage). For non peripheral PPD symptom development, a scale of 0 to 100% developed by Venturini *et al*., (2015) was used. Average of the scores of all the three sections were taken as the PPD score for the genotype. Morphological tuber characteristics such as tuber length, tuber girth and tuber weight were also recorded along with evaluation for PPD. Kalpaka, Black Thailand, Sree Vijaya, CI-848, Burma, H-165, Sree Prabha and Sree Reksha were found to be free of PPD symptoms whereas, Vellayani Hraswa, CR-43-11, 8S-501-2, 9S-127, 9S-132, CO-4, White Thailand and 8W-5 were found to be highly susceptible to PPD (Fig. 19). The two consecutive years (2016-17 and 2017-18) data on evaluation for PPD tolerance showed that Kalpaka and Sree Reksha were found to be free of PPD symptom whereas, Vellayani Hraswa, CR-43-11, 9S-127 and 9S-132 were found to be highly susceptible to PPD in both the years. Hence, these genotypes were selected as parents for developing mapping population segregating for PPD tolerance. Hybridisation was attempted between the genotypes contrasting for PPD tolerance during 2017-18 and hybrid seeds were collected. The gene expression analysis of the identified tolerant and susceptible parents was conducted to identify the genes expressed during the onset and progress of PPD. The role of genes involved in PPD viz., those included in ROS turnover, biosynthesis and metabolism, signal transduction, programmed cell death (PCD), and cell wall metabolism and remodelling was also examined. The RT-PCR clearly showed that transcripts for genes involved in the metabolism of cyanogenic glycosides, with roles in cell wall remodelling and repair, enzymes involved in the inter-conversion and detoxification of ROS and programmed cell death (PCD) were induced. There was significant polymorphism in the expression of the same between the fresh tuber sample and three-day old tuber sample as well as between the tolerant and the susceptible cassava tubers.

In the experiment on identification of drought tolerant lines in cassava, early period drought stress tolerance was studied with 15 lines of cassava in the polyhouse. Paired t-test values confirmed that there was significant difference between control and stressed plants for plant height, number of leaves per plant, leaf weight per plant, stem weight per plant, total biomass development per plant, leaf moisture content, stem moisture content, leaf total carbohydrate content and leaf HCN content. All the above traits were found to be reduced under

Black Thailand at 10 DPH

Burma at 10 DPH

Kalpaka at 20 DPH

Sree Reksha at 20 DPH

Sree Vijaya at 10 DPH


Sree Prabha at 7 DPH

Fig. 19. Promising PPD tolerant genotypes of cassava

the stress condition when compared with control conditions (Fig. 20). At 5 months after planting a reduction of 47.40% in plant height; 80.72% in leaf weight; 79.53% in stem weight; and 82.87% in total biomass was observed in water deficit stressed (WDS) plants. Total carbohydrate content in the leaf was significantly decreased under WDS conditions (1.38 g $100g^{-1}$ DW) when compared to the control/irrigated conditions (4.073 g $100g^{-1}$ DW). There was no significant difference between control and stressed plants for carbohydrate content of inner cambium including pith of the middle portion of the stem, but the density of central pith was found low in the WD plants. The leaf HCN content was found to be reduced in the water deficit conditions (42.60 ppm DW) in comparison with control conditions (166.80 ppm DW). Chlorophyll content of the leaf was not found significantly different when the leaves were sampled from mid-canopy, but significant difference between control and WDS was observed when leaves were sampled from lower canopy.


Fig. 20. Sree Visakham and Sree Sahya under water deficit stress

Sweet potato

With the aim of developing early maturing (75-90 days), high starch (>16%), high β-carotene (>12 mg $100g^{-1}$), high anthocyanin (>70 mg $100g^{-1}$) and weevil resistance sweet potato, experiments were conducted. Progressive evaluation of germplasm resulted in the selection of four lines namely Baster-45, Acc. no. 527, No. 15 and S-30/16, with high yield (18-19.5 t ha^{-1}), short crop duration (75 to 80 days) and responded well to half doses of N and K (37.5 : 37.5). Through evaluation of OP generated breeding lines, 75 days maturity was observed in seven lines of which two were orange fleshed, two white fleshed and three purple fleshed. Another set of seven purple fleshed, six white fleshed and nine orange fleshed sweet potato were observed to have 90 days maturity. The yield of these ranged between 18.0 to 22.0 t ha^{-1} and 20.6 to 31.2 t ha^{-1} for 75 days and 90 days maturity lines, respectively. Reciprocal crosses are being continued to evolve early maturing sweet potato with valued traits. The evaluation of clonal generations of reciprocal cross products of 2014-15 resulted in identifying 15 lines (white-5, orange-4, purple-6) of which 75 days maturity was recorded in two white, two orange and three purple fleshed lines. The remaining was of 90 days maturity. The crossed products of 2015-16 showed yield ranging from 20.5 to 28.8 t ha^{-1} in 11 lines; 75 days maturity was recorded in three white fleshed and two orange fleshed lines, whereas, 90 days maturity was recorded in three white, two orange and one purple fleshed lines. The clonal generation of 2016-17 revealed seven lines (white-4, orange-2, purple-1) [Fig. 21 and 22] with targeted traits of which 75 days maturity was recorded in two white and two orange fleshed lines with a yield range of 16.8 to 20.8 t ha^{-1} and the rest with 90 days maturity showed an yield range of 19.2 to 26.8 t ha^{-1}. All the early maturing (75 days duration) lines showed no weevil infestation. Starch content ranged from 15.5 to 19.2%; β-carotene ranged from 9.5 to 15.2 mg 100g^{-1} and anthocyanin, 60 to 98.8 mg 100g^{-1}.


Fig. 21. Sweet potato lines 75 DAP


Fig. 22. Sweet potato lines 90 DAP

Yams

During this year, three varieties of yams *viz.*, one in greater yam, one dwarf white yam and one trailing white yam were recommended by the Kerala State Seed Sub Committee for Varietal Release.

Sree Nidhi (IC625797) is a greater yam variety (Fig. 23), which produces medium cylindrical tubers with pinkish cortex and white flesh colour, with no browning when cooked. It recorded an average yield of 35.0 t ha^{-1} with optimum tuber size, good culinary quality, white flesh colour without any undesirable coloration, very little apical portion and less wastage. It is tolerant to anthracnose disease and has medium dry matter (32.0%), starch (23.2% FW) and crude protein (2.5% FW).

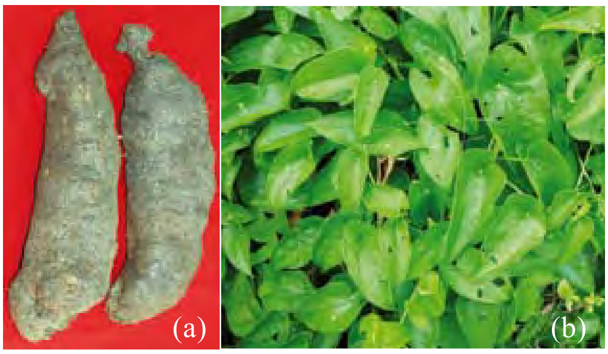


Fig. 23. Sree Nidhi, a high yielding greater yam variety a) tubers and b) aerial portion

Sree Swetha (Fig. 24) is a high yielding (34.0 t ha^{-1}) dwarf white yam variety with good culinary quality which was released for cultivation in Kerala under non trailing condition. It has medium dry matter (32.98%), starch (22.0% FW) and crude protein (3.8% FW).

Fig. 24. Sree Swetha, a high yielding bushy white yam variety a) plant and b) tubers

Sree Haritha is a high yielding (46.0 t ha^{-1}) white yam variety (Fig. 25) with compact tuber shape which was released for cultivation in Kerala. It is a trailing type with medium dry matter (37.6%), starch (26.0% FW) and crude protein (3.22% FW).

Fig. 25. Sree Haritha, a trailing white yam variety with high yield a) tuber and b) plant

The pre-breeding lines of greater yam were screened for resistance to anthracnose disease and three hybrids *viz.*, DaH-9/196, DaH-22-2-3 and DaH-58FG with high field tolerance/resistance to anthracnose disease was identified. In the advanced yield trial of greater yam hybrids, DaH-10-1-4 recorded the highest tuber yield (49.38 t ha^{-1}) followed by DaH-15 (46.91 t ha^{-1}), DaH-10-403 (45.42 t ha^{-1}) and DaH-8-174 (43.20 t ha^{-1}).

Among the yellow fleshed greater yam hybrids, DaH-99/24 recorded the highest tuber yield (53.08 t ha^{-1}) followed by DaH-24-1-1 (39.50 t ha^{-1}). Three profusely flowering fertile female clones were identified for future use in greater yam breeding programmes. A novel interspecific hybrid having dark yellow flesh with outer purple ring was also identified.

Among the new dwarf white yam lines, three hybrids *viz.*, Drd-1095, Drd-1142 and Drd-1148 recorded yields greater than 35.0 t ha^{-1}. In the on farm trial of non trailing white yam, SD-15 recorded significantly higher yield than Sree Dhanya. SD-15 has broader leaves and thicker vines as compared to other dwarf white yam varieties. It recorded yield on par with the trailing white yam variety and Sree Priya as well. It has medium dry matter (34.0%), starch (17.0% FW) and crude protein (2.51% FW).

Edible aroids

Taro

In the activity for introgression of TLB resistance in taro, seven accessions have shown tolerance to taro leaf blight for four consecutive seasons. For identification of molecular markers associated with TLB, DNA isolation from 18 resistant lines and 18 susceptible lines were completed and screening is in progress with 15 ISSR, 10 SSR and 15 RAPD markers. Last year, crossing was attempted with two accessions as female parent (C-157 and C-688) with TLB tolerant lines – Muktakeshi, C-565 and C-203 as male parents. Seeds were raised from these crosses. Apart from these, OP seeds from a TLB tolerant line (C-690-V) and a susceptible parent (C-157) were also raised in trays. OP seeds had more vigour as compared to the hybrids. Now the seedlings of the hybrids and OP seeds are ready for transplanting to the pots for further evaluation. The seeds were collected, dried and stored for further germination studies. In another trial with elite clones, AYT II was conducted with 6 accessions. The yield was low for all accessions including Sree Rashmi (3.8 t ha^{-1}), the check variety and it ranged from 0.1 to 2.0 t ha^{-1}.

In the activity on breeding for quality improvement in taro, selected high yielding fifty lines of taro were evaluated for micronutrient content such as crude protein, phosphorous, potassium, iron, copper, zinc and manganese. Crude protein content ranged from 3.31g 100g^{-1} to 19.48 g 100g^{-1} dry weight in corms and 3.09 g 100 g^{-1} to 21.33 g 100g^{-1} dry weight in leaf. Phosphorous content ranged from 97.34 mg 100 g^{-1} to 424.89 mg 100 g^{-1} dry weight in corms and 38.45 mg 100 g^{-1} to 268.41 mg 100 g^{-1} dry weight in leaf. Potassium content ranged from 789.90 mg 100 g^{-1} to 1187.43 mg 100 g^{-1} dry weight in corms and 641.78 mg 100 g^{-1} to 1042.07 mg 100 g^{-1} dry weight in leaf. Iron content ranged from 4.45 mg 100 g^{-1} to 16.53 mg 100 g^{-1} dry weight in corms and 3.30 mg 100 g^{-1} to 17.56 mg 100 g^{-1} dry weight in leaf. Copper content ranged from 0.57 mg 100 g^{-1} to 1.29 mg 100 g^{-1} dry weight in corms and 0.39 mg 100 g^{-1} to 1.62 mg 100 g^{-1} dry weight in leaf. Zinc content ranged from 2.84 mg 100 g^{-1} to 13.87 mg 100 g^{-1} dry weight in corms and 1.30 mg 100 g^{-1} to 7.85 mg 100 g^{-1} dry weight in leaf. Manganese content ranged from 2.22 mg 100 g^{-1} to 6.71 mg 100 g^{-1} dry weight in corms and 0.81 mg 100 g^{-1} to 6.66 mg 100 g^{-1} dry weight in leaf. On the basis of biochemical and micronutrient profile, fifteen nutritionally rich lines were selected and planted in crossing block for hybridization. Seven single crosses, 2×39, 5×36, 6×39, 6×43, 6×46, 39×43 and 52×36 were made and F_1 seeds were collected for further evaluation.

Elephant foot yam

In elephant foot yam, the hybrid seedlings from the previous year crosses were harvested upon maturity and observations on corm and cormel characters were recorded. These corms were replanted for further studies. The corm weight of hybrid seedlings ranged from 10.0 g to 250.0 g. Apart from this, 20 elephant foot yam accessions were screened for collar rot resistance, and none had tolerance/resistance.

RNA isolation is completed from two elephant foot yam accessions which are highly acrid for undertaking studies on transcriptome profiling for acridity.

Tannia

For standardization of polyploidy induction in tannia, two accessions *viz.,* AKI/2015-8 and AKI/2015-9 were used. Colchicine (0.05 and 0.1%) was tried for three time intervals (12, 24 and 48 hr) in the newly sprouting buds. After the mentioned time intervals, the sprouts were excised and planted in trays and watered. However, the sprouts failed to germinate and the experiment will be repeated again.

PYT II in tannia was conducted in 2017 with 7 accessions in RBD with 3 replications. Highest yield was produced by the accession Xa-AD/2014-15 (5.98 t ha^{-1} cormel yield and 8.68 t ha^{-1} total yield). The lowest yield was recorded in the accession Xa-Wayanad (0.56 t ha^{-1} cormel yield and 1.28 t ha^{-1} total yield). However, the accessions were at par with each other statistically.

Arrowroot

Advanced yield trial of seven arrow root genotypes for yield and yield attributing traits was conducted. The genotype M2 recorded the highest tuber yield of 21.03 t ha^{-1} with single tuber weight of 171.11 g. The number of tubers per plant was higher in the genotypes M2 and M6 (22). Moreover, biochemical evaluation of tubers of the seven genotypes for moisture content, total starch, total sugars, crude fibre and ash on fresh weight basis was done. The total starch content ranged from 18.0% in the genotype M1 to 19.87% in M4 while the total sugar content ranged from 0.76% in M1 to 0.91% in M7. Total moisture content ranged from 63.57% in M2 to 68.17% in M1 while, the total ash content is maximum in the genotype M7 (1.19%) and lowest in M1 and M2 (1.03%). The total crude fibre content was the lowest in the accession M4 (0.66%) and highest in the accession M6 (0.89%).

Yam bean

F_3 generation of five best F_1 hybrids along with check variety (RM-1) were planted in 2017 for evaluation of yield and other yield attributing traits. In another set of five best F_1 hybrids, F_3 generation seeds were raised for production of F_4 generation for evaluation of successive generation (Fig. 26). Tuber yield in F_3 generation of best F_1 hybrids ranged from 29.28 t ha^{-1} (3x9) to 32.44 t ha^{-1} (3x10) as compared to 22.44 t ha^{-1} in RM-1. Starch content (8.22-14.56%) and sugar content (3.55-7.84%) were recorded. Micronutrient content range recorded was as follows: Cu content (120.4 to 149.5 ppm), Mn content (15.22 to 43.22 ppm), Zn content (33.3 to 39.5 ppm) and Fe content (130.2 to 203.4 ppm).

Fig. 26. Tubers of F_3 generation of promising F_1 hybrids in yam bean

Pyramiding of genes for cassava mosaic disease (CMD) resistance

The 150 hybrid seedlings having both *cmd-1* and *cmd-2* genes were evaluated under field conditions. All these lines had 100% field resistance to CMD disease. Among the 150 progenies, 50 progenies with high yield, high starch and good plant types were selected and will be used in cassava breeding program for evaluation and further improvement.

Identification of marker linked to high starch in cassava

For identification of markers linked to high starch, a total of 150 hybrid seedling progenies between high starch line 9S-127 and Sree Padmanabha (MNga-1) were established along with parents in the field for evaluating starch content and mapping study. The parental screening was done with 40 SSR markers and 31 SSR primers showed polymorphism between parents (78%). Among 31 polymorphic SSR primers, 10 primers were used for screening the seedling progenies and genotypic data scored.

Genetic modifications for quality improvement in cassava

In vitro micropropagation was done in CMD resistant 9S-127 and CR-43-11 accessions of cassava and also variety H-226 (Fig. 27). Somatic embryogenesis of CMD resistant cassava accessions 9S-127 and CR-43-11 using immature leaf lobes was done. Compared to the accessions, 9S-127 and CR-43-11, cassava varieties including H-226, Sree Padmanabha, Sree Prakash and Sree Swarna produced lesser number of somatic embryos. The nodes, intermodal segments and immature leaf lobes of cassava accession, 9S-127 was transformed with EHA having *glgC* gene.

Fig. 27. Somatic embryos of CMD resistant cassava

Allele mining for abiotic stress genes in cassava

Genome-wide HMM based-analysis led to the identification of 67 small *heat shock proteins* (*MeHSP20*) and 41 *SNF-related serine/threonine-protein kinase* (*MeSnRK*) family genes in cassava. The *MeHSP20* family genes are distributed in all the chromosomes except on chromosome no. 5 whereas, the *MeSnRK* family genes are distributed in all the chromosomes except on chromosome no. 4. Promoter analysis of 67 *MeHSP20* and 41 *MeSnRK* family genes of cassava revealed the presence of tissue-specific, biotic, abiotic, light-responsive, circadian and cell cycle-responsive *cis*-regulatory elements. Phylogenetic/evolutionary analysis of cassava *MeHSP20* family genes with *HSP20* family of Malpighiales genomes grouped the members into 22 sub-groups (CI sHsp, CII sHSP, CIII sHSP, ER sHSP, MTI sHSP, MTII sHSP, P sHSP, P-Like sHSP, PXI sHSP, PXII sHSP, TF, UAP I, UAP II, UAP IV, UAP V, UAP VI, UAP VII, UAP VIII, UAP IX, UAP X, UAP XI and NaLi). Phylogenetic/evolutionary analysis of cassava *MeSnRK* family genes with *SnRK* family of Malpighiales genomes grouped the members into 3 sub-groups (SnRK1, SnRK2 and SnRK3). This study contribute to a better understanding of the complexity of *MeHSP20* and *MeSnRK* family members in cassava and provide the basis for further studies to ascertain the function of these genes during plant growth and development as well as in response to environmental stimuli.

Statistical tools and technologies for tuber crops research and development

Comparative and functional genomics analysis of starch biosynthesis pathways in cassava

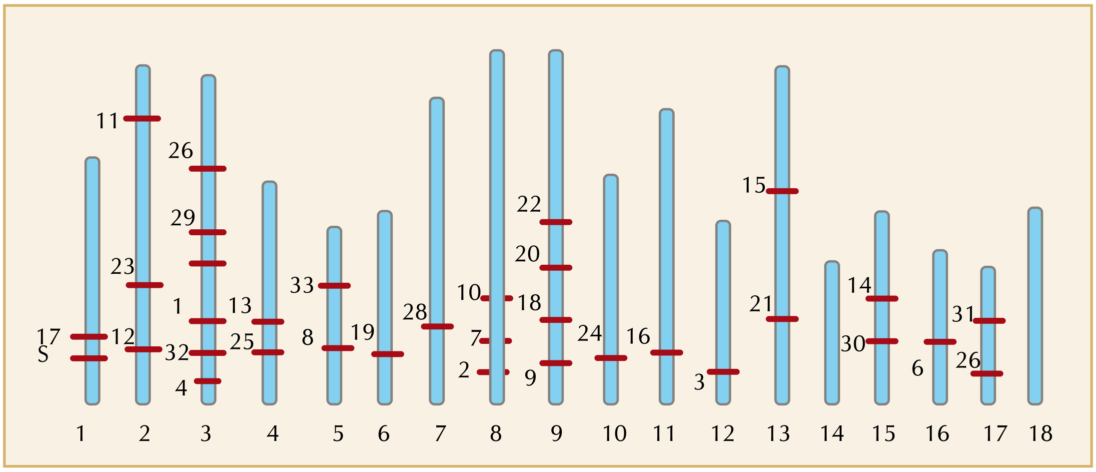
The reconstruction of starch biosynthesis pathway in cassava was done using the databases Phytozome, TAIR, Gramene, Rice Genome Annotation Project, Sol Genomics Network and KEGG for cassava, *Arabidopsis*, maize, rice, potato and castor bean, respectively. The template plants were selected as they are starchy crops and also having evolutionary and physiological resemblance with cassava.

Reciprocal BLASTp was used for the *in silico* prediction of the putative orthologues in an unknown organism by means of bidirectional sequence alignments. Reciprocal BLASTp progresses through two steps. In the first step, a particular protein sequence derived from a template plant was used as query to compare against the cassava protein library which is called as the first BLASTp. Consequently, the cassava proteins from the BLASTp were used to align against the template plant protein library. Based on a lower E-value and a higher query coverage (>= 80%), those cassava sequences that met the given set critical value were taken for further analysis.

E2P2 version 3.0 was used for assigning function to the identified starch synthesis related gene sequences. The Ensemble Enzyme Prediction Pipeline version 3.0 is composed of Enzyme Function (EF) classes containing Enzyme Commission numbers and MetaCyc reaction identifiers. Using the E2P2 software, species-specific metabolic databases could be created. The annotation of sequences by E2P2 was done by homology transfer through integration of single and multiple sequence models having enzymatic function. Based on the literature review and comparative analysis in one of the template plant, Oryza, five genes were prioritised in cassava which can be used as candidate genes in starch biosynthesis pathway. One of the genes prioritised is a negative regulator in the starch biosynthesis pathway in cassava which has a role similar to plastidialadenylate kinase. It was reported that when the levels of plastidial ADK increases, the rate of starch biosynthesis was found to be retarded. Other genes identified assist in chromatin remodulation, root elongation, lncRNA metabolism etc. The candidate genes were predicted using ToppGene suite. The reconstructed pathway was viewed on VANTED platform.

In silico analysis of carotenoid biosynthesis pathway in cassava (*Manihot esculenta* Crantz.)

In silico analysis of carotenoid biosynthesis pathway in cassava (*Manihot esculenta* Crantz.) was carried out for identification and functional annotation the genes involved in the carotenoid biosynthesis pathways in cassava using templates



1.	DXS	17.	ZISO
2.	XDR	18.	LUT
3.	GGPS1	19.	CHY
4.	PSY	20.	CYP97B3
5.	CRITSO	21.	ZEP
6.	PDS	22.	VDE
7.	ZDS	23.	NSY
8.	CCD1	24.	NCED
9.	LYC	25.	ABA
10.	MCT	26.	AAO3
11.	CMK	27.	CCD2
12.	MDS	28.	CRITSO2
13.	HDS	29.	CCD3
14.	HDR	30.	CCD4
15.	IDI	31.	CCD5
16.	GGR	32.	CCD6
		33.	CCD7

Fig. 28. Chromosomal location analysis of carotenoid biosynthesis in cassava

of *Arabidopsis*, tomato, potato and sweet potato. Conserved domain analysis and regulatory sequence analysis were done to predict the regulatory elements of the carotenoid pathway in cassava. Phylogenetic analysis, expression profiling and sub cellular localization prediction were carried out to identify the components in the carotenoid pathway. Carotenoids biosynthesis pathway was constructed by integrating the precursor pathway, core carotenoid pathway and apocarotenoid pathway and the data was collected from regulatory analysis.

The template plant sequences were retrieved from two different databases, NCBI and Phytozome. BLASTp search was done using the protein sequences of template plants against the carotenoid genome in Phytozome and identified 39 carotenoid genes in cassava. The carotenoid gene length varied from 1320 to 13300 bp nucleotides. Three carotenoid genes (Manes.01G117500, Manes.16G135300 and Manes.02G018300) had less than 1500 bp nucleotides with 1324, 1484 and 1340 bp nucleotides, respectively. Based on the classification of precursor pathway, core pathway and degradative pathway, the 39 genes were classified into different pathways, seven genes were classified into MEP pathway, 21 genes to the core carotenoid pathway and 11 genes belonged to the carotenoid degradative pathway.

Functional annotation was carried out by using E2P2 (Ensemble Enzyme Prediction Pipeline). The regulatory sequence analysis such as Transcription Factor (TF) prediction by analysing TFBS using PlantregMap showed 18 significant transcription factors regulating carotenoid genes in cassava. CpG island analysis using the online EMBOSS CpG plot tool were useful in analysing the expression pattern of carotenoid genes. The chromosomal location analysis by NCBI map viewer and the phylogenetic analysis were done by MEGA software which revealed that carotenoid genes were distributed throughout the whole genome.

Carotenoid genes were located on 17 out of 18 cassava chromosomes. More number of genes were located on chromosome 3 (6 genes), chromosome 9 (4 gene), chromosome 2 and 8 harboured 3 genes each and other chromosomes contain 1-2 genes. No genes were localized on chromosome number 18 (Fig. 28).

Finally, the carotenoid biosynthesis pathway was constructed using the identified genes in cassava and all the data regarding regulatory sequence analysis and *in silico* analysis was combined into the pathway. Study of the complete set of carotenoid biosynthetic genes in cassava will provide an insight into the carotenoid metabolic mechanisms in cassava crop and can be utilized for molecular breeding in cassava.

CROP PRODUCTION

INTEGRATED CROP, WATER AND NUTRIENT MANAGEMENT FOR IMPROVING PRODUCTIVITY OF TROPICAL TUBER CROPS

Production of disease free planting materials in tropical tuber crops

Mass multiplication of virus free planting materials was done through procedures involving indexing, micro propagation, hardening and minisett multiplication under protected environment, large scale multiplication of disease free planting materials in selected areas of Kerala, Tamil Nadu, Odisha and the North East India in a farmer's participatory mode together with farmer's training programmes for mass multiplication and popularization of disease free planting materials.

A total number of 210 micro plants of different cassava varieties were indexed against cassava mosaic virus through micro propagation technique in the tissue culture laboratory. A total of 140 elephant foot yam variety Gajendra were indexed. Hardening of micro plants were done in cassava. Those hardened micro plants were further multiplied in the net house at ICAR-CTCRI and in field conditions. The details of quality planting material production of tuber crops at ICAR-CTCRI, Thiruvananthapuram and Regional Centre, Bhubaneswar are given in Table 1.

Table 1. Quality planting material production of tuber crops during the crop season 2017-18

Sl. No.	Name of the Crops	Varieties	Quantity of planting material produced
1.	Cassava (No. of stems)	Sree Vijaya	25,000
		Sree Jaya	20,000
		Sree Pavithra	10,000
		Sree Swarna	10,000
		Sree Athulya	5,000
		Total	70,000
2.	Elephant foot yam (ton)	Gajendra	5.80
		Sree Padma	0.20
		Total	6.00
3.	Greater yam (ton)	Sree Keerthi	3.5
		Sree Karthika	2.0
		Sree Shilpa	2.0
		Sree Roopa	2.5
		Da 293	2.0
		Orissa Elite	2.0
		Total	14.00
4.	Taro (ton)	Telia	1.5
		Muktakeshi	3.0
		Total	4.5
5.	Sweet Potato (No of vine cuttings)	Bhu Sona	1,15,000
		Bhu Krishna	1,20,000
		Total	2,35,000
6.	Yam bean (kg)	RM-1	300

Mass multiplication of disease free planting material production in tuber crops

Cassava

Virus free planting material production of cassava varieties *viz.,* Sree Vijaya, Sree Jaya, Sree Pavithra, Sree Swarna and Sree Athulya was carried out in block III and V of ICAR-CTCRI farm in an area of 4.70 acres, during 2017-18. The planting material production of cassava was done following the procedure mentioned in the Indian minimum seed certificate standards (Fig. 29). The planting materials were monitored for health status and leaves sample were collected from standing crop at different interval for testing virus. The field inspection, rogueing and intercultural operations were carried out as and when required. The planting material crop was harvested at maturity stage. A total of 70,000 cassava stems of good quality planting materials were produced.

Sree Jaya

Sree Vijaya

Fig. 29. Field view of quality planting material production of cassava variety Sree Jaya and Sree Vijaya

Elephant Foot Yam

Quality planting material production of Elephant foot yam (variety Gajendra) was taken up in Block V of ICAR – CTCRI in area of 1.80 acres as per the procedure mentioned in the Indian minimum seed certification standards. The planting material was monitored for pest and disease at different intervals. Leaves were collected from standing crop for testing virus incidence. The field inspection, rogueing and intercultural operations were carried out as and when required. The planting material was harvested at full maturity stage. A total of 6 tons of elephant foot yam of good quality planting materials was produced.

Greater Yam

Quality planting material production of greater yam varieties *viz.,* Sree Keerthi, Sree Roopa, Sree Karthika and Sree Shilpa was taken up in the block II and V of ICAR – CTCRI farm with a total area of 1.25 acres (Fig. 30) as per the procedure mentioned in the Indian minimum seed certification standards. The planting material of seed crops were monitored regularly for health status of standing crop. The field inspection, rogueing and intercultural operations were carried out at different stages of the crop. The planting material crop was harvested at maturity stage and a total of 8 tons of quality planting materials were produced.

Sree Roopa

Sree Shilpa

Fig. 30. Field view of quality planting material production of greater yam

Taro

The quality planting material production of taro (var. Muktakeshi) was taken up in 0.20 acre in the block IV of ICAR – CTCRI (Fig. 31) as per procedures mentioned in the Indian minimum seed certification standards. The seed crops were monitored at different intervals for health status of planting material. The field inspection, rogueing and intercultural operations were carried out at different stages of the crop. The planting material crop was harvested at maturity and a total of 800 kg taro quality planting materials were produced.

Under the license agreement with farmer for quality planting material production, 230 ton of elephant foot yam and 30 ton of greater yam were produced and distributed to farmers.

Fig. 31. Field view of quality planting material production of taro var. Muktakeshi

Multiplication through minisetts technique in cassava

Mass multiplication of virus free planting materials were carried out through minisett technique in cassava varieties *viz.*, Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Swarna. The minisetts were planted inside the net house for one month and then transplanted in the net house as well as in the field.

Integrated crop health management approach for quality planting materials production in cassava

Planting material of cassava stems of varieties *viz.*, Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Swarna were treated by soaking in hot water. This resulted in zero cassava mosaic virus infection for two months and it was 4, 6, 8 and 10% at 3rd month and 35, 38, 43 and 40% at 8th month after planting. Cassava planted at KVK, Thirupathisaram, Kanyakumari district in Tamil Nadu, showed that the cassava mosaic virus infection was zero upto two months, which showed CMD symptoms after 2 months and the virus incidence was 2, 4, 7 and 5% at 3rd month and 28, 33, 43 and 38% at 8th month in the varieties of Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Swarna respectively. In the Karumanthurai village of Kalvarayan hills in Salem district of Tamil Nadu, cassava crop showed CMD symptoms only after three months and the virus incidence was 30 and 42% at 8th month in the varieties, Sree Vijaya and Sree Jaya respectively.

Induction of early and uniform sprouting in elephant foot yam

A field experiment was conducted at ICAR-CTCRI, Thiruvananthapuram, to study the effect of different growth regulators and chemical treatments on induction of early and uniform sprouting in elephant foot yam. There were thirteen treatments replicated thrice in randomized block design (RBD) with elephant foot yam variety Gajendra during summer season of 2017. Elephant foot yam corms were treated with different treatment *viz.*, GA_3 100 ppm (T_1), GA_3 200 ppm (T_2), IAA 100 ppm (T_3), IAA 200 ppm (T_4), Thiourea 0.5% (T_5), Thiourea 1% (T_6), Potassium nitrate 0.5% (T_7), Potassium nitrate 1% (T_8), Carbon disulphide 80 ml @100 kg corm fumigated (T_9), combination of GA_3 200 ppm + Thiourea 0.5% (T_{10}), Cow dung slurry (T_{11}), Water treatment (T_{12}) and control (T_{13}). The crop was planted with 90 cm x 90 cm spacing. The standard recommended package of practice was followed. Steps involved in fumigation method given in Fig. 32. The crop was harvested at 9th month after planting and the corm yields were recorded treatment wise.

The results revealed that elephant foot yam corms treated with fumigation of carbon disulphide @ 80 ml 100 kg^{-1} resulted in maximum uniform sprouting (99%) at 30 days after planting (DAP), followed by GA_3 200 ppm treatment (94%) at 30 DAP (Fig. 33). The plant growth parameters revealed higher plant height (64 cm), stem girth (21cm) and leaves spread (76 cm) in plants raised from carbon disulphide treated corm followed by GA_3 200 ppm treatment at 60 days after planting.The corm yield data revealed that fumigation treatment with carbon disulphide resulted in maximum corm yield (24.50 t ha^{-1}) followed by GA_3 corm treatment (17.30 t ha^{-1}). (Fig. 34 and 35).

Fig. 32. Fumigation of corm

Fig. 33. Corm with uniform sprout after fumigation and single corm with sprout

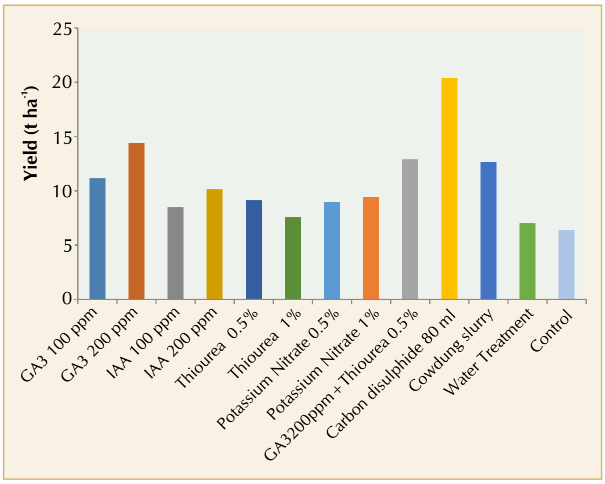


Fig. 34. Effect of growth regulators on corm yield in elephant foot yam

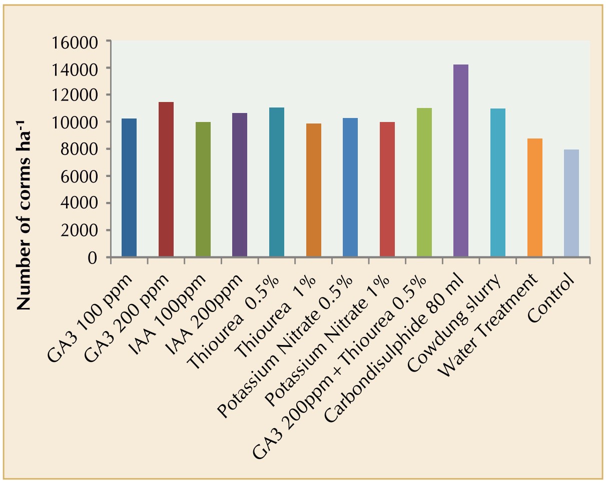


Fig. 35. Effect of growth regulators on number of corms in elephant foot yam

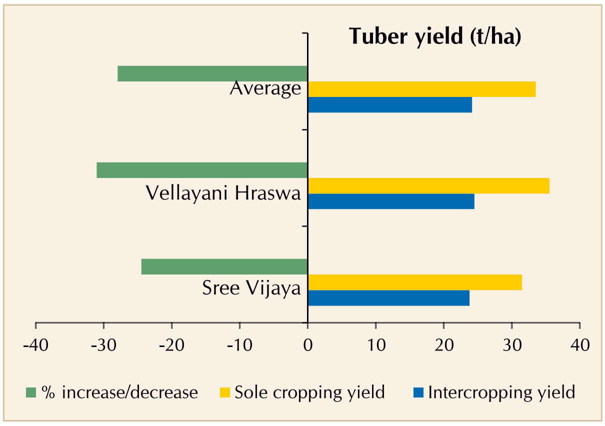
Cropping systems involving tuber crops and legumes

Intercropping short-duration cassava and pulse crops in rice based system

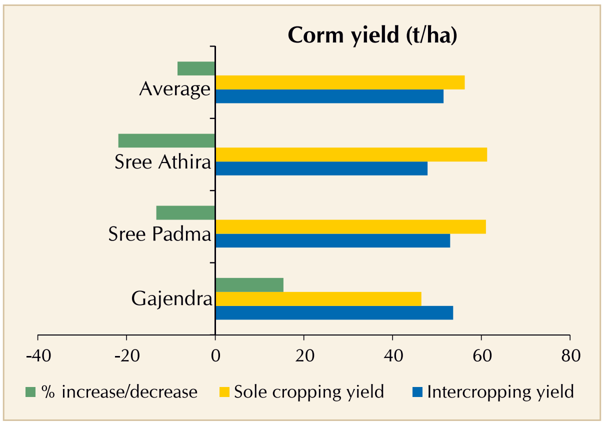
The field experiment to evaluate the feasibility of intercropping short-duration cassava and pulse crops in rice based system was carried out for the second season. Rice var. Kanchana was planted during the first season followed by short-duration cassava varieties Sree Vijaya and Vellayani Hraswa intercropped with pulse crops, green gram (var. Co-Gg-7), black gram (var. Co-6) and soybean (var. JS-95-60). The grain yield and straw yield of rice were 3.61 t ha^{-1} and 6.07 t ha^{-1}, respectively. There was significant yield reduction (28%) in cassava under intercropping (24.16 t ha^{-1}) over sole cassava (33.53 t ha^{-1}). Both the varieties of cassava and all the pulse crops tested were suitable for intercropping. But intercropping short-duration cassava var. Sree Vijaya with black gram, Vellayani Hraswa with green gram or Vellayani Hraswa with soybean under reduced fertility level was preferred due to greater cassava tuber yield (27-28 t ha^{-1}; lesser yield reduction of -18%) on par with sole cassava (33.53 t ha^{-1}) and saving of nutrients. Nutrient saving to cassava to the extent of half FYM and N and full P was possible. Based on two years data, rice var. Kanchana followed by short-duration cassava var. Sree Vijaya + black gram at the reduced fertility level was found to be productive (tuber equivalent yield of 40.19 t ha^{-1} and production efficiency of 111.64 kg ha^{-1} day^{-1}), energy efficient (191.11 x 10^{3} MJha^{-1}) and profitable (additional profit of ₹61,736 ha^{-1} over sole cassava).

Intercropping system involving elephant foot yam and pulse crops

The field experiment to evaluate the feasibility of intercropping elephant foot yam with pulse crops was carried out for the second season. The treatments comprised factorial combinations of three varieties of elephant foot yam, Gajendra, Sree Padma and Sree Athira, three pulse crops, green gram, black gram and soybean and two fertility levels, (full FYM, N and K; half FYM and N, full K) (Fig. 36). Sole crops of all varieties of elephant foot yam under full FYM, N, P and K were also maintained for comparison. Intercropping pulses with elephant foot yam proved feasible as the yield of elephant foot yam under intercropping with pulses (51.49 t ha^{-1}) was on par (-8.5%) with sole cropping (56.27 t ha^{-1}). The yield of Gajendra variety was higher under intercropping (+15.36%) than that of Sree Padma (- 13%) and Sree Athira (- 22%). Among the treatment combinations, elephant foot yam var. Gajendra + soybean under full fertility level resulted in maximum corm yield (66.40 t ha^{-1}), tuber equivalent yield (66.77 t ha^{-1}), production efficiency (247.30 kg ha^{-1} day^{-1}) and equivalent energy (239.91 x 10^{3} MJ ha^{-1}) over sole cropping of elephant foot yam var. Gajendra (46.48 t ha^{-1}, 46.48 t ha^{-1}, 172.45 kg ha^{-1} day^{-1} and 167.33 x 10^{3} MJ ha^{-1}.

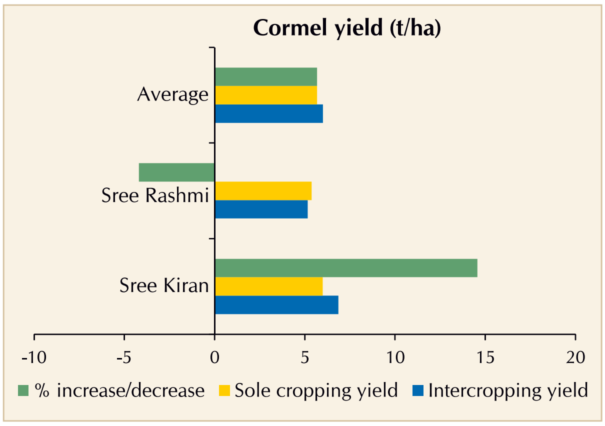


Cassava yield: Intercropping vs sole cropping



Elephant foot yam yield: Intercropping vs sole


Field view of elephant foot yam after harvest of pulses



Taro yield: Intercropping vs sole cropping

Fig. 36. Intercropping tuber crops with pulses

Intercropping system involving taro and pulse crops

The field experiment to evaluate the feasibility of intercropping taro with pulse crops was carried out for the first season. The treatments comprised factorial combinations of two varieties of taro, Sree Kiran and Sree Rashmi, three pulse crops, green gram, black gram and soybean and two fertility levels, (full FYM, N and K; half FYM and N, full K). Sole crops of taro varieties were also maintained under full FYM, N, P and K for comparison.

The yield of taro under intercropping with pulses (6.01 t ha^{-1}) was on par (+6.0%) with sole cropping (5.68 t ha^{-1}), during the first year. Of the two taro varieties, Sree Kiran proved superior and resulted in a yield increase of 14.56%, whereas Sree Rashmi could not withstand competition and the cormel yield was reduced by 4.20%. Sree Kiran intercropped with green gram (11.22 t ha^{-1}) or black gram (10.38 t ha^{-1}) at the reduced fertility level produced greater yield over sole taro (5.69 t ha^{-1}; Fig. 37).

Sree Kiran + Green gram

Sree Kiran + Black gram

Fig. 37. Intercropping taro with pulse crops

Weed management in elephant foot yam

A field experiment was conducted during 2017-18 at the Regional Centre, ICAR – CTCRI, Bhubaneswar to study the effect of weed management practices on the yield of elephant foot yam. The experiment was laid out in randomized block design with three replications. The experiment consisted of eleven treatments: 1. Pendimethalin (1 DAP) + Glyphosate (45 DAP), 2. Metribuzin (1 DAP) + Glyphosate (45 DAP), 3. Pendimethalin (1 DAP) + Tank mix of 2, 4-D amine salt and Quizalofop ethyl (45 DAP), 4. Metribuzin (1 DAP) + Tank mix of 2, 4-D amine salt and Quizalofop ethyl (45 DAP), 5. Pendimethalin (1 DAP) + 2 rounds of manual weeding (at 60 and 90 DAP), 6. Metribuzin (1 DAP) + 2 rounds of manual weeding (at 60 and 90 DAP), 7. Two rounds of manual weeding (30 and 60 DAP) + Glyphosate (at 90 DAP), 8. Two rounds of manual weeding (at 30 and 60 DAP) + Tank mix of 2, 4-D amine salt and Quizalofop ethyl (at 90 DAP), 9. Weed control ground cover (WCGC), 10. Four rounds of manual weeding (at 30, 60, 90 and 120 DAP) and 11. Control (No weeding). Dry weed weight was recorded before manual weeding and herbicide applications, and at harvest. Weed control efficiency was computed by following the standard procedure. The crop was harvested at 8 MAP.

The results revealed that, maximum dry weed biomass of 239.6 gm^{-2} was recorded in control treatment wherein no weeding was done. Weed control ground cover (T9) resulted in lowest dry weed biomass. This was due to suppression of weeds by the weed control ground cover. The next lower dry weed biomass was recorded with four rounds of manual weeding (30, 60, 90 and 120 DAP). Significantly higher corm yield (32.4 t ha^{-1}) was recorded with weed control ground cover as compared to other treatments. However, it was statistically at par with 4 rounds of manual weeding (30, 60, 90 and 120 DAP) (32.1 t ha^{-1}) and 2 rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) (30.4 t ha^{-1}). These were due to lower weed stress and higher weed control efficiency (Fig. 38). Maximum gross return (₹ 4, 85,500/-) was attained in weed control ground cover treatment. Maximum net return (₹ 2, 58,200/-) was attained in 4 rounds of manual weeding (30, 60, 90 and 120 DAP). However, higher benefit cost ratio

(2.22) was attained in 2 rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) treatment due to lower cost of cultivation.

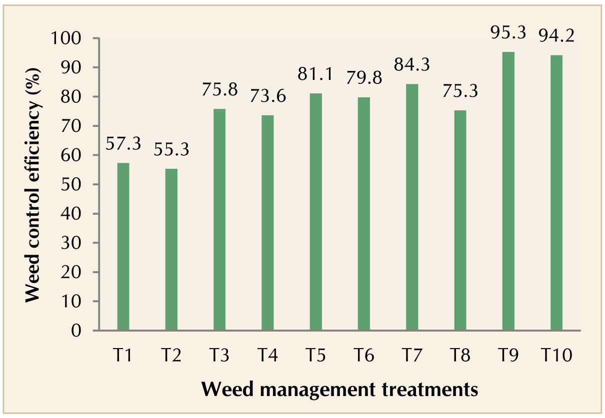


Fig. 38. Effect of weed management practices on weed control efficiency

Weed management with new generation herbicides in tropical tuber crops

A new field experiment was conducted during 2017-18 at ICAR-CTCRI, Thiruvananthapuram to study the effect of new generation herbicides on weed management in elephant foot yam. The experiment was laid out in randomized block design with three replications. The experiment had nine treatments *viz.*, T_1-Imazethapyr (PE) + Propaquizafop (45 DAP) + Propaquizafop (90 DAP), T_2-Imazethapyr (PE) + Clodinofop propargyl (45 DAP) + Clodinofop propargyl (90 DAP), T_3-Imazethapyr (PE) + Propaquizafop (45 DAP) +Clodinofop propargyl (90 DAP), T_4-Tembotrion (PE) + Propaquizafop (45 DAP) + Propaquizafop (90 DAP), T_5-Tembotrion (PE) + Clodinofop propargyl (45 DAP) + Clodinofop propargyl, T_6-Tembotrion (PE) + Propaquizafop (45 DAP) + Clodinofop propargyl (90 DAP), T_7-Pendimethalin (PE) + Glyphosate (45 DAP) + Glyphosate (90 DAP), T_8-Weed free control (weeding at 30, 60, 90 and 120 DAP) and T_9-Un weeded control. Initial soil properties were taken for soil physical, chemical and microbiological studies prior to experiment. Dry weed biomass was recorded at 30, 60, 90, 120 days after planting and at harvesting stage. Weed control efficiency was done by using standard procedure. The crop was harvested at 8 months after planting. Maximum dry weight of weeds was recorded in the control plot, where no weeding was done. Treatment 7 [Pendimethalin (PE) + Glyphosate (45 DAP) + Glyphosate (90 DAP)] resulted in lowest dry weed biomass at 45, 90, 120 days after planting and at harvesting stage. This was due to complete suppression of weeds due to the chemical residue for more periods in the soil (Fig. 39). The next best treatments for less dry weed biomass was weeding free control (T8) *viz.*, weeding at 30, 60, 90 and 120 DAP. Significant higher plant growth, canopy spread, pseudo stem height, fresh and dry weight of shoot portion was recorded with treatment T_4 [Tembotrion (PE) + Propaquizafop (45 DAP) + Propaquizafop (90 DAP)] followed by treatment T_5 [Tembotrion (PE) + Propaquizafop (45 DAP) + Propaquizafop (90 DAP)]. Significantly higher corm yield was recorded with treatment T_7 (38.47 t ha^{-1}), which was due to best weed control efficiency and less weed dry matter production, followed by treatment T_8 (33.84 t ha^{-1}), followed by treatment T_4 (32.72 t ha^{-1}). Significantly maximum gross return was recorded in treatment T_7 (₹17,31,299 ha^{-1}), followed by treatment T_8 (₹ 15,22,764). Maximum net returns were recorded by treatment T_7 (₹ 13,95,417) followed by treatment T_8 (₹ 11,67,487) and treatment T_4 (₹11,29,365). Higher benefit cost ratio was recorded under treatment T_7 (5.15) followed by two treatments T_8 and T_4 (4.29).

Fig. 39. Effect of new generation herbicides on weed management in elephant foot yam

Studies on fertigation requirement in greater yam+maize intercropping system

A field experiment was conducted during 2017-18 at the Regional Centre of ICAR – CTCRI, Bhubaneswar to study the effect of fertigation intervals and number of splits in greater yam+maize intercropping system. The experiment was laid out in split plot design with fertigation intervals in main plots (I_1-2 days, I_2-3 days and I_3-4 days) and in sub plots number of splits (S_1-40 splits, S_2-50 splits and S_3-60 splits). Control (1): (soil application of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} at basal (40%), 45 (30%) and 90 (30%) days after planting) and control (2): (No fertilizer) were also included to compare the treatments. The treatments were replicated thrice. In fertigation treatments, water soluble N, P and K was applied in 5 splits (basal, 30, 60, 90 and 120 DAP @ 20% each). In control 1; P_2O_5 was applied in the last plough. N and K was applied in 3 splits at basal (40%), 45 DAP (30%) and 90 DAP (30%). Farmyard manure @ 10 t ha^{-1} was incorporated in the last plough in all the treatments except control (2). Greater yam weighing 200 g cut tubers were planted on ridges formed at 90 cm spacing. The plant to plant distance of 90 cm was maintained. In the intra-rows, in between two greater yam plants 3 maize seeds were sown on the same day at the spacing of 30 cm. The irrigation was withheld for 10 days before harvesting in all the treatments. The crop was harvested 280 days after planting.

The results revealed that the treatment I_1 (2 days interval) resulted in significantly higher maize yield (2.9 t ha^{-1}) compared to other treatments. It indicates that maize requires fertilizers in quick succession for its robust growth and development. The greater yam tuber yield and tuber equivalent yield (TEY) increased with increasing fertigation intervals. However, maximum greater yam and tuber equivalent yield (32.9 and 35.4 t ha^{-1} respectively) was noticed in the treatment I_2 (3 days interval). Increasing number of splits of the recommended dose of fertilizer decreased maize yield, whereas increased greater yam and tuber equivalent yield. The former case may be due to insufficient quantity of fertilizers received by the maize crop during crop growth period and the latter case may be due to availability of fertilizer for longer period for the long duration greater yam crop. The treatment I_1S_1 (40 splits in 2 days interval) resulted in greater maize yield (3.1 t ha^{-1}) compared to other treatments. It indicated that maize utilized maximum of the applied N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1}. However, fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} in 60 splits at 3 days interval (I_2S_3) resulted in greater yam yield (35.6 t ha^{-1}) and tuber equivalent yield (37.9 t ha^{-1}). Fertigation beyond 180 days after planting resulted in decrease tuber equivalent yield (Fig. 40). The treatment I_2S_3 resulted in 26.2 and 23.5% greater yam yield and tuber equivalent yield respectively over check (NPK soil application). The lowest maize, greater yam and tuber equivalent yield were recorded in control (no fertilizers). The nutrient use efficiency in the treatment I_2S_3 was greater compared to other treatments and it was 19.4% greater than check (NPK soil application).

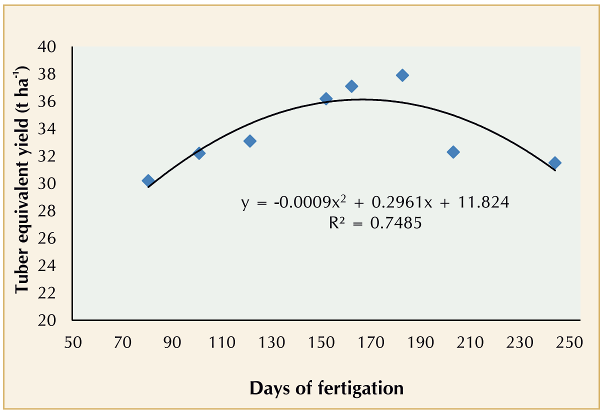


Fig. 40. Relationship of fertigation duration and tuber equivalent yield

The economics of fertigation revealed that fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} in 60 splits at 3 days interval (I_2S_3) resulted in greater gross (₹ 5,68,500/-) and net returns (₹ 3, 58, 500/-) as well as B: C ratio (2.71). Significantly minimum gross returns (₹ 2, 11, 000/-) and net returns (₹ 77, 700/-) as well as B: C ratio (1.58) was recorded in control (no fertilizer).

Water management in tropical tuber crops

Water saving techniques in elephant foot yam

The field experiment in elephant foot yam on water saving techniques with modified set of treatments was carried out to assess the possibilities of reducing the water requirement of the crop. The experiment was laid out in RBD with nine treatments including two controls for comparison. Irrigation was given @ 50% CPE along with different water saving techniques such as using ground cover, use of antitranspirant, application of pusa hydrogel, application of super absorbent polymer, (SAP 1 and SAP 2), use of coir pith, and crop residue mulching. Drip irrigation at 100% CPE and a rainfed crop was kept as control. Drip irrigation was given once in alternate days based on the daily evaporation rate and the crop coefficient factor.

The crop took 18-27 days for initiating sprouting and 32-39 days for achieving 50% sprouting. Full sprouting was achieved within 48-58 days under different treatments. Rainfed crop took 35 days for first sprouting, 65 days for 50% and 79 days for 100% sprouting. Morphological characters recorded at monthly intervals were more or less similar, once the canopy was established. However, girth of psuedo stem, canopy spread and leaf area index were significantly superior in the treatment where ground cover mulching was done. Surface soil moisture content was assessed over a period of six months from planting at monthly intervals using soil moisture probe. Available soil moisture varied from 6.5 to 10.5% at different sampling intervals. Under rainfed conditions, moisture varied from 6.5 to 7.3% in the top soil during different months.

During 2017-18, significant difference in corm yield was recorded among the treatments. Maximum corm yield was recorded by providing 50% irrigation along with ground cover plastic mulching (41.81 t ha^{-1}), followed by application of Pusa hydro gel (33.35 t ha^{-1}). The rainfed crop produced the lowest corm yield of 16.93 t ha^{-1}.

Root studies in elephant foot yam

The experiment on root distribution studies in elephant foot yam was repeated under irrigated and rainfed conditions by planting the full corms approximately weighing one kg in 2m x 2m x 0.6 m cement tanks filled with soil. The plants were sampled at various stages *viz.*, at sprouting, shoot elongation, leaf emergence and full emergence and then at monthly intervals upto senescence and morphological characters of roots were recorded. Root length, number of roots and root volume increased from sprouting to full canopy development stage and thereafter started declining both under rainfed and irrigated conditions (Fig. 41).

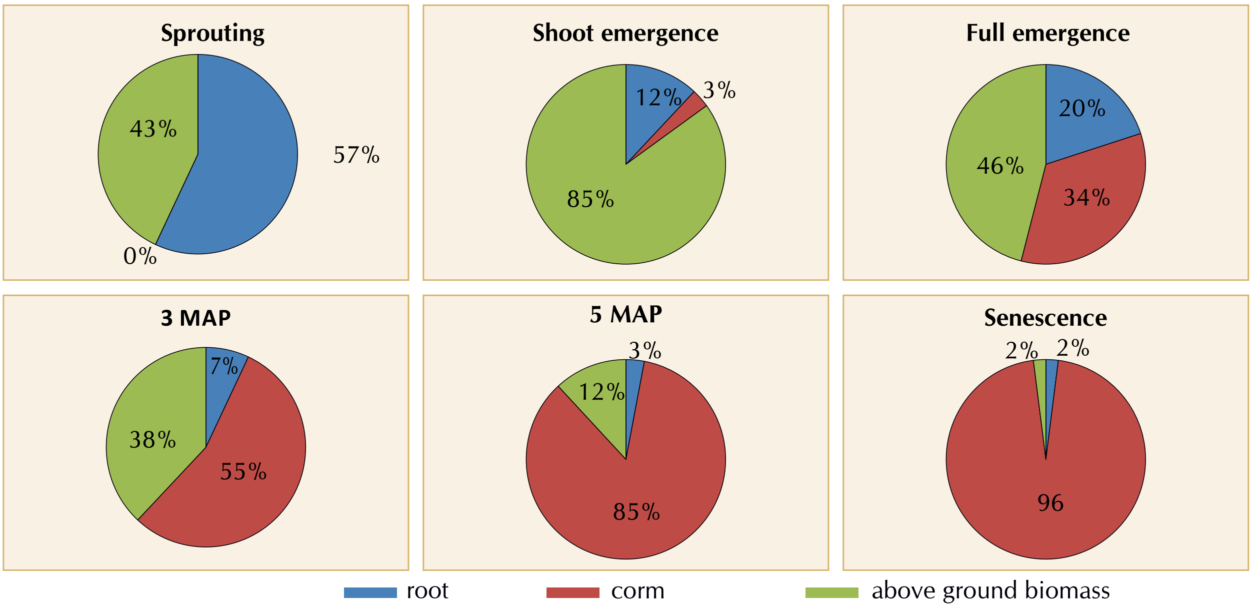


Fig. 41. Rooting pattern of elephant foot yam at different stages of growth

Water management studies in Taro

A new experiment was initiated during November, 2016 to standardise irrigation scheduling for taro under upland conditions. The field experiment was laid out with twelve treatments in 3 x 4 factorial designs along with two controls, furrow irrigation and a rainfed crop. The factors included were three periods of irrigation (irrigation during 0-8 weeks after planting, 0-16 WAP, 0-24 WAP) and four levels of micro irrigation [IW/CPE ratio 0.75 (I_1), 1.0 (I_2), 1.25 (I_3) and 1.50 (I_4)]. Biometric observations were recorded at monthly intervals and the treatments showed significant difference at different stages, especially in number of leaves, number of tillers and LAI. Soil moisture content recorded at monthly intervals indicated significant variation at different intervals. The soil moisture content varied from 5.2 to 14.5% (v/v) under micro irrigation treatments, 7.9 to 17.8% under furrow irrigation and 6.4 to 7% under rainfed control.

The crop was harvested during May, 2017. There was significant difference in both cormel yield and total yield (corm + cormels) among periods of irrigation, but different levels of irrigation did not result in significant variation in yield (Fig. 42). Irrigation during 0-24 weeks resulted in maximum yield and the yield decreased when irrigation was confined to 16 weeks and 8 weeks. Irrigation during 0-24 weeks @ IW/ CPE ratio 1.25 resulted in maximum cormel yield (30 t ha^{-1}) among the interaction effects of the two factors, which was on par with irrigation for 24 weeks under different irrigation levels. Furrow irrigated and rainfed crop produced 19.15 t ha^{-1} and 3.47 t ha^{-1} respectively which were significantly lesser than maximum cormel yield. Total yield was highest when irrigation was given for 24 weeks @ IW/CPE ratio 0.75 and was on par with the other three levels of drip irrigation and the furrow method.

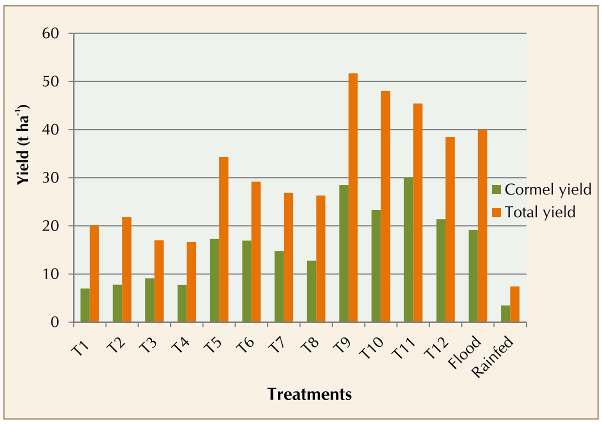


Fig. 42. Effect of different treatments on total and cormel yield of taro

Long term fertilizer cum manurial experiment in cassava

The results of the experiment for the 13th season on tuber yield, tuber quality, soil chemical properties, plant nutrient content and plant nutrient uptake under the influence of different levels of fertilizers including soil test based fertilizer recommendation and absolute control, different organic manure sources, single, two and three nutrient combinations of secondary nutrient (Mg) and micronutrients (Zn and B) are presented below.

The results of continuous cultivation of cassava in the same field for the 13th year confirmed cassava as a benign crop for continuous cultivation in the same field by establishing the sustainability of cassava for long term cultivation with a tuber yield of 8 t ha^{-1} under absolute control and 11. 43 t ha^{-1} under package of practices (PoP) (NPK @ 100:50:100 kg ha^{-1} + FYM @12.5 t ha^{-1}) with a sustainable yield index (SYI) of 0.43 under absolute control and 0.76 in PoP over these 13 years (Fig. 43, 44). Different levels of NPK @ 125:50:125 (14.24 t ha^{-1}), 100:50:100 (11.43 t ha^{-1}), 50:25:100 (11.63 t ha^{-1}), 50:25:50 (10.31 t ha^{-1}) kg ha^{-1} did not result in significant difference in tuber yield after 13 years of continuous cultivation. Soil test based fertilizer (STBF) cum manurial recommendation (NPK @ 71:0:71 kg ha^{-1} along with FYM @ 5 t ha^{-1}) for cassava with complete omission of P resulted in a tuber yield of 11.50 t ha^{-1} on par with PoP (11.43 t ha^{-1}) after cultivation in the same field continuously for the 13th season. Green manuring *in situ* with cowpea (green biomass added @ 18.71 t ha^{-1}) (Fig. 45) was found as the best organic manure alternative during all these 13 years with an yield of 13.99 t ha^{-1} on par with FYM @ 12.5 t ha^{-1} (11.43 t ha^{-1}), vermicompost @ 3.91 t ha^{-1} (12.62 t ha^{-1}), coir pith compost @ 4.6 t ha^{-1} (12.35 t ha^{-1}) during the 13th season without weed growth during all stages of the crop under green manuring. Application of organic manures alone as vermicompost, coir pith compost, ash and crop residue (leaf and stem residue on dry weight basis was 2.21 and 3.11 t ha^{-1} respectively) to substitute for the total N through chemical fertilizers and FYM resulted in significantly lower tuber yield of 6.60 t ha^{-1} during this year. In the case of secondary and micronutrients, the need to apply these nutrients based on soil test is again confirmed based on the yields under the different treatments as single nutrient, two nutrient and three nutrient combination of Mg, Zn and B giving significantly higher yield with Mg alone (16.40 t ha^{-1}) where the soil Mg content was only 0.538 meq 100 g^{-1} which was far below the soil critical level of Mg (1 meq 100 g^{-1}).

There was no significant effect of levels of fertilizers, different organic manures and secondary and micronutrients on starch and cyanogenic glucoside content of cassava tubers.

In the case of biometric characters, stem girth at 3 months after planting (MAP), fallen leaves at 6 and 9 MAP were significantly influenced by different treatments. Among the different treatments, green manuring *in situ* with cowpea resulted in thicker stems and highest number of fallen leaves at both intervals on par with FYM.

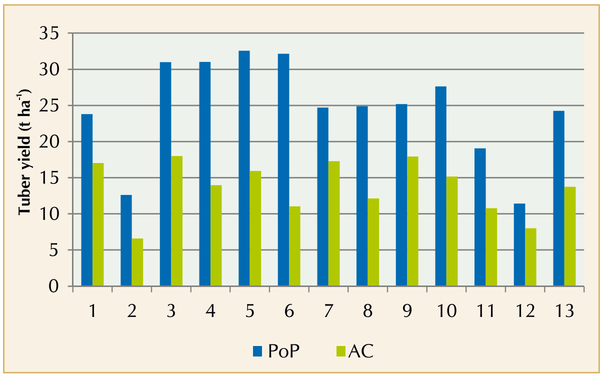


Fig. 43. Tuber yield of cassava under POP and absolute control over a period of 13 years

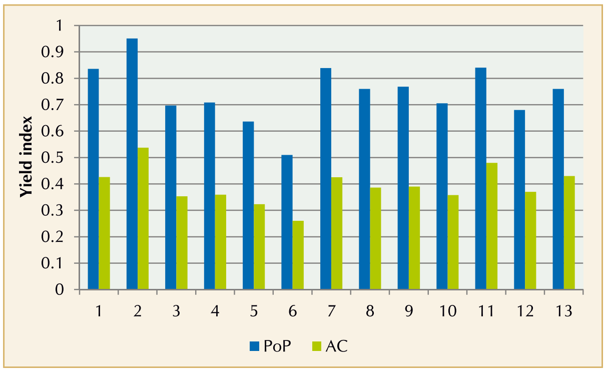


Fig. 44. Sustainable Yield Index (SYI) under PoP and absolute control over a period of 13 years

Soil chemical properties *viz.*, available P, Ca, Cu and Fe were significantly influenced by different treatments. Application of P @ 25 kg ha^{-1} resulted in significantly lower available P to the tune of 88.77 and 111.51 kg ha^{-1} respectively under NPK @ 50:25:100 and 50:25:50 kg ha^{-1}. STBF with complete omission of P had an available P status of 135.35 kg ha^{-1} over POP with 50 kg ha^{-1} having 280.97 kg ha^{-1}. However, absolute control resulted in a significantly low P status of only 73.73 kg ha^{-1}. Exchangeable Ca content of the soil was found significantly the maximum (1.59 meq $100g^{-1}$) in organic manures alone applied plots where ash was one of the components. Application of NPK @ 125:50:125 (1.41 ppm) and PoP (1.29 ppm) and organic manures alone (1.59 ppm) resulted in significantly the maximum soil available Cu. Availability of soil Fe was the least with organic manures alone (28.60 ppm) whereas application of FYM (79.40 ppm) resulted in significantly higher available Fe content in the soil.

In the case of plant nutrient content, only P content of stem was significantly influenced by treatments where combined application of B and Zn along with PoP (0.448%) and green manuring *in situ* with cowpea (0.434%) resulted in significantly greater stem P contents. The leaf, stem, tuber and total plant dry weight and the leaf, stem, tuber and total plant uptake of major (N, P, K) secondary (Ca, Mg) and micronutrients (Fe, Cu, Mn and Zn) were not influenced by the treatments.

Fig. 45. Green manure cowpea growth

Incorporation and mound preparation

The soil bulk density value was the maximum (1.58 Mg m^{-3}) in absolute control treatment among the six treatments studied. Significant differences in the values of soil bulk density (1.40 Mg m^{-3}), porosity (47.2%) and maximum water holding capacity (49.8%) was observed in the treatment consisting of combination of organic materials *viz.*, vermicompost, coir pith compost, ash and crop residue treatment as compared to the rest of the treatments. The average values of surface moisture content estimated during two different periods (June and October, 2017) was found to be the maximum under this combination of organics treatment (11.6%, v/v).

Screening nutrient use efficient cassava genotypes for low input management

The second season experiment conducted with nutrient use efficient genotypes *viz.*, Sree Pavithra, 7 III E3-5, CI-905 and CI-906 at four levels of NPK *viz.*, 25, 50, 75, 100% to reduce/substitute NPK fertilizers indicated significant effect of genotypes in influencing the tuber yield (Fig. 46).

Fig. 46. Tuber yield of 7 III E 3-5 at different levels of NPK

Among the three genotypes, CI-905 produced significantly higher tuber yield (25.20 t ha^{-1}) on par with Sree Pavithra (23.90 t ha^{-1}) and 7 III E3-5 (22.10 t ha^{-1}). The third season tuber yield also resulted in significant effect of treatments with 7 III E 3-5 producing significantly higher yield (43.90 t ha^{-1}) on par with CI-905 (41.07 t ha^{-1}) which in turn was on par with Sree Pavithra (35.30 t ha^{-1}). The pooled mean of the tuber yield of three years showed significant effect of genotypes with 7III E3-5 (38.48 t ha^{-1}) producing significantly higher tuber yield on par with CI-905 (36.46 t ha^{-1}) and Sree Pavithra (32.89 t ha^{-1}) (Fig. 47). As in the case of first year, the second and third year tuber yield data and pooled data of the three years indicated no significant effect of levels of fertilizers on tuber yield indicating the saving upto 75% NPK by using NPK efficient cassava genotypes (Fig. 48).

During the second season, genotypes significantly influenced biometric characters like plant height at 3, 6, 9 months after planting (MAP), retained

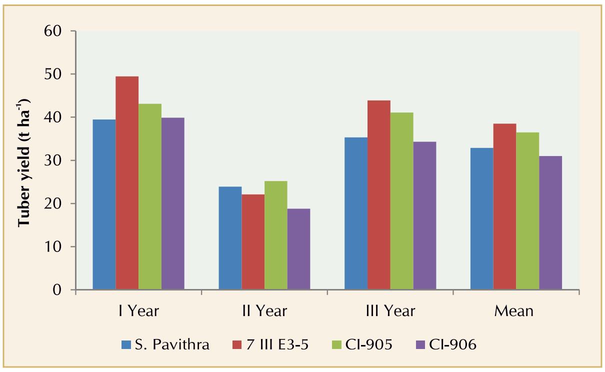


Fig.47. Tuber yield of NUE genotypes during the three years

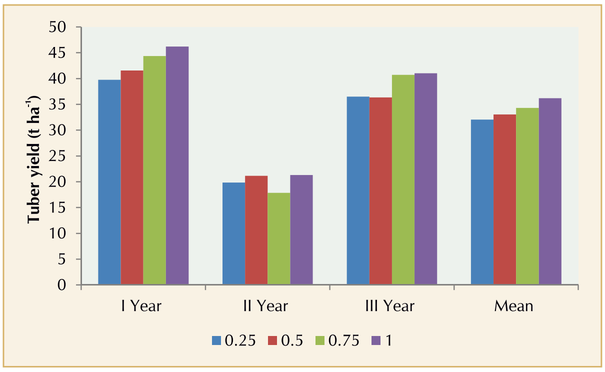


Fig. 48. Tuber yield of NUE genotypes at different levels of NPK during three seasons

and fallen leaves at 3 MAP, leaf dry weight at 3, 6 MAP, stem dry weight at 3MAP, tuber dry weight at 3, 9 MAP, leaf N at 3, 9 MAP, stem N and P at 3, 6, 9 MAP and tuber quality attributes *viz.*, cyanogenic glucosides and starch. Sree Pavithra had significantly the minimum HCN (36.43 ppm) while the other three genotypes *viz.*, 7 III E3-5, CI-905 and CI-906 were on par with HCN levels to the tune of 60.17, 63.20 and 75.93 ppm respectively. The genotype CI-906 had significantly the maximum starch content (21.90%) and Sree Pavithra (19.69%) and 7III E3-5 (20.20%) were on par while the genotype CI-905 (17.99%) had significantly the minimum starch content on fresh weight basis.

Levels of NPK significantly influenced apparent recovery efficiency (ARE), agronomic efficiency (AE), NPK uptake ratio, nutrient efficiency ratio (NER), utilization efficiency (UE) which were significantly the highest at 25% NPK (Fig. 49). NUE parameters *viz.*, agro physiologic efficiency, harvest index, NPK uptake ratio, NPK utilization for biomass, NPK utilization for tuber, NPK harvest index were not influenced by levels of NPK. Physiological parameters *viz.*, RGR, CGR, TBR were not significantly influenced either by genotypes or NPK levels. Leaf, stem and tuber NPK and NPK uptake at 3, 6, 9 MAP, tuber quality parameters *viz.*,HCN, starch plant dry weight and soil chemical properties *viz.*, pH, OC, available NPK were also not influenced by levels of NPK. These genotypes are tolerant to CMD, have good plant architecture, tubers have low cyanogen and medium starch content and have excellent cooking quality. These genotypes were distributed to 25 farmers throughout Kerala for on farm trials.

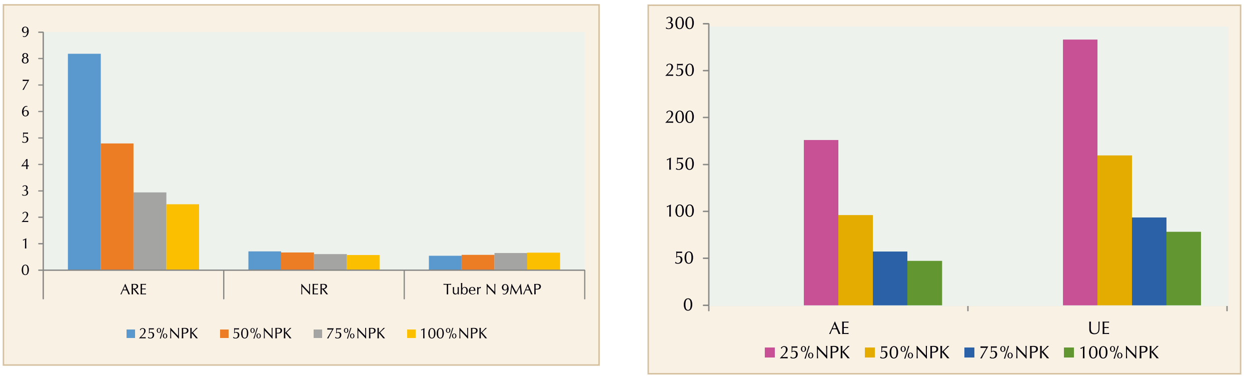


Fig. 49. Effect of levels of fertilizers on NUE parameters

Response of tropical tuber crops to secondary and micronutrients under integrated nutrient management (INM) practice

The results of three seasons trials conducted during 2017-18 in sweet potato (Variety: Sree Arun) to standardise the INM package comprising major, secondary and micronutrients revealed that in the case of major nutrients, among the different levels of N, P, K tried independently, N @ 50, P @ 50 and K @ 100 kg ha^{-1} resulted in maximum tuber yield (Fig. 50).

Fig. 50. Effect of levels of P on tuber yield of sweet Potato

Among the combination of NPK at different levels, NPK @ 100:50:150 kg ha^{-1} along with 10 t ha^{-1} FYM is the best. Among the liming materials, soil application of gypsum @ 2 t ha^{-1} followed by dolomite @ 2 t ha^{-1} and calcium nitrate @ 62.5 kg ha^{-1} is the best. In the case of independent application of secondary and micronutrients, soil application of Mg as Mg SO_4 @ 80 kg ha^{-1} followed by Zn as $ZnSO_4$ @ 20 kg ha^{-1} is the best and for foliar application B (0.1%) as solubor followed by Mg (1%) as $MgSO_4$ at maximum vegetative growth stage is the best. In the combination of nutrients for foliar, K as KNO_3 (1%) along with B (0.1%) as solubor at tuber bulking stage is the best (Fig. 51).

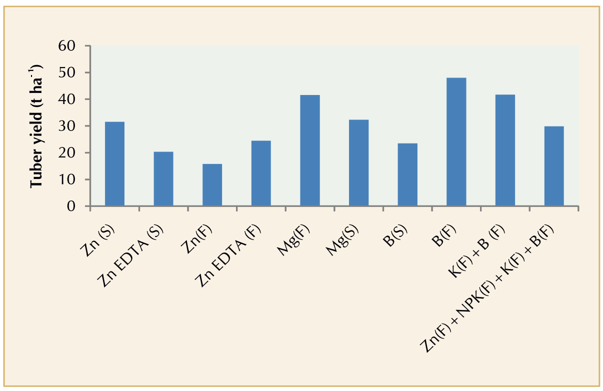


Fig. 51. Effect of soil and foliar application of secondary and micronutrients on sweet potato tuber yield

In the case of elephant foot yam, the trial conducted for the second season indicated dolomite @ 2 t ha^{-1}

as the best liming material. Soil application of Mg as $MgSO_4$ @ 80 kg ha^{-1} or foliar application of 1% $MgSO_4$ at maximum vegetative growth stage or soluble NPK (19:19:19) @ 5 kg ha^{-1} along with Zn EDTA (0.1%) as foliar at tuber bulking stage as the best (Fig. 52).

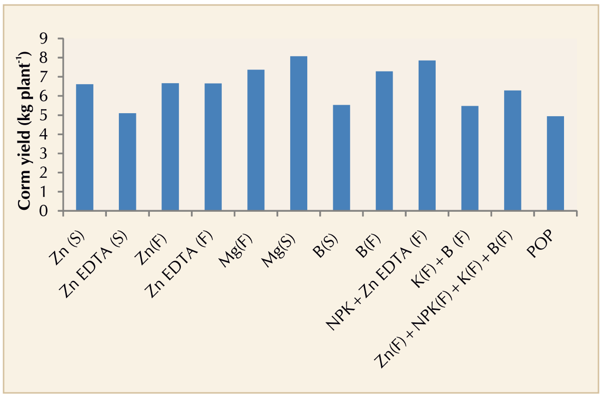


Fig.52. Effect of soil and foliar application of secondary and micronutrients on elephant foot yam yield

Fertilizer best management practices by SSNM for sustainable tuber crops production and soil health

Five on-station experiments were continued for cassava, elephant foot yam, greater yam (crop holiday), white yam and taro. The FBMP by SSNM treatment proved to be significantly superior than present recommendation (PR) (cassava : SSNM – 23.51 t ha^{-1} and PR – 25.76 t ha^{-1}; 8.73% decrease; elephant foot yam : SSNM – 46.72 t ha^{-1} and PR – 40.59 t ha^{-1}; 15% increase; white yam : SSNM – 18.86 t ha^{-1} and PR – 17.83 t ha^{-1}; 5.8% increased; taro : SSNM – 11.44 t ha^{-1} and PR – 10.01 t ha^{-1}; 14.28% increase). On-farm validation experiments of customised fertilizers developed for cassava based on SSNM technology were completed in 35 farmers' fields spread across five agro-ecological unit (AEU) zonations of Kerala (Malappuram, Palakkad, Idukki, Alappuzha and Pathanamthitta). In Pathanamthitta and Alappuzha districts, the SSNM resulted in significantly higher tuber yield (42.00 and 38.00 t ha^{-1} respectively) than farmer fertilizer practice (FFP) (36.50 and 31.00 t ha^{-1} respectively). (Fig. 53). On an average, the customized fertilizer treatment resulted in 22% greater tuber yield over FFP across the five agro-ecological units studied. Based on the results of validation experiments, the technology has been transferred to three KVKs in Kerala for further evaluation and popularization.

Sree Poshini, a mobile app for SSNM of tropical tuber crops was developed. This app will help tropical tuber crops farmers across the country to calculate the fertilizer requirements for their individual fields. Five foliar liquid micronutrient formulations for SSNM of cassava (2 products), sweet potato, elephant foot yam and yams were developed and are being commercialized through *Agrinnovate* for ₹ 2.5 lakhs (Fig. 54). Five foliar solid micronutrient formulations for SSNM of cassava (2 products), sweet potato, elephant foot yam and yams were also developed. Besides these, two decision support systems for SSNM of elephant foot yam and sweet potato are in the final stage of development (Fig. 55 and 56).

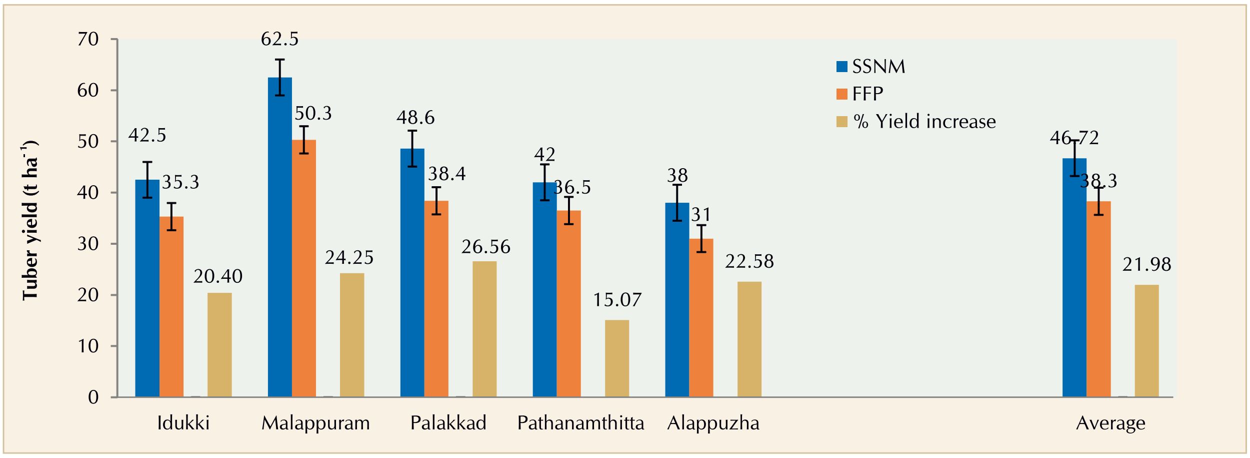


Fig. 53. Results of on-farm validation trials in cassava conducted at 35 locations across Kerala state

Fig. 54. Liquid foliar micronutrient formulation developed for cassava

Fig. 55. Yield of elephant foot yam after seven years of balanced fertilization by SSNM

Fig. 56. On-farm trial of SSNM validation in elephant foot yam in Alaparamba panchayat, Malappuram.

Effect of organic sources, secondary and micronutrients on soil quality, yield and proximate composition of elephant foot yam – black gram cropping system

A field experiment was conducted for 3rd consecutive kharif season during 2017-18 at Regional Centre, ICAR-CTCRI, Bhubaneswar to study the effect of integrated use of lime, inorganic and organic manures on soil quality, yield and bio-chemical constituents of elephant foot yam – black gram cropping system. The experimental soil is sandy loam, acidic (pH 5.16), non saline (0.24 dSm^{-1}) and having 0.25% OC, and 226, 24.64 and 189 kg N, P and K ha^{-1}. The experiment was laid out with 14 treatments, replicated thrice in a randomized block design. Elephant foot yam (var. Gajendra) corms were cut into a size of 250 g, and planted in 45 cm^3 pits at a spacing of 75x75 cm. Black gram (local cultivar) seeds were dibbled in between elephant foot yam crop as an intercrop and grown upto 70 days. The crops were harvested at maturity, recorded yield parameters and plant samples were analyzed for proximate composition and nutrient contents.

Significantly maximum corm yield (26.34 t ha^{-1}) was recorded due to integrated application of lime + FYM + NPK + $MgSO_4$ (Fig. 57) with maximum yield response of 159% over control followed by lime + FYM + NPK + Borax (25.48 t ha^{-1}). The increase in tuber yield was pronounced to be 37, 65 and 107% due to application of 50, 100 and 150% NPK over control. Among the organic sources, incorporation of neem cake has shown higher tuber yield (16.72 t ha^{-1}) at par with vermicompost (16.53 t ha^{-1}). Lime addition along with organic manure and micro nutrients showed higher yield response rather than inorganic fertilizers. Among all the treatment combinations, significantly the maximum starch (12.83%, on fresh weight basis) was recorded due to application of lime + FYM + NPK + Borax, whereas maximum sugar and dry matter contents were observed due to integrated application of lime + FYM + NPK + $MgSO_4$ (1.64 and 22.5%, respectively). Among the organic manures, application of neem cake resulted in maximum starch, sugar and dry matter contents in the corms of elephant foot yam. Total sugar ranged from 1.32 to 1.64%, and the dry matter varied from 17.05 to 22.5%. Significantly maximum grain and haulm yields of black gram (708 and 3405 kg ha^{-1}, respectively) as an inter-crop was recorded due to integrated use of lime + FYM + NPK + $MgSO_4$ followed by lime + FYM + NPK + B (686 and 3320 kg ha^{-1}, respectively) (Fig. 58).

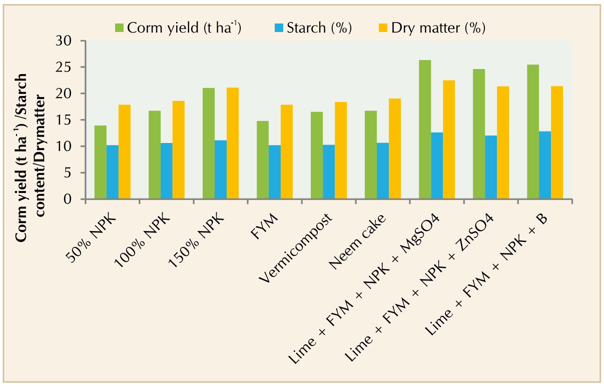


Fig. 57. Effect of integrated use of inorganic and organic sources on elephant foot yam

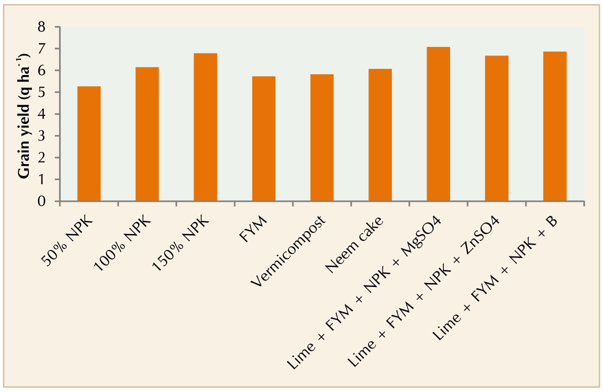


Fig. 58. Effect of integrated use of inorganic and organic sources on black gram yield

Significantly maximum uptake of N and P (67.75 and 6.05 kg ha^{-1}, respectively) by elephant foot yam corms was recorded due to integrated application of lime + FYM + NPK + $MgSO_4$ during 2016-17, whereas maximum uptake of K by the corms (99.6 kg ha^{-1}) was recorded due to integrated use of lime + FYM + NPK + $ZnSO_4$. Significantly highest uptake of Fe and Mn was recorded due to application of FYM + NPK + $ZnSO_4$ (670 and 441 g ha^{-1}, respectively). The uptake of Cu and Zn was highest (34.5 and 263 g ha^{-1}, respectively) due to application of lime + FYM + NPK + $ZnSO_4$. Highest total uptake of N by black gram (64.72 kg ha^{-1}) was recorded due to integrated application of lime + FYM + NPK + $MgSO_4$, whereas highest uptake of P and K was recorded due to application of lime + FYM + NPK + $ZnSO_4$ (12.1 and 45.8 kg ha^{-1}, respectively). Increased dehydrogenase (1.268 µg TPF $g^{-1}h^{-1}$) and Fluorescein diacetate activities (3.011 µg g^{-1} h^{-1}) were recorded due to application of 150% NPK. Dehydrogenase activity of the soil showed significant relationship with pH and organic C (0.74^{**} and 0.55^{**}, respectively). Dehydrogenase and phosphatase activities showed significant relationship with dry matter and starch content of elephant foot yam. The acid and alkaline phosphatase activities had positive and significant relationship with grain yield of black gram. In conclusion, integrated use of balanced dose of fertilizers along with organic manure, lime and $ZnSO_4$ or $MgSO_4$ not only improved the soil quality, but also produced highest corm yields of elephant foot yam with good quality tubers and the grain yield of black gram.

Assessment of micro nutrients and heavy metal contaminants in tuber crops based cropping systems adjacent to mines and industrial areas of Odisha

Soil samples (0-30 cm depth) were collected during 2017-18 representing 17 locations adjacent to industrial areas from Bhadrak (2), Balasore (6), Mayurbhanj (2), Cuttack (5) and Ganjam (2) districts of Odisha to assess the accumulation of heavy metals. The soils varied widely in pH (4.23-7.05), non saline, low to high in organic carbon (0.20-0.85%) and having 146-385, 8.96-95.8, and 88-300 kg ha^{-1} of available N, P, and K, respectively. The soils also contain 45.6-240.8, 1.86-7.83, 7.2-126.8 and 0.52-5.44 mg kg^{-1} of available Fe, Cu, Mn and Zn, respectively. It was observed that the heavy metals like Cr, Ni and Pb in the polluted soils ranged from 2.52-29.5, 0.32-5.68 and 4.21-18.42 mg kg^{-1}, respectively. Dehydrogenase activity and fluorescein diacetate activity (FDA) in the soils ranged from 0.357-1.712 µg TPF g^{-1} $h^{-1}$and 0.525-2.058 µg g^{-1} h^{-1}, respectively. The acid and alkaline phosphatase activities in the soils ranged from 11.88-36.48 and 12.59-31.79 µg PNP g^{-1} h^{-1}.

Hydro-physical properties on soil water-nutrient use, root characteristics and cassava productivity

The impact of three tillage conventional (CT), deep (DT) and minimum (MT) and mulch types in laterite soils on variations in soil bulk density (BD), water holding capacity (WHC) and porosity properties were studied based on field soil samples collected during June and November, 2017 in the third year experiment. Results revealed that the maximum BD (1.62 Mg m^{-3}) was recorded in soils under minimum tillage whereas the CT and DT were on par (1.46-1.52 Mg m^{-3}). Increased soil porosity (45.6%) and maximum WHC (42.7%) was observed under deep tilled soils. Surface soil moisture storage (volumetric) and soil temperature variations were studied at different periods of the year 2017-18 *viz.,* June, November, 2017 and soil water transmission properties *viz.,* saturated hydraulic conductivity (HC), sorptivity (SS) and matric potential (MP) were also estimated during August 2017 for soils receiving different tillage and mulch treatments. Average soil water storage values were 9.3, 8.7 and 8.2% (v/v) and the soil temperature values were 35.1, 35.6 and 36.1°C under CT, DT and MT practices, respectively. Among the mulch practices, GC has shown high moisture content (10.4%, v/v) as compared to no mulch (6.8%, v/v). The cassava tuber yield of 31.8, 33.4 and 28.6 t ha^{-1} was obtained in the third year of study (2016-17) under conventional (CT), deep (DT) and minimum tillage (MT) practices, respectively. The influence of different types of mulches on the yield was in the order of porous ground cover (GC) > crop residue (CR) > no mulch (NM). Soil hydraulic properties *viz.,* field saturated hydraulic conductivity (HC), matric potential (MP), and sorptivity (SS) estimated under different treatments has shown that HC and SS of CT was found to be 16 and 20% greater as compared to minimum tillage whereas 18% increase in matric potential was observed under GC as compared to NM. The interactions among minimum tillage and GC mulch showed improved values (0.039 cm $min^{-1/2}$) as compared to second year (0.029 cm $min^{-1/2}$) but significantly lesser than soil sorptivity of deep tillage treatment. Correlation studies showed that bulk density and available K had a significant positive relationship with tuber yield in conventional tilled soils whereas minimum tillage was not found having improved soil transmission properties in the third year of study.

STUDIES ON IMPACT OF CLIMATE CHANGE AND DEVISING MITIGATION AND ADAPTATION STRATEGIES FOR SUSTAINING PRODUCTIVITY OF TUBER CROPS

Studies on heat stress management in tropical tuber crops

The objective of the study was to induce tolerance to high temperature stress through chemical treatments in elephant foot yam. For this purpose, the elephant foot yam variety Gajendra was planted in randomized block design with four replications under field conditions and the growth and yield performance was studied under heat stress. Corms weighing 500 g of variety Gajendra was planted under open field and polychamber conditions with and without humidification. Five foliar spraying treatments were given as follows (1) Control without water spray (2) Control with water spray (3) Foliar spraying of 0.2% $CaCl_2$ during 4-8th month at fortnight intervals (4) Foliar spraying of 0.2% Salicylic acid during 4-8th month at fortnight intervals (5) Foliar spraying of 1000 ppm Benzyl adenine (BA) during 4-8th month at fortnight intervals. Prevailing weather conditions under open field and polyhouse conditions with and without humidification were recorded.

On bright sunny day plants under open field conditions experienced 30-32°C temperature with 65-70% RH and 2159-2320 µmol m^{-2} s^{-1} light intensity during day time. Inside the polychamber, elephant foot yam plants experienced high temperature stress of ~32 to ~40°C with 52-56% RH and 750-1200 µmol m^{-2} s^{-1} light intensity during day time (10 am to 4 pm). Plants under humidified polychamber conditions experienced >80% RH. On cloudy day, light intensity was 260-350 µmol m^{-2} s^{-1}, temperature 29°C and 67% RH under outside conditions and light intensity was 140 µmol m^{-2} s^{-1}, temperature 30°C and 66% RH under polyhouse conditions. Plants under open field conditions were irrigated when there was water deficit stress whereas plants under polychamber conditions were regularly irrigated. Plant height, leaf area, relative water content in plants, soil and air temperature were recorded under field as well as polychamber conditions. The crop was harvested at 8 MAP.

Under field conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 35.59%, 22.44% and 1.23% respectively as compared to control plants under ~30-32°C day temperature. Under humidified polychamber conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 33.98%, 19.41% and 30.09% respectively under 32-40°C day temperature and >80% RH (10am-4pm) as compared to control plants. Under polychamber conditions without humidification, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 28.81%, 21.9% and 27.39% respectively under 32-40°C day temperature and ~54% RH (10 am–4 pm) as compared to control plants. Compared to field conditions, the corm yield was significantly reduced by 31.27% to 64.0% under polychamber conditions in control as well as under $CaCl_2$, Salicylic acid and BA treatments. Plant height, leaf area, RWC, in plants and soil and air temperature were recorded under field as well as polychamber conditions. The results indicated that elephant foot yam can tolerate high temperature stress upto 40°C with adequate irrigation and foliar spraying of salicylic acid can improve heat tolerance and improve corm yield.

Response of sweet potato to nutrients in natural saline soils under Island ecosystem

Increasing soil salinity is one of the disturbing impacts of climate change. In order to understand the response of sweet potato to phosphorus and potassium under saline soil conditions in island ecosystem of Andaman, a field experiment was conducted for second consecutive 2016-17 *rabi* season in the natural saline soil in the field of Shri. Madan Mohan Joydhar of Chouldari village, Chouldari Gram Panchayat, South Andaman district, Andaman and Nicobar Islands in collaboration with ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman. The trial was laid out with four levels of P *i.e.* 0, 20, 40, 60 kg P_2O_5 ha^{-1} and four levels of K *i.e.* 0, 25, 50, 75 kg K_2O ha^{-1}. Sweet potato variety Samrat vine cuttings were planted during December, 2016 and harvested in April, 2017 and recorded yield parameters.

Significantly, maximum tuber yield of sweet potato (13.2 t ha^{-1}) was recorded due to combined application of 40 and 75 kg ha^{-1} of P_2O_5 and K_2O, respectively. Positive response on tuber yield was observed due to application of 60 and 75 kg ha^{-1} of P_2O_5 and K_2O (12.3 t ha^{-1}). Application of 40 and 75 kg ha^{-1} of P_2O_5 and K_2O, respectively has resulted in the maximum vine yield (13.2 t ha^{-1}). Highest starch (15.96%), sugar (3.38%) and dry matter (26.11%) in sweet potato was observed due to application of 40 and 75 kg ha^{-1} of P_2O_5 and K_2O, respectively.

Maximum total uptake of N and K (147.8 and 168.6 kg ha^{-1}, respectively) in sweet potato was recorded due to application of 40 and 75 kg P_2O_5 and K_2O, whereas maximum P uptake (21.95 kg ha^{-1}) was recorded due to application of 60 and 75 kg P_2O_5 and K_2O, respectively. Thus, the results of the study emphasized that application of 50-40-75 kg N, P_2O_5 and K_2O, respectively, was optimum to realize higher tuber yields with good amount of bio-chemical constituents in the natural saline soils under island ecosystem of Andaman.

Nutrient omission trial was laid out for the second consecutive *rabi* season during 2016-17 in the field of Sh. K.C. Majumdar of Lalpahar village, Chouldari G.P., South Andaman district to study the response of NPK on sweet potato in saline soils. The experiment was laid out with nine treatments (Control, NPK, NP, NK, PK, N, P, K and FYM) replicated thrice in a RBD. A fertilizer dose of 50-25-50 kg N, P_2O_5 ha^{-1} was applied. Sweet potato variety Samrat vine cuttings were planted during December, 2016, harvested the crop during April, 2017 and recorded yield parameters.

Maximum tuber and vine yields of sweet potato (12.83 and 14.26 t ha^{-1}, respectively) were recorded with application of 50-25-50 kg N, P_2O_5 and K_2O ha^{-1}. The yield response of sweet potato was in the order of K (38.2%) >N (34.6%) >P (26.2%). Combined application of NK resulted in higher yield response (71.4%) rather than combinations of NP (62.1%) and PK (59.6%). Significantly maximum dry matter (25.85%) was observed due to application of FYM at par with NPK (25.81%). Maximum starch content (16.09%) was recorded due to balanced application of NPK followed by FYM (15.87%). Total uptake of N, P and K was found maximum due to application of 50-25-50 kg N, P_2O_5 and K_2O ha^{-1}(142, 32, and 167 kg ha^{-1}, respectively). The results indicated that application of balanced doses of NPK produced sustainable crop yields of sweet potato with good quality tubers in saline soils of Andaman.

Response of tuber crops to elevated CO_2

The relentless increase in atmospheric CO_2 is one of the major components of climate change. The elevated CO_2 is beneficial to tropical root and tuber crops which are C_3 plants. The study aimed to understand the impact of elevated CO_2

on photosynthetic response of tropical root and tuber crops such as cassava, elephant foot yam and taro. The net photosynthetic rate (*Pn*), stomatal conductance (g_s) and intercellular CO_2 (*Ci*) was studied in three EFY genotypes (Gajendra, Sree Padma and Idukki land race), 9 taro genotypes (5 *eddoe* type taros *viz*., Topi, Jankri, Telia, Muktakeshi, Sree Pallavi, four *dasheen* type taro genotypes *viz*., NM/2017-1 (source Nayagarh, Odisha), NM/2017-2, (source Chakkapada, Odisha), NM/2017-3 (source: Jalandhar market) and VHAK/2017 – 4 (source: Joida, Karnataka) under ambient (400 ppm) and eCO_2 (eCO_2) (600, 800 and 1000 ppm), and the *Pn* at photosynthetic photon flux densities (PPFDs) *viz*., 200, 400, 600, 800, 1000, 1200 and 1500 µmol m^{-2} h^{-1} at 30°C and 400 ppm CO_2 using portable photosynthesis system LI-6400, LICOR, USA.

Photosynthetic response of elephant foot yam to eCO_2

The maximum *Pn* of three elephant foot yam genotypes was recorded at PPFD of 1500 µmol m^{-2} s^{-1} The *Pn* steadily increased due to short-term (ten minutes) exposure at eCO_2 concentrations between 400 ppm and 1000 ppm in three elephant foot yam genotypes. The three elephant foot yam genotypes had the average *Pn* of 17.97, 25.07, 29.44 and 30.06 µmol CO_2 m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. The three elephant foot yam genotypes had 56.71-82.51% hike in *Pn* at eCO_2 (1000 ppm) as compared to ambient CO_2 (400 ppm). However, the per cent of increment in *Pn* at eCO_2 for every 200 ppm between 400-1000 ppm significantly declined (-4.81-9.03%) at 1000 ppm CO_2. The difference in *Pn* was statistically significant across three elephant foot yam genotypes and CO_2 concentrations. However, the interaction effect of genotypes and CO_2 concentrations on *Pn* was insignificant whereas the *Pn* had a quadratic relation with the increase in CO_2 concentration. The g_s of three elephant foot yam genotypes increased at 600/800 ppm eCO_2 concentrations but declined at 1000 ppm CO_2 as compared to 400 ppm. The elephant foot yam genotypes had the average g_s of 0.394 0.480, 0.491, 0.280 mol H_2O m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. However, the per cent of increment in *Ci* at eCO_2 for every 200 ppm between 400-1000 ppm significantly declined (-36.40 to -40.04%) at 1000 ppm CO_2. The differences in g_s were statistically significant across elephant foot yam genotypes and CO_2 concentrations. However, the interaction effect of genotypes and CO_2 concentration on g_s is insignificant. The three elephant foot yam genotypes had the average *Ci* of 319.33, 487.07, 655.73 and 815.24 µmol CO_2 mol^{-1} air at 400, 600, 800 and 1000 ppm CO_2 respectively. However, the per cent of increment in *Ci* at eCO_2 for every 200 ppm between 400-1000 ppm significantly declined (22.46-27.38%) at 1000 ppm CO_2. The differences in *Ci* were statistically significant across genotypes and CO_2 concentrations. However, the interaction effect of genotypes and CO_2 concentrations on *Ci* was insignificant. Statistically the net photosynthetic rate had a quadratic relation with the *Ci*. The differences in the total chlorophyll and protein content in the leaves of three elephant foot yam genotypes were statistically significant. Nevertheless, the gas exchange parameters were not influenced by the total chlorophyll and protein content.

Photosynthetic response of taro to eCO_2

The maximum *Pn* of nine taro genotypes was recorded at PPFD of 1500 µmol m^{-2} s^{-1}. The *Pn* steadily increased due to short-term (ten minutes) exposure at eCO_2 concentrations between 400 ppm and 1000 ppm in nine taro genotypes. The average *Pn* of nine taro genotypes was 24.4, 33.79, 40.60 and 45.12 µmol CO_2 m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. The nine taro genotypes had 61.80 – 113.3% hike in *Pn* at eCO_2 (1000 ppm) as compared to ambient CO_2 (400 ppm). However, the per cent of increment in *Pn* at eCO_2 for every 200 ppm between 400-1000 ppm significantly declined (4.4-18.4%) at 1000 ppm CO_2. The difference in *Pn* were statistically significant across nine taro genotypes, CO_2 concentrations and the interaction effect of genotypes and CO_2 concentrations on *Pn* was significant. The changes in g_s in response to eCO_2 varied among nine taro genotypes. The differences in g_s were statistically significant across taro genotypes and CO_2 concentrations. The interaction effect of genotypes and CO_2 concentration on g_s was significant. The *Ci* steadily increased at eCO_2 concentrations between 400 ppm and 1000 ppm in nine taro genotypes. The nine taro genotypes had the average *Ci* of 297.27, 459.53, 621.68 and 793.89 µmol CO_2 mol^{-1} air at 400, 600, 800 and 1000 ppm CO_2 respectively. However, the percent increment in *Ci* at eCO_2 for every 200 ppm between 400-1000 ppm significantly declined (16.2-31.3%) at 1000 ppm CO_2. The differences in *Ci* were statistically significant across genotypes and CO_2 concentrations. The interaction effect of genotypes and CO_2 concentrations on *Ci* was significant. Statistically the net photosynthetic rate had a quadratic relation with the *Ci*. The differences in the total chlorophyll and protein content in the leaves of nine taro genotypes were statistically significant. Nevertheless, the gas exchange parameters were not influenced by the total chlorophyll and protein content.

Climate smart agriculture (CSA) practices for tropical tuber crops

Two on-station experiments were continued during the year to study the effect of different climate smart agriculture (CSA) practices of cassava on growth and yield and to study the mitigation potential of each of the selected practice in comparison to conventional practice (Fig. 59). Significantly higher tuber yield was recorded in CSA practice (27.50 t ha^{-1}) than conventional practice (21.40 t ha^{-1}) at ICAR-CTCRI, Thiruvananthapuram farm whereas in Regional Centre, Bhubaneswar, the yields were 24.8 t ha^{-1} and 14.2 t ha^{-1} for CSA and CP respectively. The mitigation emission potentials of different water, nutrient, carbon and energy smart practices included as components of CSA practice are being analysed using mitigation omission tool (MOT).

Studies on relationship of Carbon Isotope Discrimination (CID) and physiological parameters to assess WUE and identify drought tolerant genotypes in tropical tuber crops

The objective of the study was to quantify the relationship between $\delta^{13}C$, WUE, physiological, growth and yield parameters of cassava grown under normal and water deficit stress (WDS) conditions. Split plot design was used to conduct this experiment. For this purpose, ten cassava varieties (as sub plots) were planted under normal (control) and WDS (imposed between 3-5 MAP) conditions and considered as main plots and replicated twice. Ten cassava varieties *viz.*, Sree Jaya, Sree Vijaya, Sree Pavithra, Sree Visakham,

Fig. 59. A view of on-station CSA experiment

Sree Athulya, Sree Swarna, Sree Reksha, PDP CMR–1, H-165 and H-226 were grown during November 2017. Mid season water deficit stress was imposed for three months from 3 – 5 MAP. All the observations except physiological parameters were recorded on monthly intervals upto 5 MAP. Statistical analysis of the data revealed that all the treatments were significant. Vast difference was observed between growth of plants under normal and WDS conditions. In control conditions at 3, 4 and 5 MAP, Sree Athulya outperformed other varieties in terms of plant height (116.9, 155.5 and 190.8 cm), leaf retention (115.1, 131.9 and 179.4 plant) and number of leaflets per leaf (863.1, 944.1 and 1277.2) and leaf area index (7.0, 8.6 and 11.7). Physiological parameters also showed significant differences among varieties and water regimes. In control and WDS conditions, cassava genotypes had the average net photosynthetic rate (*Pn*) of 28.2 and 18.4 µmol CO_2 m^{-2} s^{-1} (34% reduction in stressed plants over control), respectively, while, in control and WDS conditions, cassava genotypes had the average stomatal conductance (g_s) of 0.3 and 0.18 mol H_2O m^{-2} s^{-1} (39% reduction in stressed plants over control), respectively. In control plants transpiration varied from 8.23–14.33 mmol H_2O m^{-2} s^{-1}, and on the other hand transpiration ranged from 6.04–9.43 mmol H_2O m^{-2} s^{-1} in stressed plants. In control plants sub-stomatal/intercellular CO_2 concentration (C_i) varied from 187.1 – 287.2 µmol mol^{-1} and on the other hand it varied from 179.6 – 224.9 µmol mol^{-1} in stressed plants. Considering the overall performance of the varieties, Sree Athulya was observed to be the top performing variety under WDS free conditions while, under WDS conditions Sree Reksha outperformed other varieties in terms of growth and physiological parameters.

CROP PROTECTION

ECO-FRIENDLY STRATEGY FOR THE MANAGEMENT OF INSECT PESTS IN TUBER CROPS

Development of suitable strategy for the management of whitefly (*Bemisia tabaci*) in cassava

Cassava whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is one of the most notorious invasive insect pests reported, infesting more than 900 species of plants and spreading more than 200 plant viral diseases including cassava mosaic disease. Fourteen insecticides were used at different concentrations, *viz.,* Chlorpyriphos 50 EC (0.8, 1, 1.2 ml l^{-1}), Quinalphos 20 EC (2, 2.5, 3 ml l^{-1}), Dimethoate 30 EC (1.5, 2, 2.5 ml l^{-1}), Fenvelarate 20 EC (0.8, 1, 1.2 ml l^{-1}), Cypermethrin 10 EC (1.5, 1.75, 2 ml l^{-1}), Lambda-Cyhalothrin 5 EC (0.8, 1, 1.2 ml l^{-1}), Bifenthrin 10 EC (1.25, 1.50, 1.75 ml l^{-1}), Imidachloprid 17.8 SL (0.2, 0.3, 0.4 ml l^{-1}), Thiamethoxam 25 WG (0.2, 0.3, 0.4 ml l^{-1}), Spiromesifen 22.9 SC (0.25, 0.50, 0.75 ml l^{-1}), Diafenthiuron 50 WP (0.6, 0.8, 1.0 ml l^{-1}) *Nanma* (3, 4, 5 ml l^{-1}), Bioneem (3, 4, 5 ml l^{-1}) and Guard (3, 4, 5 ml l^{-1}) to manage the whitefly, *Bemisia tabaci*, in cassava.

Thiamethoxam 25 WG showed maximum reduction in whitefly populations (92.3%) followed by Imidachloprid 17.8 SL (83.3%) and Dimethoate 30 EC (70%) (3rd day). Infield study, insect observations were taken from upper, middle and lance leaves of cassava plants. The per cent reduction in insect population (7th day after spraying) was highest in Thiamethoxam 25 WG (88%), followed by Imidachloprid 17.8 SL (81.97%), Dimethoate 30 EC (72.6%), Bifenthrin 10 EC (66.6%), Spiromesifen 22.9 SC (66.31%) and *Nanma* (53.93%) (Fig. 60). In drenching study, nine insecticides were used and four among them were found to be effective and the order of reduction in insect population on 7th day after drenching was Thiamethoxam 25 WG (89.82%) > Imidachloprid 17.8 SL (83.5%) > Dimethoate 30 EC (65.91%) > Diafenthiuron 50 WP (65.14%). Also, periodicity of application was standardized as 14 days, as its effectiveness was reduced drastically after two weeks.

Management of sweet potato weevil using chemical insecticides

Sweet potato weevil (*Cylas formicarius*) is the most serious pest of sweet potato, which reduces the tuber yield and also its marketability. Sweet potato cuttings were treated with 0.001, 0.01 and 0.05% concentrations of six insecticides *viz.,* Imidacloprid, Chlorpyrifos, Malathion, Dimethoate, Dichlorvos and Quinalphos for one hour before planting. Leaves collected at 1, 3, 5, 7, 9 and 12 days after treatment (DAT) and fed to the weevil revealed that Imidacloprid, Chlorpyrifos, Dichlorvos and Quinalphos were highly toxic to sweet potato weevil. The mortality of weevil was 93% in the case of Imidacloprid at 0.01% and 0.05% whereas, in the case of Chlorpyrifos, the mortality was 70% and 81% at 0.01% 0.05% concentrations, respectively. Malathion at 0.05% resulted in least mortality (16%). The mortality due to feeding of treated leaf collected on 3 DAT was 33.0% as in the case of Imidacloprid at 0.001%, but in other treatments it was found negligible. Leaf collected 5 DAT showed over 75% mortality in Imidacloprid at 0.01 and 0.05%. Subsequently the rate of mortality decreased considerably and it was recorded only in the treatment of Imidacloprid.

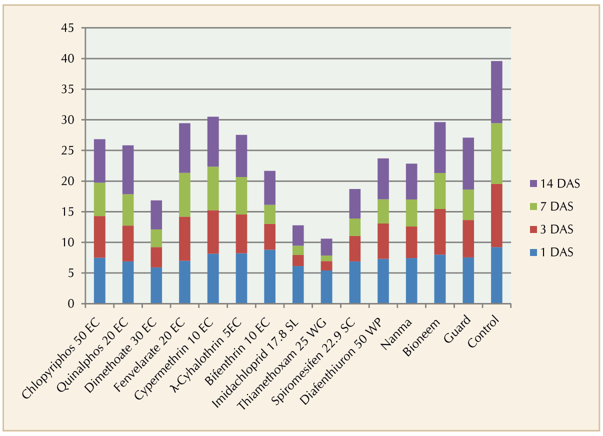


Fig. 60. Effectiveness of different insecticides against *Bemisia tabaci* in cassava field

Impact of synthetic insecticides on the visit of spiralling whitefly (*Aleurodicus disperses*) in cassava

Spiralling whitefly (*Aleurodicus disperses*) is as an important pest of cassava from last few years, as they found to reduce vigour of the plant by sucking sap from leaves and acting as a predisposing factor for sooty mould fungus development. Six insecticides *viz.*, Chlorpyrifos, Dimethoate, Imidacloprid, Dichlorvos, Fenvalerate, and Quinalphos at three different concentrations (0.001, 0.01, and 0.05%) were sprayed in the cassava field infested by spiralling whitefly. The observation on the revisit of spiralling whitefly was recorded at 6 and 12 hours after treatment (HAT) and 1, 3, 5 and 7 DAT from the top, middle and bottom leaves. The result revealed that the visit of whitefly at 6 HAT with Dimethoate, Imidacloprid, Dichlorvos, Fenvalerate at 0.001% was negligible, but at 12 HAT, except Dimethoate and Imidacloprid, at 0.01% the visit of whitefly was very minimal in all other treatments. As the days after treatment advanced, the visit of whitely increased accordingly. In the case of higher concentration (0.05%), on 3 and 5 DAT, the occurrence of whitefly was the minimal in the case of Dimethoate sprayed plot. However, at 7 DAT, except the Dimethoate spray, the visit of whitefly was found in all treated plants.

Characterization of defence related genes in sweet potato with respect to sweet potato weevil infestation

Identification of host plant resistance genes against sweet potato weevil is one of the alternative pest control method and these genes have an important role in the management of pest. In this context the experiment was designed to identify those genes related to sweet potato weevil infestation. The sweet potato transcriptome sequences (JP104589-JP160056) were retrieved from NCBI's Transcriptome Shotgun Assembly (TSA) database. The annotated transcriptome gene sequences coding for plant proteinase inhibitors (PIs) such as kunitz-type protease inhibitor, cysteine protease inhibitor and trypsin inhibitor which are toxic to insect pests were selected for designing gene specific primers. Gene specific primers were designed for proteinase inhibitor (131 and 122 bp) and cysteine protease inhibitor (451 bp). A total of 41 sweet potato genotypes including released varieties and germplasm accessions were used for the validation of the primers. The sequences of the cloned PCR amplified fragments had 99% similarity with sweet potato proteinase inhibitor SPLTI-1 gene (AF330701.1), SPLTI-a mRNA(AF330700.1), SPLTI-b mRNA (AF404833.1), SPLTI-2 gene (AF330702.1) and cysteine protease mRNA (AF260827.1). Sweet potato genotypes such as Sree Bhadra, Sree Kanaka, Sree Vardhini, Sree Arun, Sree Retna, Sree Nandini, Kanhangad, Bhu Sona, Bhu Krishna, H-42, Gouri, Shankar, Varsha, S-1401 and S-1652 have been used for Reverse Transcriptase PCR (RT-PCR) (Fig. 61). RNA was isolated from sweet potato weevil infested as well as control plant leaves and cDNA were synthesised for RT-PCR. Out of 15 genotypes the proteinase inhibitor gene of 122bp was amplified from five genotypes Kanhangad, Bhu Sona, Bhu Krishna, Sree Arun and S-1401 using the forward primer CTAGCTGGCCGGAACTGG and reverse primer GATATACTCCCGTGTTTCGGG by RT-PCR. Further the relative expression of the proteinase inhibitor gene in these sweet potato genotypes was studied by real time quantitative PCR (RT-qPCR) with cytochrome c oxidase subunit Vc (COX) (159bp) as reference gene. The gene expression of the five sweet potato genotypes was calculated by $2^{-\Delta\Delta C_T}$ method and the expression of proteinase inhibitor gene was high in Kanhangad followed by Bhu Sona, S-1401, Sree Arun and Bhu Krishna.

Survey, collection and identification of plant parasitic nematodes associated with tuber crops in India

In India, potato, elephant foot yam and yams are the important tuber crops that suffer economic damage due to nematodes. The nematodes of particular importance in elephant foot yam are the endoparasitic forms like *Pratylenchus* spp. and *Meloidogyne* spp. They cause blackening of tubers and render them unfit for consumption. Furthermore, they extend the damage and cause postharvest losses in combination with pathogenic fungi like *Fusarium* sp. and *Sclerotium* sp. Five genera of plant parasitic nematodes were identified *viz., Pratylenchus coffeae*, *Meloidogyne incognita*, *Tylenchorhynchus* sp., *Xiphinema* sp. and *Tylenchus* sp. from the soil samples of elephant foot yam fields of ICAR-CTCRI during April to December 2017, out of which, *P. coffeae*, and *M. incognita* were observed in maximum Relative Frequency (RF 29.41 and 23.53) and abundance (Relative Density (RD) 43.08 and 29.23), respectively (Table 2).

Fig. 61. Proteinase inhibitor gene amplification of sweet potato genotypes

(M-1Kb plus ladder, 1-S-1401, 2-Sree Bhadra, 3-Sree Arun, 4-Shankar, 5-Sree Nandini, 6-Sree Retna, 7-Sree Kanaka, 8-H42, 9-Kanjangad, 10-Sree Vardhini, 11-Bhu Krishna, 12-Bhu Sona 13-Gouri, 14-Varsha, 15-S-1652, 16-Non template control)

The soil samples collected from elephant foot yam fields of Omaloor (Pathanamthitta district, Kerala) during March 2018 had four genera of plant parasitic nematodes *viz., Hoplolaimus* sp., *Meloidogyne incognita*, *Helicotylenchus* sp. and *Tylenchus* sp., of which, *Hoplolaimus* sp. and *M. incognita* were the predominant species with Prominence Values (PV) of 47.25 and 19.65, respectively (Table 3). Out of the five genera of plant parasitic nematodes *viz., Meloidogyne incognita*, *Pratylenchus* sp., *Helicotylenchus* sp., *Rotylenchulus reniformis* and *Tylenchorhynchus* sp., only, *M. incognita* and *Pratylenchus* sp. were the most predominant nematodes with PV of 29.36 and 20.74, respectively in soil samples collected from elephant foot yam fields of Appakoodal, Erode, Tamil Nadu during June 2017 (Table 4). The soil samples from yams and elephant foot yam fields of Kollegal, Karnataka during January 2018 had three genera of plant parasitic nematodes *viz., M. incognita*, *Pratylenchus* sp., and *Rotylenchulus reniformis* but their population densities were less than a nematode per gram of soil.

Table 2. Plant parasitic nematode community in elephant foot yam fields of ICAR-CTCRI, Thiruvananthapuram, Kerala

Nematode species	Absolute frequency[1]	Relative frequency [2]	Absolute density [3]	Relative density [4]	Prominence value [5]
Pratylenchus coffeae	71.43	29.41	400.00	43.08	33.80
Meloidogyne incognita	57.14	23.53	271.43	29.23	20.52
Tylenchorhynchus sp.	42.86	17.65	114.29	12.31	07.49
Xiphinema sp.	42.86	17.65	85.71	09.23	05.61
Tylenchus sp.	28.57	11.76	57.14	06.15	03.06

Table 3. Plant parasitic nematode community in elephant foot yam fields of Omaloor Pathanamthittta, Kerala

Nematode species	Absolute frequency[1]	Relative frequency[2]	Absolute density[3]	Relative density[4]	Prominence value [5]
Hoplolaimus sp.	57.14	33.33	625.00	47.17	47.25
Meloidogyne incognita	42.86	25.00	300.00	22.64	19.65
Helicotylenchus sp.	42.86	25.00	275.00	20.75	18.01
Tylenchus sp.	28.57	16.67	125.00	09.43	06.69

Table 4. Plant parasitic nematode community in elephant foot yam fields of Appakoodal, Erode, Tamil Nadu

Nematode species	Absolute frequency [1]	Relative frequency[2]	Absolute density [3]	Relative density [4]	Prominence value [5]
Meloidogyne incognita	75.00	30.00	337.50	37.50	29.36
Pratylenchus sp.	62.50	25.00	262.50	29.17	20.74
Helicotylenchus sp.	50.00	20.00	137.50	15.28	09.76
Rotylenchulus reniformis	37.50	15.00	112.50	12.50	06.86
Tylenchorhynchus sp.	25.00	10.00	50.00	05.56	02.50

[1] Absolute frequency = number of samples containing a species/ number of samples collected × 100

[2] Relative frequency = frequency of a species/sum of frequency of all species × 100

[3] Absolute density = number of individuals of a species in a sample/ units of sample × 100

[4] Relative density = number of individuals of a species in a sample/ total of all individuals in a sample × 100

[5] Prominence values = absolute density × square root of absolute frequency/ 100

Management of nematodes in tuber crops

Following crop rotation, growing resistant cultivars and spraying nematicides are not always viable options for the management of nematodes. There is an immediate need to address all soil borne/inhabiting fauna with a single management strategy. In this regard, soil solarisation is a simple, safe and effective alternative to the existing expensive methods of control. A field experiment was conducted for sterilisation of root knot nematode infested soil by soil solarisation. A thin polythene sheet (100 µm) was spread over the moistened soil for two months. The average initial nematode population was recorded 1.0 nematode gram of soil. After two months, the final root knot nematode population declined to 0.7 nematode in the treated plot *vis-a-vis* control. The efficacy of four biocontrol agents, *Bacillus amyloliquefaciens* (CTCRI, isolate 14.5), *Trichoderma viride* (NIPHM), *Paecilomyces lilacinus* (NIPHM) and *Pseudomonas fluorescens* (NIPHM) was evaluated against root knot nematode, *Meloidogyne incognita*. Cell free culture filtrate of biocontrol agents significantly inhibited the egg hatching and caused juvenile (J2) mortality of *M. incognita*. Maximum suppression in egg hatching was recorded in *B. amyloliquefaciens* (99.9%) followed by *P. fluorescens* (97.9%). *Bacillus amyloliquefaciens* (CTCRI isolate, 14.5), which had strong nematicidal activity against root knot nematode was used to isolate and identify the nematicidal compounds. Secondary metabolites from culture filtrate of this strain were extracted by methanol solvent and 16 fractions were obtained by silica gel column chromatography. Two fractions (F1 and F4) were selected based on bioassay studies and samples were analysed by GC-MS for presence of nematicidal compounds. Compounds such as Stigmastan-3, 5-diene, Pregna-5, 16-dien-20-One, Pyrrolo (1, 2-a) pyrazine-1, 4-dione, Octadecanoic acid, 2, 3-dihydroxy propyl ester, Hexadecanoic acid, 2-hydroxy-1 (hydroxyl methyl) ethyl ester, Pyrrol (1, 2-a) pyrazine-1, 4-dione, hexahydro-3(2 methl propyl) and 3-Methyl-1, 4 – diazabicyclo (4, 3, 0) nonan-2, 5-dione, N acetyl were identified by GC-MS analysis. Among these, Octadecanoic acid 2, 3-dihydroxy propyl ester and Hexadecanoic acid had nematicidal properties. Other compounds possessing antimicrobial properties are yet to be confirmed for their nematicidal activity.

DEVELOPMENT AND REFINEMENT OF INTEGRATED DISEASE MANAGEMENT AND FORECASTING SYSTEM FOR IMPROVED TUBER CROP PRODUCTION

The taro leaf blight caused by *Phytophthora colocasiae*, collar rot in elephant foot yam caused by *Sclerotium rolfsii* and anthracnose in greater yam caused by *Colletotrichum gloeosporioides* are the most damaging diseases of tropical tuber crops which cause substantial yield reduction. Nowadays, the less acceptability of chemical fungicides due to health hazards leads to the reduction of fungicides usage and use of bio-agents for managing plant diseases. So, exploitation of bio agents has been done for integrated management of diseases of tuber crops.

Management of fungal diseases of aroids

Isolation, characterization and *in vitro* screening of bio-agents against *Phytophthora colocasiae* and *Sclerotium rolfsii*

With an objective of utilizing novel bio-agents against *P. colocasiae* and *S. rolfsii*, totally 60 bacterial and fungal organisms were isolated from soil samples collected from different parts of the country. Ten bacterial isolates were selected for further study based on mycelial growth suppression by direct confrontation, metabolite and volatile production under *in vitro* conditions. Indole acetic acid (IAA) production by the 10 potential isolates varied from 5.06 µg ml^{-1} to 8.07 µg ml^{-1} (Fig. 62). Three most efficient isolates, *viz*., *Pseudomonas aeruginosa*, *P. alkylphenolica* and *Myroides odoratimimus* were identified based on 16s r DNA amplification (Fig. 63). In addition, 30 bacterial isolates were isolated from cow dung and cow urine and seven isolates had high inhibition towards mycelial growth of *S. rolfsii* and *P. colocasiae*.

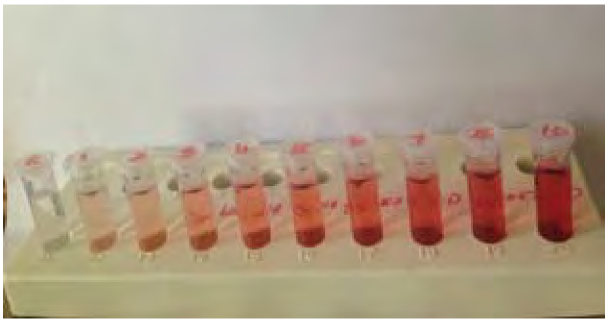


Fig. 62. IAA production shown by bacterial isolates

Fig. 63. 16s rDNA amplification of bacterial isolates

Multiplication of *Trichoderma* asperellum on tuber crops waste

Multiplication of potential bio control agent (BCA) is one of the important steps for field level application. Generally in lab condition, potato dextrose agar medium is used to multiply fungal BCAs. In the present study, to develop cost effective multiplication media, the possibilities of utilizing cassava wastes as well as products of cassava origin including cassava rind, bio-pesticide waste, cassava powder and cassava tuber extract were tried for the multiplication of *Trichoderma*. The population in various substrates was monitored at an interval of 48 h for 12 days in terms of colony forming units per gram substrate (cfu g^{-1}) using *Trichoderma* selective medium. Even though the maximum population of 1.33 $x10^{40}$ cfu g^{-1} was obtained with vermicompost, the population in substrates of cassava origin was very high compared to potato dextrose broth and dolomite (Fig. 64).

Epidemiological studies on taro leaf blight

The systematic study on the development of disease during the crop period in correlation with the weather parameters is lacking which is very much needed to develop and execute management strategies effectively. The onset of taro leaf blight and its spread were studied under Thiruvananthapuram conditions in three taro varieties released from ICAR-CTCRI, *viz*., Sree Kiran, Sree Rashmi and Muktakeshi.

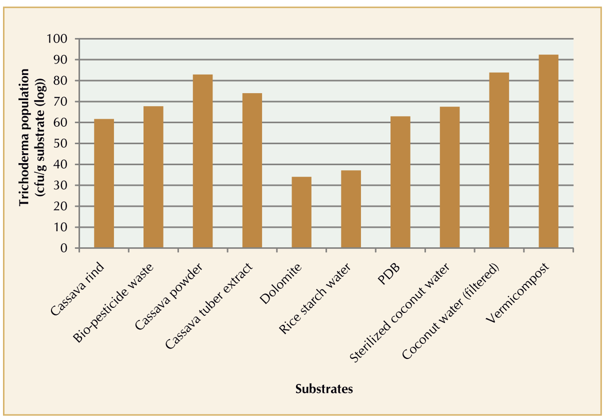


Fig. 64. Population of *Trichoderma* in various substrates 12 days after inoculation (12 DAI)

Sree Kiran and Sree Rashmi are susceptible to *Phytophthora colocasiae* whereas Muktakeshi is resistant to the disease. The first appearance of leaf blight symptom was recorded in the month of May 2017. The disease incidence increased with time and the maximum PDI of 55.25 was recorded in the variety Sree Kiran in the month of November 2017 (Fig. 65). Area under disease progress curve (AUDPC) score calculated based on the PDI estimated for different months (Fig. 66) clearly showed that Muktakeshi is resistant to taro leaf blight.

To study the host range of *P.colocasiae*, twenty weed plants which were found in and around taro fields were challenge inoculated with *P. colocasiae* under lab conditions. Barring wild Colocasia, none of the plants had the infection.

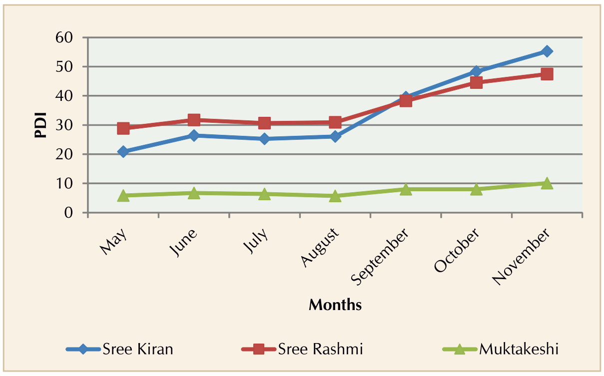


Fig. 65. Taro leaf blight incidence in taro varieties during May-November, 2017

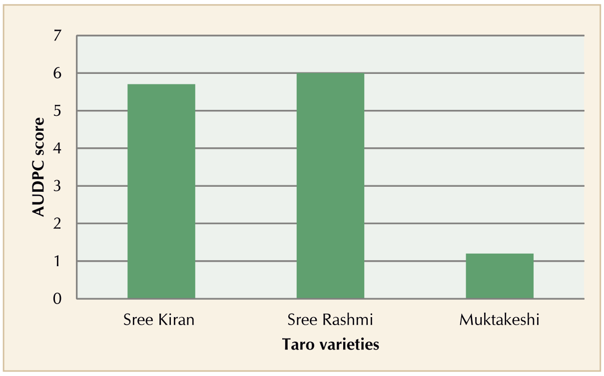


Fig. 66. AUDPC score of taro varieties

Evaluation of strategies to manage taro leaf blight

The present management strategies for taro leaf blight could not arrest the disease satisfactorily under congenial conditions. The bio intensive strategy which could induce resistance in plants were attempted to mitigate the infection. A field experiment was laid out with two treatments *viz.*, cormel treatment with *Bacillus amyloliquefaciens* + *B. amyloliquefaciens* incorporated vermicompost (T_1) and cormel treatment with *Trichoderma asperellum* + *T. asperellum* incorporated vermicompost (T_2) with a control. The cormels were dipped in cow dung slurry mixed with BCAs @ 5g Kg^{-1} cormels for 30 minutes. The treated cormels were surface dried under shade. BCAs were mixed with vermicompost and applied @ 75g $plant^{-1}$ at the time of planting. The disease incidence was recorded and PDI was calculated. The least PDI (25.0) was recorded in plants raised from cormel treated with *Bacillus amyloliquefaciens* + *B. amyloliquefaciens* incorporated vermicompost followed by cormel treatment with *Trichoderma asperellum* + *T. asperellum* incorporated vermicompost (31.67) against control (52.08). The maximum cormel yield (6.09 t ha^{-1}) was also recorded in plants raised from cormel treated with *Bacillus amyloliquefaciens* + *B. amyloliquefaciens* incorporated vermicompost against control (2.60 t ha^{-1}).

Evaluation of strategies to manage collar rot incidence in elephant foot yam

The experiment was laid out with six treatments *viz.*, corm treatment with *Trichoderma asperellum* + application of *T. asperellum* incorporated vermicompost (T_1), corm treatment with *T. asperellum* + (mancozeb+ carbendazim 0.2%) (T_2), corm treatment with *B. amyloliquefaciens* + application of *B. amyloliquefaciens* incorporated vermicompost (T_3), corm treatment with *B. amyloliquefaciens* + (mancozeb+ carbendazim 0.2%) (T_4), corm treatment with *Nanma* 0.7%+ application of *T. asperellum* incorporated vermicompost(T_5), corm treatment with *Nanma* 0.7% + application of *B. amyloliquefaciens* incorporated vermicompost (T_6) with control (T_7) (Fig. 67). The treatments were applied twice immediately after intercultural operations at three and four months after planting. The disease incidence were monitored at 15 days interval (Fig. 68). The least collar rot incidence was recorded in T_2 (8%) followed by T_1 and T_3 (12%) against control (22.7%). Maximum cormel yield (32.92 t ha^{-1}) was also obtained from plants under T_2.

Etiology and mitigation of post harvest rots in elephant foot yam

Reports indicated the presence of rots in elephant foot yam tubers which build up under storage condition lead to loss of produce and non availability of quality planting material. To study the post harvest pathogen profile causing rots in EFY and to mitigate the problem, sixty one diseased EFY corms were collected from 13 different storage yards in Kerala and 16 organisms were isolated. Koch's postulates (isolation, culturing, inoculation and reisolation) were proved with 12 organisms (Fig. 69). Apart from the already reported organisms, *Colletotrichum* spp., *Rhizoctonia* spp., *Aspergillus* spp., *Penicillium* and *Pythium* spp. were found associated with post harvest rot in *A. paeoniifolius* (Fig. 70).

Fig. 67. Elephant foot yam under various collar rot management practices.

Fig. 68. Collar rot affected elephant foot yam plants in field

Fig. 69. Elephant foot yam corm with post harvest infection

Fig. 70. Elephant foot yam corm affected by *Colletotrichum*

To develop management practice for post harvest rot of EFY, an experiment was laid out with five treatments. The corms were treated (dipped) immediately after harvest in Mancozeb + Carbendazim-Saaf 0.2% (T_1), Mancozeb + Carbendazim-Sprint 0.2% (T_2), *Nanma* 0.7% (T_3), Mancozeb + Carbendazim-Saaf 0.2% + *Nanma* 0.7% (T_4), Mancozeb + Carbendazim-Sprint 0.2% + *Nanma* 0.7% (T_5) and stored. One set was kept as control (T_6). The corms were cut after two months of storage and individual pieces (500-600g) were checked for post harvest infection. The least incidence (5%) was recorded in corms under the treatment T_2 against 55% in control (Fig. 71).

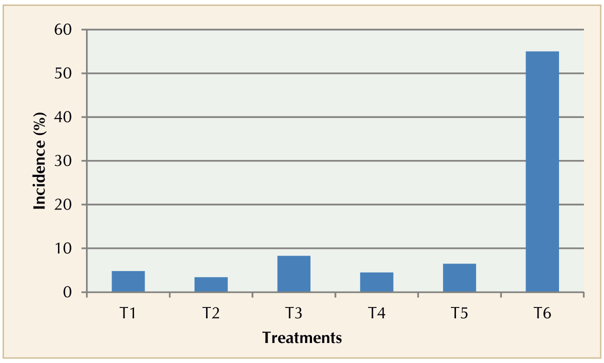


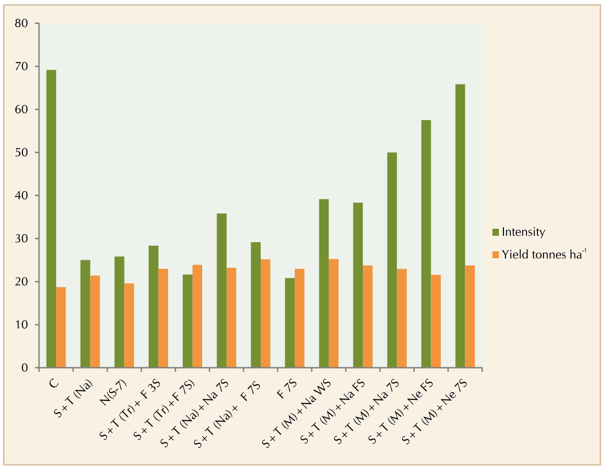
Fig. 71. Percentage of incidence in EFY corms as affected by various post harvest treatments

Greater yam anthracnose

The present practice of managing anthracnose in greater yam is through soil and tuber treatment with *Trichoderma* along with seven sprays of carbendazim (0.05%). To develop bio intensive management and to refine the present method for better management by reducing the quantity of fungicides, field and pot trials were performed with different combinations of bio rational and fungicides.

Field management

Field trial on the management of anthracnose in greater yam with 13 different treatments of bio-rationals, fungicide, carbendazim (0.05%) and combination were laid out. Different combinations of soil and tuber treatment with *Trichoderma asperellum*; ICAR-CTCRI developed biopesticide, *Nanma* and *Menma* and spraying of Carbendazim, *Nanma* (7%) and neem oil (0.2%) were tested under field conditions against anthracnose in greater yam in the variety Orissa Elite. Although disease intensity and yield are not significantly different between treatments, there was reduction in disease intensity and greater yield in all the treatments relative to control. Among all treatments, spraying carbendazim seven times showed maximum reduction in disease intensity (70%) which was closely followed by the soil and tuber treatment with *Trichoderma* and spraying carbendazim seven times, first three at fortnight by interval and the remaining four at monthly interval after symptom initiation (69%). Soil and tuber treatment with *Nanma* and spraying *Nanma* seven times reduced the disease intensity by 48%. Even though difference in the yield is insignificant, soil and tuber treatment with *Menma* and spraying *Nanma* weekly (S+T (Na)+F 7S) resulted in maximum increase in yield (34.71%) relative to control which is closely followed by soil and tuber treatment with *Nanma* along with spraying carbendazim seven times (S+T(Na)+F7S) (34.41%). The soil and tuber treatment with *Nanma* and spraying *Nanma* seven times increased yield by 24% (S+T(Na)+Na7S) (Fig. 72) relative to control.

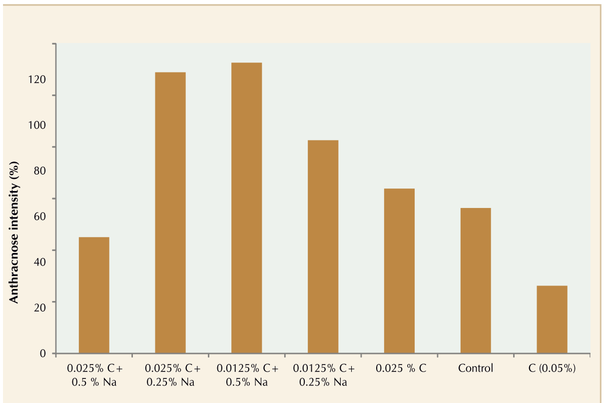


C-Control; S-Soil treatment; T-Tuber treatment; Tr-*Trichoderma*; Na- *Nanma*; Ne-Neem oil; F-Fungicide (Carbendazim); 7S-seven sprays; 3S-three sprays; FS-fortnightly spray; WS- weekly spray

Fig. 72. Effect of biorationals and Carbendazim on the intensity of anthracnose disease and tuber yield in greater yam, *var*. Orissa Elite.

Management of yam anthracnose through combination of fungicides and bio rational

The commonly used fungicides *viz*., mancozeb and carbendazim and ICAR-CTCRI developed fungicide, *Nanma* were evaluated for their efficacy to inhibit *Colletotrichum gloeosporioides* causing greater yam anthracnose *in vitro* through dual culture technique. It was found that Carbendazim (7.5 ppm), Mancozeb (500 ppm) and *Nanma* @ 1% had maximum effect individually. Based on the inhibition by different combinations of the above, a pot trial was laid out with seven treatments of five different combinations of Carbendazim and *Nanma* along with the fungicide control and absolute control. Since there was no significant difference in the effect with and without mancozeb *in vitro* in dual culture it was not added in the combination for pot trial. The disease intensity was significantly low (23%) in the fungicide control (0.05% Carbendazim) which was on par with spraying the combination of Carbendazim 0.025% and 0.5% *Nanma* (40%). The stability of the combination mixture was also tested weekly for 1st month and then monthly (Fig. 73). It was stable for nine months.



C – Carbendazim; Na – *Nanma*

Fig. 73. Effect of combination of Carbendazim and Nanma (cassava based biopesticide) on the intensity of anthracnose in greater yam, var. Orissa Elite.

Isolation and evaluation of endophytes against *C. gloeosporioides*

Fungal and bacterial endophytes were isolated from the leaves, stem and roots of greater yam, taro, coleus and arrowroot. Sixty one endophyte isolates including 31 fungal and 30 bacterial were obtained. Bacterial endophytes had more inhibitory activity (70%) against *Colletotrichum gloeosporioides* compared to fungal endophytes (60-65%). Among them, three bacterial endophytes were potential against the pathogen (Fig.74) which were identified as *Bacillus* spp.

Fig.74. Inhibition of *C. gloeosporioides* by endophytes isolated from *Plectranthus rotundifolius*

Epidemiology

A field experiment was laid out for the third year during 2017-2018 with an aim of developing decision support system to advise the farmers for managing anthracnose based on weather parameters. For this three released varieties of greater yam, *viz*., Orissa Elite (Highly susceptible), Sree Karthika and Sree Keerthi (Tolerant) were used and the disease intensity was observed at weekly intervals till 9th month after planting, December. The maximum disease intensity was observed with Orissa Elite (75%) followed by Sree Karthika and Sree Keerthi. Generally the disease intensity advances in August after rainfall followed by high temperature and will be static in September and shoots up in October and peak in 1st week of November. But during 2017-2018 it was maximum at the end of November and December. Augmented disease progress curve (AUDPC) of Sree Keerthi, Sree Karthika and Orissa Elite was 1960, 1305.5 and 5085.5 respectively and the AUDPC score was 1.9, 1.3 and 5.0 which revealed that Sree Keerthi and Sree Karthika were resistant whereas Orissa Elite is highly susceptible.

Characterisation, diagnosis and management of viruses of tuber crops

Presence of *Taro bacilliform CH virus* which has 100% sequence similarity with *Taro bacilliform* China virus isolates was confirmed in taro leaf samples. Analysis of *sweet potato feathery mottle virus* infected samples through cloning and sequence analysis showed out of eight clones, five are closely related to SPFMV-Argentina isolate, two are Korea isolate and one with China isolate. Only *Yam mild mosaic virus* and *Yam mottling virus* could be detected in greater yam and lesser yam samples showed different viral symptoms Fig.75. The healthy EFY tubers planted in farmer's field after indexing for DsMV were symptom free throughout the crop period and free from virus when tested through DAS-ELISA.

Thermotherapy of DsMV positive EFY corms was performed with four different treatments, *viz*., steam treatment at 45-50^{o}C for 1 hour and 1.30 hrs, hot water at 45 to 50^{o}C for one hour, showed induction of resistance treated direct sunlight for three hours 38-40^{o}C along with positive and negative control. Only hot water treatment at 45 to 50^{o}C for one hour reduced the disease incidence over control (34%). However, the sprouting of corm treated in hot water at 45 to 50^{o}C for one hour was only 57% whereas it was 100% in other treatments. Hot water treatment will be continued with different time interval to increase the sprouting percentage.

Development of diagnostic kit for fungal pathogens infecting tuber crops

Conventional PCR technique was used for the identification and detection of *Phytophthora colocasiae* and *Colletotrichum gloeosporioides* isolated from taro and greater yam respectively. Fungal mycelium was used for isolation of DNA and PCR amplification of partial fungal genomic DNA using internal transcribed spacer (ITS) primers, designed specifically for both the pathogens. The result revealed the association of the concerned pathogen with these diseases.

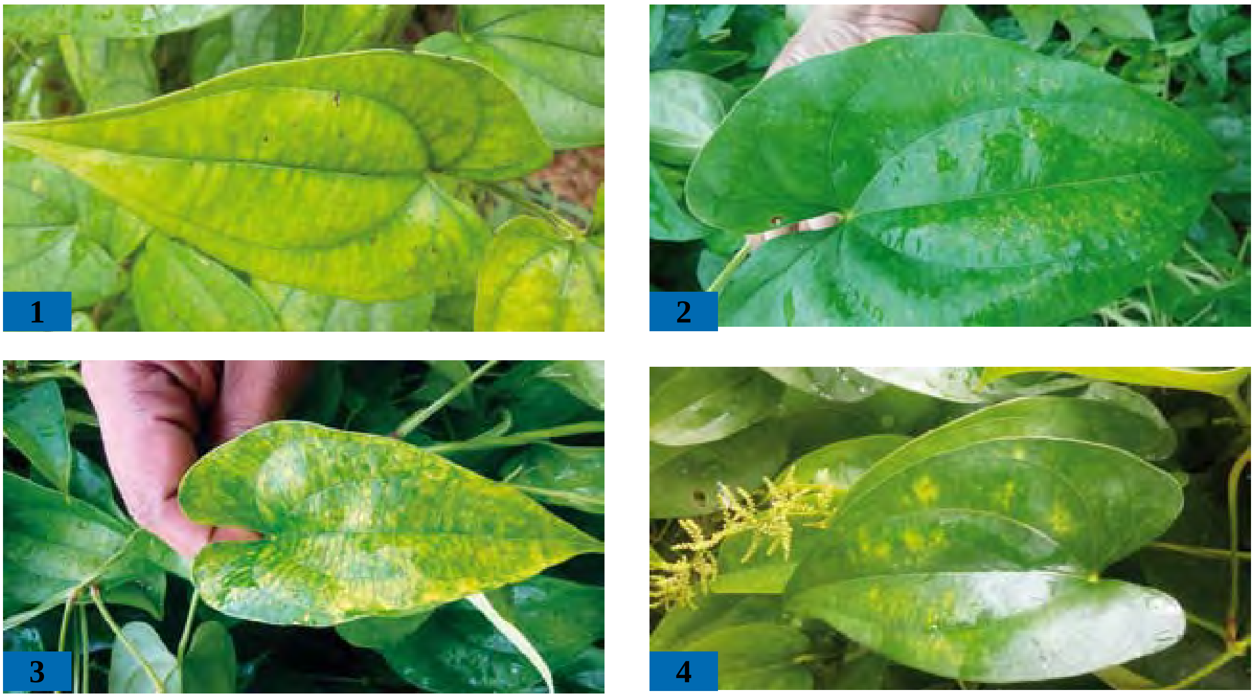


Fig.75. Greater yam leaves positive to *Yam mild mosaic virus* (1-4) and *Yam mottling virus* (2-4).

Loop mediated isothermal amplification (LAMP) was employed for rapid and effective detection of fungal pathogen. LAMP Primer designing was carried out using *P. colocasiae* (Accession KY432681), *C. gloeosporioides* (Accession KJ632430) and *Sclerotium rolfsii* (Accession KC894861). Designed three types of primers based on the following six distinct regions of the ITS target gene: the F3c, F2c and F1c regions at the 3' side and the B1, B2 and B3 regions at the 5' side after considering the length, base composition, GC contents and the formation of secondary structures. Final verification of primer regions was done by using the Primer Explore (special software to design LAMP primers). Using LAMP technique, DNA of *P. colocasiae* and *C. gloeosporioides* was amplified from the fungal mycelium under isothermal condition of 63°C for one hour in PCR which could detect the pathogen by visual evaluation of the reaction mixture. Visual detection of amplification product is done in-tube by adding different nucleic acid dyes like ethidium bromide, calcein and HNB in LAMP reaction mixture (Fig.76). The products of LAMP reaction could also be detected by electrophoresis on 2% agarose gels, and showed ladder-like patterns. Given its specificity, sensitivity, easy handing and cost-efficiency, the LAMP assay is recommended to be suitable diagnostic kit for fungal pathogens infecting tuber crops.

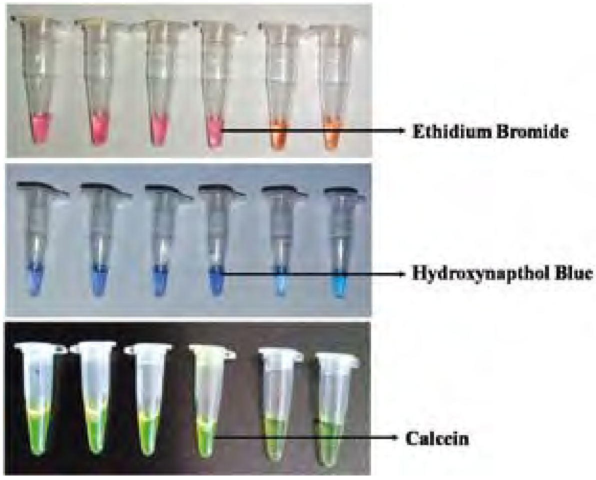


Fig. 76. Visual detection of amplification product of fungal DNA by adding different nucleic acid dyes.

CASSAVA MOSAIC DISEASE–VARIABILITY, DIAGNOSIS, VECTOR RELATION AND MANAGEMENT

Molecular mechanism of cassava mosaic virus infection

Homology modelling of coat protein sequence of *Sri Lankan cassava mosaic virus* (SLCMV) was done for understanding the three dimensional structure and suitability for docking studies which will provide information for devising management options. In homology model study, different bioinformatics tools and biological databases like

GenBank-NCBI, UniProt and PDB (Protein Data Bank) were used for coat protein of SLCMV. Coat protein sequence of SLCMV, in FASTA format was mined from GenBank-NCBI database (SLCMV coat protein (AV1) gene, complete cds GenBank: KX343908.1) and UniProt database (Q7T6F2) for homology modeling and docking study. By the BLAST search, we selected the closest homologue of coat protein sequence from NCBI (SLCMV coat protein (AV1) gene, complete cds GenBank: KX343908.1) with the maximum sequence identity of 75.37%, positives 89% and gaps were 0%. The three-dimensional structure of the SLCMV coat protein was predicted by homology modelling. The homology model of SLCMV was constructed by SWISS-PROT (Fig. 77). Predicted three-dimensional structure of SLCMV consists of the N-terminal domain (*red*) and C-terminal arm (*blue*). The result of homology modelling reveals partial similarity between NCBI database and Uniprot Database which is completely insignificant to the control (Tomato leaf curl virus coat protein). The PDB file of query and homologous target sequence were further utilized for 3D model energy validation and docking studies.

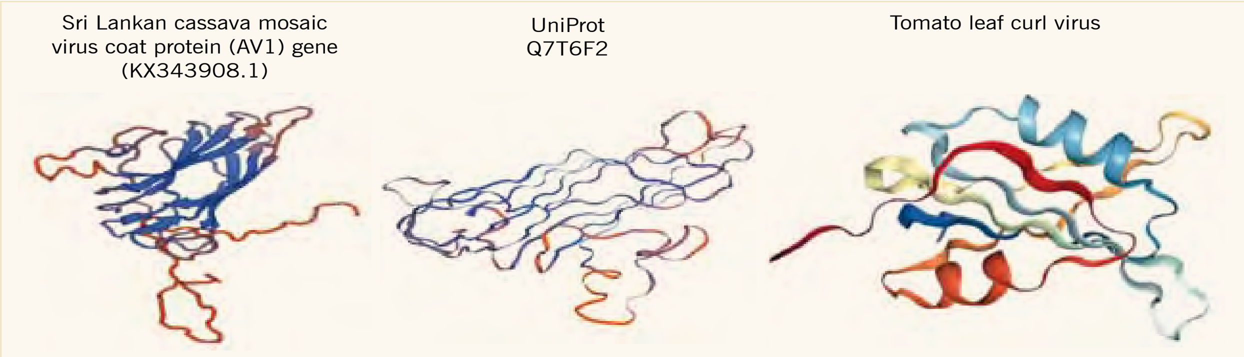


Fig. 77. Homology model of SLCMV

A preliminary *in silico* analysis was carried out for the identification of miRNAs targeting SLCMV. 153 miRNAs previously reported from *Manihot esculenta* was analysed *in silico* for their RNAi effects on SLCMV (Fig.78). Among the conserved miRNAs, ten miRNA candidates that belong to three miRNA families such as MIR399, MIR 159, and MIR172 were predicted to target the AC1 and BC1 protein coding regions of SLCMV. Among this ten predicted miRNA's, two of them (miR408a and a novel miR1) were predicted to have a role in stress response and they were cloned from small RNA isolated from the susceptible variety H226, by stem-loop RT-PCR. The sequencing confirmed the mature miRNAs (Fig.79).

Management of cassava mosaic disease through resistant varieties

Ten cassava hybrids that produced high yield (>50 t ha^{-1}) having CMD resistance, high starch content and good plant type were selected and planted in replicated evaluation trial for identifying CMD resistant varieties suitable for industrial use. All the hybrids remained symptom free throughout the growth period. The CMD resistance of all these hybrids were confirmed through field screening (Fig. 80), grafting and multiplex PCR (Fig. 81). CMD resistance of these lines was found to be linked to the marker SSRY28. The yield and dry matter content of the hybrids/ varieties are given in Fig. 82.

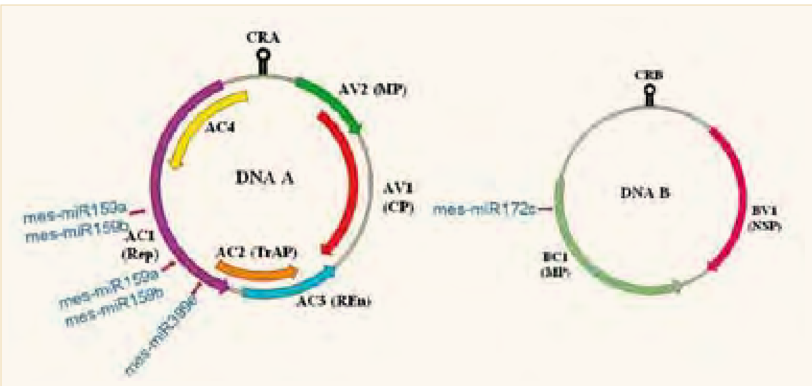


Fig. 78. *In silico* predicted cassava miRNAs targeting SLCMV

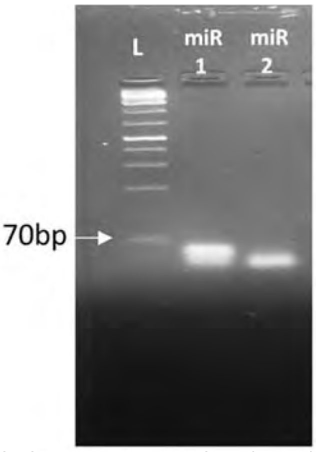


Fig. 79. Stem-loop qRT-PCR of miR1 and miR2

Fig. 80. Field screening of cassava hybrids for CMD resistance (S: susceptible, R: Resistant)

1. 100bp DNA ladder	2. 15S139	3. 15S184	4. 15S113	5. Sree Pavithra
6. 15S419	7. 15S407	8. 15S142	9. 15S436	10. 15S256
11. 15S433	12. 1540	13. Sree Reksha	14. 9S127	15. Negative control
16. Positive control				

Fig. 81. Diagnosis of SLCMV infection in CMD hybrids through Multiplex PCR

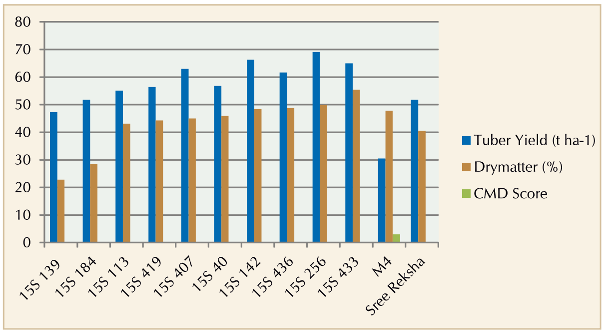


Fig. 82. Tuber yield and dry matter content of the cassava mosaic disease resistant varieties

The dry matter content of the resistant hybrids ranged from 22.8% to 55.4%. Among the hybrids, 15S433 had maximum dry matter (55.4%) followed by 15S256 (49.8%), 15S 436 (48.8%) and 15S 142 (48.4%). The maximum tuber yield was recorded in 15S256 (69.1 t ha^{-1}). Eight hybrids with high yield and cooking quality were also selected and planted in replicated evaluation trial for identifying CMD resistant hybrids suitable for culinary purpose. Among the hybrids selected with good cooking quality, 15S 409 (66.6 t ha^{-1}) produced maximum tuber yield followed by 15S59 (64.2 t ha^{-1}). Based on AYT, six CMD resistant hybrids (*viz.*, 9S 73, 9S 132, 9S 164, 9S 172, 9S 174 and 9S286) that produced high yield (>50 t ha^{-1}) were multiplied for conducting agronomic trial. Identification and characterisation of stress tolerant genes (such as MeNAC gene families) in CMD resistant hybrid will help in identifying the hybrids suitable for water stress locations. Genome-wide HMM based-analysis led to the identification of 123 MeNAC family genes in cassava. The MeNAC family members are distributed in all the 18 chromosomes of cassava genome. The maximum of nineteen genes are located on chromosome 1, followed by twelve genes on chromosome 2, ten genes on chromosome 9, nine genes each on chromosome 5 and 8, eight genes on chromosome 6, seven genes on chromosome 3, six genes on chromosome 17, five genes each on chromosome 11, 15 and 16, four genes each on chromosome 12, 13, 14 and 18, three genes on chromosome 4, two genes on chromosome 7 and one gene on chromosome 10. Promoter analysis of 123 MeNAC family genes of cassava revealed the presence of tissue-specific, biotic, abiotic, light-responsive, circadian and cell cycle-responsive cis-regulatory elements. Phylogenetic/Evolutionary analysis of cassava MeNAC family genes with *Arabidopsis* genome grouped the family members into 2 large groups and 18 sub-groups (Fig. 83).

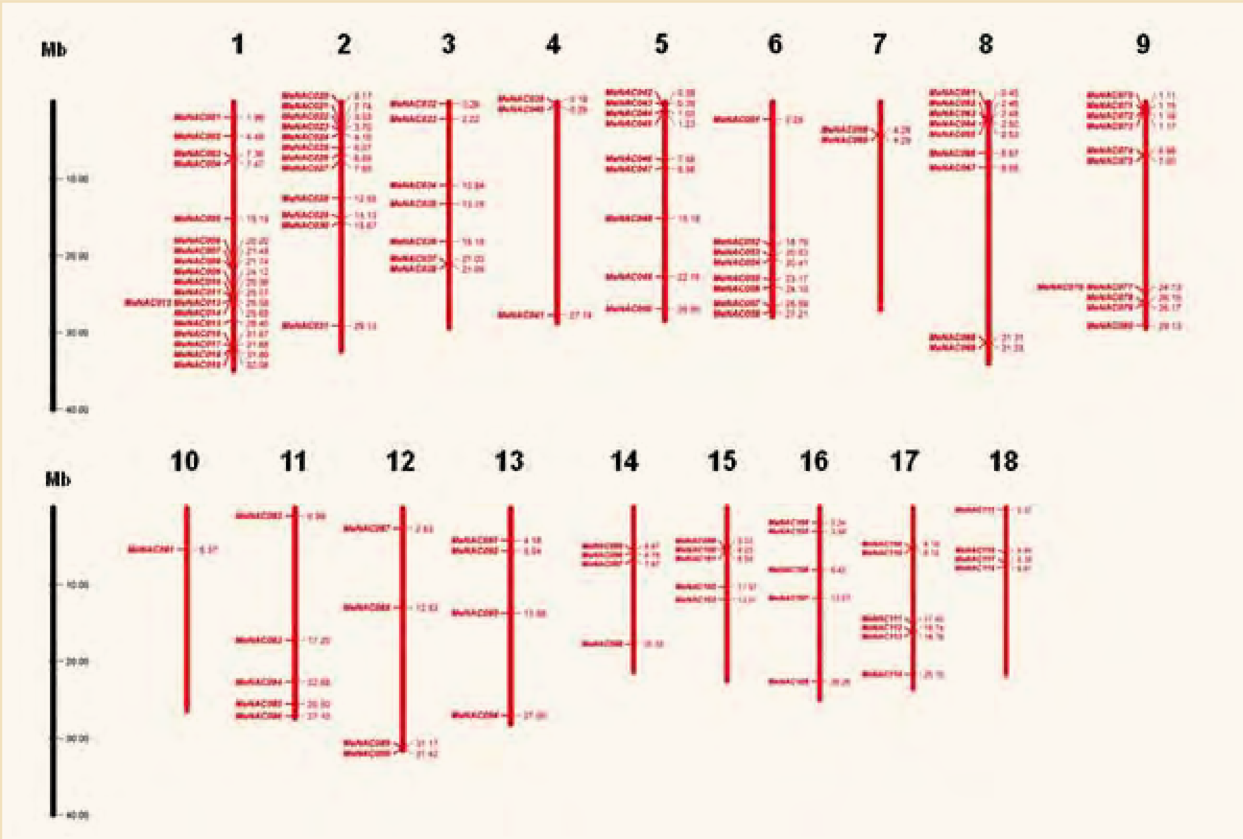
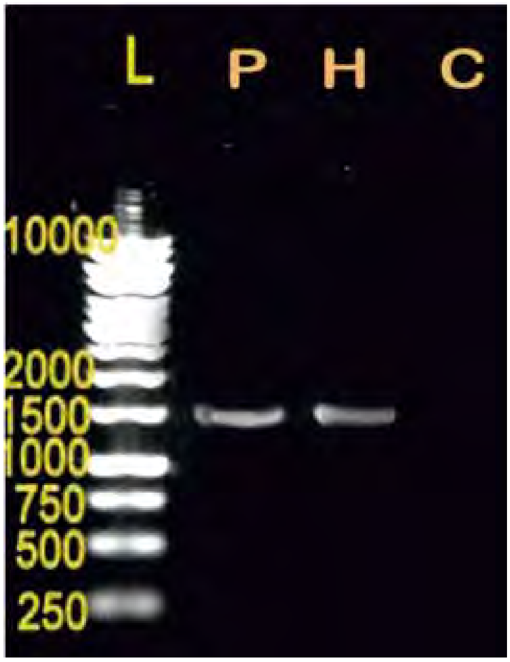


Fig. 83. Chromosomal distribution pattern of *MeNAC* family genes in cassava

Virus– vector relationship and vector management

The polyphagous agricultural pest *Bemisia tabaci* is known to harbour diverse bacterial communities in its gut which are reported to perform many diverse functions in whiteflies that contribute to the polyphagous nature and general fitness of the host. Endosymbionts present in the whitefly system could be a factor responsible for making them a successful sucking pest, virus transmitting agent and formation of different biotypes. A detailed study in these aspects could be useful in planning management strategies against the pest. For the characterization of endosymbionts in *B. tabaci*, bacterial communities associated with cassava whitefly collected from different agro ecological zones of Kerala, India were compared. Metagenomic DNA of *B. tabaci* was isolated by SDS based metagenomic DNA extraction procedure (Fig. 84) and used in the Illumina Next Generation Sequencing platform to reveal total bacterial community present. Analysis of hyper varible V3 region of 16S rRNA fragment resulted in 1, 321, 906 and 690, 661 high quality paired end sequences with mean length of 150 base pairs. Highly diverse bacterial communities were present in the sample containing approximately 3,513 operational taxonomic units (OTUs). Downstream analysis using QIIME and MG-RAST programmes showed a marked difference in the abundance of bacteria in the two populations (P and H) of whitefly (Fig. 85). Altogether, 16 bacterial phyla were detected both in P and H samples. Among the phyla for P populations of *B. tabaci*, *Proteobacteria* was the most dominant which consisted of 87.57% of total bacterial community and for H populations, *Firmicutes* was the most dominant with 82.67%. It was followed by *Firmicutes* (9.29%) for P populations and *Proteobacteria* (13.40%) for H populations. *Bacteroidetes* was found 2.91% in P populations and 0.84% in H populations. In the present study, altogether 236 and 225 bacterial genera were present for P and H populations respectively. For P populations, *Bacillus* was the most dominant group followed by *Arsenophonus*, *Vibrio*, *Riemerella*, *Lysinibacillus*, *Flavobacterium*, *Janthinobacterium*, *Sphingobacterium*, *Bacteroides*, *Enterococcus* and for H populations, the order of abundance was *Bacillus*, *Alcanivorax*, *Staphylococcus*, *Pantoea*, *Lysinibacillus*, *Bacteroides*, *Alistipes*, *Photobacterium*, *Terribacillus* and *Enterococcus*. At species level, a total of 409 species were identified in sample P and total of 355 species were identified in sample H. Secondary endosymbiont of *Bemisia tabaci* [un-specified], *Arsenophonus*, *Bacillus cereus*, *Bacillus megatherium*, *Bacillus flexus*, *Riemerella anatipestifer*, *Vibrio harveyi*, *Lysinibacillus sphaericus*, *Janthinobacterium sp.* J3 and *Bacillus pumilus* were the major 10 species identified for P populations. For H populations, the major species identified were *Bacillus thuringiensis*, *Alcanivorax sp. EPR 6*, *SBR proteobacterium*, *Staphylococcus pasteuri*, *Bacillus amyloliquefaciens*, *Staphylococcus sciuri*, *Bacillus megatherium*, *Pantoea dispersa*, *Lysinibacillus sphaericus* and *Bacillus pumilus*. Mining out of functional diversity of bacterial community present in the insect, revealed their role in making *B. tabaci* a successful vector and polyphagous pest of global importance. Analysis also showed the presence of specific endosymbionts like *Asenophonus* which was present only in high CMD infested area. Insecticidal toxin producing opportunistic bacteria like *B. thuringiensis*, *Bacillus cereus* are also reported in *B. tabaci*.



(L: Ikb ladder, *B. tabaci* metagenomic DNA extracted from Whiteflies (P-plains, H-hilly region, C-control)

Fig. 84. Agarose gel electrophoresis of metagenomic DNA isolated from *Bemisia tabaci* upon amplification with I6S rDNA primer

Integrated management of cassava mosaic disease

Produced cassava mosaic virus free planting materials of cassava varieties, Sree Vijaya (5000 stems) and Sree Jaya (4000 stems) *in vitro* and indexed for virus. The rate of reinfection was nil upto two months and it was 6% and 8% at 3 month and 12%, 18% at 4th month and 38% and 41% at 8th month of planting the virus free cassava varieties of Sree Vijaya and Sree Jaya respectively. Planting of virus infected cassava material showed the virus symptoms at first month itself and the virus incidence was 15 and 12% at 2nd month, 19 and 21% at 3rd month and 33 and 29% at 4th month and at 8th month it was 67% and 78% in the varieties of Sree Vijaya and Sree Jaya respectively.

A study was initiated with the most CMD susceptible variety H 165 by planting in pots by applying nutrients *viz.*, Si, Ca, B, Zn, P, Mg, K both in soil and by foliar to determine the effect of nutrients on management of CMD. There was a reduction in CMD intensity from 96.02% at 1month after planting (MAP) to 70.12, 44.86 and 32.39% respectively at 2, 3, 4 MAP with application of nutrients *viz.*, Ca, Zn, K and P individually (Fig. 86).

Under field condition Si, Ca, B, Zn, P, Devirus, ginger mixture and biogas slurry were applied. The maximum reduction in CMD intensity as compared to control was observed with application of boron (54%) followed by silicon (41%) calcium (24%) phosphorous (16%) at four months after planting.

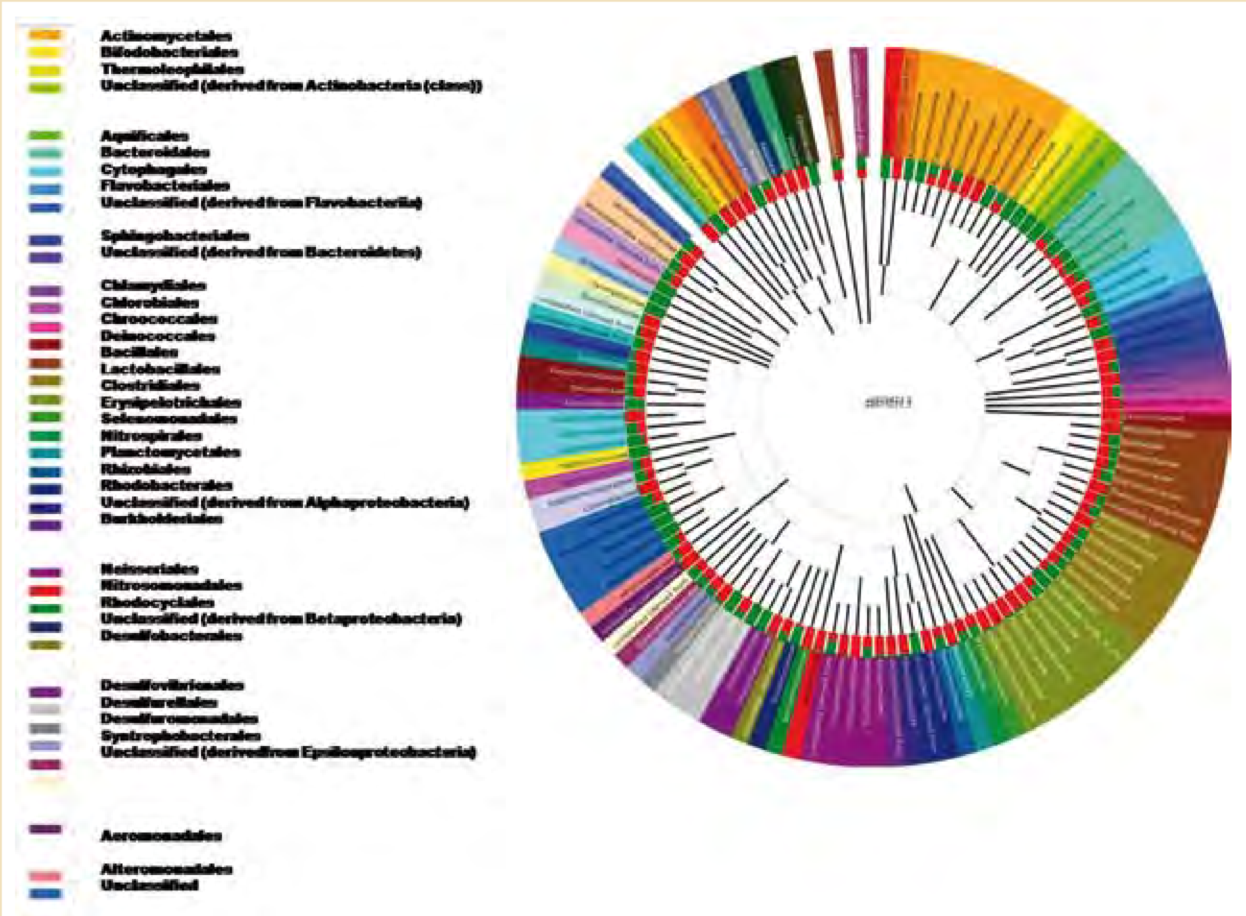


Fig. 85. Phylogenetic tree of bacteria at family level constructed in MG-RAST with illumine sequencing data set (Tree is present with orders (coloured slices) and families belong to each classes are given inside colored slices. The RDP database was used as annotation source, and a minimum identity cut off (90%) was applied.

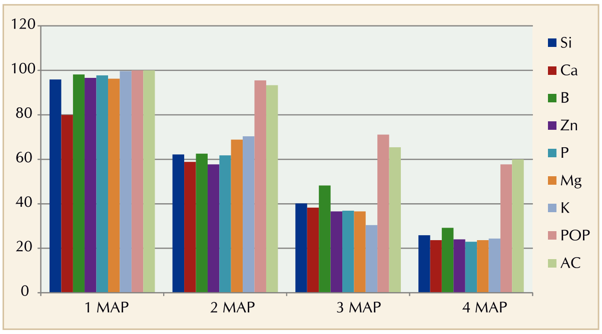


Fig. 86. Effect of nutrients on CMD intensity

Production of cassava mosaic virus free synthetic seed

Synthetic seeds have multiple advantages including mass propagation of elite plant, ease of handling, short/medium-term as well as long-term storage and low cost of production. The nodes containing axillary buds from *in vitro* grown cassava variety, H-226 were encapsulated with 3% sodium alginate polymerized in 100 mM calcium and beads of uniform size, shape, sufficiently firm and high *in vitro* germination were produced with 3% sodium alginate and 100mM calcium chloride. Cassava synthetic seeds were sealed aseptically under a laminar flow in sterile (autoclaved) polythene bags (Fig. 87) and subjected to short/medium-term storage studies at room temperature (25 ± 2^{o}C). This protocol can be used for mass propagation, easy transportation and short/medium-term conservation of elite, disease free cassava planting materials.

Fig. 87. Cassava synthetic seeds sealed in sterile (autoclaved) polythene bags for short/medium-term storage studies.

CROP UTILIZATION

DEVELOPMENT AND REFINEMENT OF POST-HARVEST HANDLING, STORAGE AND PROCESSING TECHNIQUES FOR MINIMIZATION OF LOSSES IN TROPICAL TUBER CROPS AND PRODUCTION OF VALUE ADDED PRODUCTS

Value added food products from tuber crops

Papads from cassava tuber/flour based dough

Traditionally papads are made from the gelatinized mash/slurry of cassava tubers. However, handling of the cooked batter and subsequent drying is a tedious and time consuming process. Hence, studies were carried out to develop papad from fresh cassava tuber mash/flour and sago polish powder based dough and biochemical and physical properties of the papads were analyzed. Among all the treatments, the papad with minimum moisture content of 12.59% was obtained from 65% sago powder mixed with raw tuber mash whereas maximum of 14.66% from 75% sago powder mixed with raw tuber mash. The moisture content of the papad made from the control sample (raw tuber mash) without adding any sago polish powder was 14.51%, whereas the starch content was 67.66%. The starch content of all other treatments were higher due to the addition of sago polish powder. The sugar content of the papads varied from 1.33 to 1.66% for various treatments, whereas it was 1.40% for the control. The protein content was in the range of 1.10 to 1.57% and fibre content was 0.15% to 0.80%. Among the treatments, the papad with minimum fat content of 0.30% was obtained for the dough of 12 h fermented cassava tubers mixed with 60% sago polish powder. Maximum diametrical expansion of the papad after frying was 2.5% for the papads from 6 h fermented cassava tubers with 75% sago powder. The total colour difference of the papads made from the raw tuber mash (control) was 38.35. Among the treatments, the total colour difference was 30.11-45.55. The yellowness index ranged from 27.35 to 47.56 for various treatments; whereas it was 37.33 for the papads made from the raw tuber mash (control). The overall acceptability score of the papads made from the raw tuber mash was 8. Among the treatments, the papad with overall acceptability score of 9 was for the papad made from the dough of 6 h fermented cassava tubers with all proportions of sago powder.

Papads from cassava flour based dough

Papads were made from cassava flour-sago powder by varying the later from 20 to 40% and the resulting dough after making sheets were steamed (Fig. 88). The sheets were dried and their biochemical and frying characteristics were analysed. For the papads made from the steamed dough, the maximum moisture content was 15.49% and the minimum was 11.01% whereas for the papads made from the sheets steamed for different time interval, the moisture content ranged from 12.30 to 14.77%. The crude protein content varied between 1.22 and 1.57% which was on par with that of control raw papads. The ash content ranged from 1.89 to 2.84% whereas for the raw papads made from unsteamed dough of cassava flour and dry sago powder it was 2.51 to 2.65%. The total colour difference of raw papads made from unsteamed dough of cassava flour and dry sago powder (control) ranged between 16.9 to 24.07% and from the steamed samples, the values ranged from 20.76 to 51.14%. The yellowness Index of raw papads made from unsteamed dough of cassava flour and dry sago powder (control) varied between 13.65 and 15.65 whereas for the papds from the steamed dough, it varied from 17.52 to 58.07. The diametrical expansion after frying of papads made from unsteamed dough of cassava flour and dry sago powder (control) varied between 0.43 to 2.59%, but it increased upto 71.34% for the papads made from the steamed sheet.

Fig. 88. (a) and (b) fried papads made from cassava flour based dough; (c) papads made from gelatinized cassava tuber mash dough

Particle boards and adhesives from cassava byproducts and starch

Development of particle board using cassava stem-coir pith composites

Cassava stem-coir pith based particle boards were made by varying temperature (120, 130 and 140°C), concentration of resin (20, 30 and 40%), pressure of moulding (30, 40 and 50 bar) and coir pith content (50, 75 and 100%). The quantity of stems-coir pith mixture was 200 g and press time was 15 min. Maximum thickness of the board was obtained with 75% coir pith but the minimum thickness was for the board made with 40% resin, 50 bar pressure at 130°C temperature and 75% coir pith. Density ranged from 1984 kg m^{-3} for the board made with 40% resin, 30 bar pressure at 130°C with 75% coir pith to 1330 kg m^{-3} for the board made with 40% resin, 50 bar pressure at 130°C with 75% coir pith. The hydration studies showed that maximum thickness swelling of 18.46% was obtained for the board made with 30% resin, 40 bar pressure at 130°C with 75% coir pith, whereas it was minimum for the board made with 30% resin, 30 bar pressure at 130°C with 100% coir pith. Maximum water absorption after 2 h of soaking was 34.52% for the board made with 30% resin, 40 bar pressure at 130°C with 75% coir pith and the minimum was 3.26% for the board made with 40% resin, 40 bar pressure at 120°C and 75% coir pith. Water absorption after 24 h of soaking was maximum (47.68%) for the board made with 40% resin, 40 bar pressure at 140°C and 75% coir pith and minimum (12.26%) for the board made with 40% resin, 40 bar pressure at 120°C and 75% coir pith. The total colour difference ranged from 69.38 for the board made with 100% coir pith, 30% resin, 40 bar pressure at 140°C to 59.76 for the board made with 75% coir pith, 20% resin, 40 bar pressure at 120°C. The physical and water absorption properties of the boards prepared from cassava stem and coir pith were compared with that of the specifications stipulated by Bureau of Indian Standards and observed that all the values for different properties are within the specified range. Hence, the study showed that good quality particle boards can be manufactured from underutilized agro-wastes like cassava stems and coir pith.

Development of particle board using modified cassava starch as binder

Cassava starch was modified with sodium hypochlorite (oxidized starch) and octenyl succinic anhydride (starch octenyl succinate) and they were used as binding agents for making cassava stem based particle board (Fig. 89). Experimental design (Box-Behnken design) for the development of particle board included the amount of modified starch: 5, 10 and 15%, pressure of moulding: 40, 60 and 80 bar and plasticiser: 5, 10 and 15%. The temperature of moulding was 100°C and time of pressing was 7 min. The boards were tested for dimensions, density, moisture content, thickness swelling and water absorption after 2 and 24 h and colour properties such as L, a, and b as well as total colour difference and mechanical properties. The thickness of particle boards prepared using oxidized starch as binder was in the range of 5.29-7.55 mm and density was 778-991 kg m^{-3}. The hydration studies showed that maximum water absorption after 2 h of soaking was 151.26% for the board made with 5% modified starch, 60 bar pressure and 5% glycerol, whereas minimum of 12.98% was obtained for the board made with 15% modified starch, 60 bar pressure and 5% glycerol. The water absorption after 24 h of soaking ranged from 251.33% for the board made with 5% modified starch, 40 bar pressure and 10% glycerol to 53.65% for the board made with 15% modified starch, 60 bar pressure and 5% glycerol. Thickness swelling varied between 21.04 and 167.92%. Maximum flexural strength of 6.5MPa was obtained for board made with 15% modified starch, 80 bar pressure and 10% glycerol pressed, but minimum of 1.77MPa was obtained for board made with 5% modified starch, 40 bar pressure and 10% glycerol. Maximum peak load of 181N was obtained at 15% modified starch, 80 bar pressure and 10% glycerol whereas minimum of 29N was obtained at 5% modified starch, 40 bar pressure and 10% glycerol. The maximum compressive strength of 0.324 Nmm^{-2} was obtained at 15% modified starch, 80 bar pressure and 10% glycerol and the minimum compressive strength of 0.069 N mm^{-2} was obtained at 5% modified starch, 40 bar pressure and 10% glycerol.

When cassava starch succinate was used as binder, thickness of the board ranged from 5.45 mm to 7.23 mm and density from 748 kg m^{-3} to 962 kg m^{-3}. The maximum total colour difference of 41.54 was obtained for the board made with 15% glycerol and 15% starch at 60 bar pressure. The minimum total colour difference of 34.24 was obtained for the board made with 5% starch and 10% glycerol at 40 bar pressure. Ater two hours of soaking in water, the board made with 5% glycerol and 5% starch at 60 bar pressure absorbed a maximum of 134.09% water whereas the minimum of 14.27% by the board made with 10% starch and 15% glycerol at 80 bar pressure. Water absorption after 24 h was 162.18% for the board made with 5% glycerol and 5% starch at 60 bar pressure whereas the minimum water absorption after 24 h was 46.35% for the board made with 15% starch and 15% glycerol at 60 bar pressure. Maximum thickness swelling of 64.89% was obtained for the board made with 5% starch and15% glycerol and 60 bar pressure whereas the minimum thickness swelling of 1.58% was obtained for board at 10% starch and 15% glycerol and 80 bar pressure. The flexural strength ranged between 8.71MPa and 1.59 MPa for various boards and maximum peak load value between 21.97 N and 144.68 N. The compressive strength ranged between 0.069 N mm^{-2} and 0.432 N mm^{-2}.

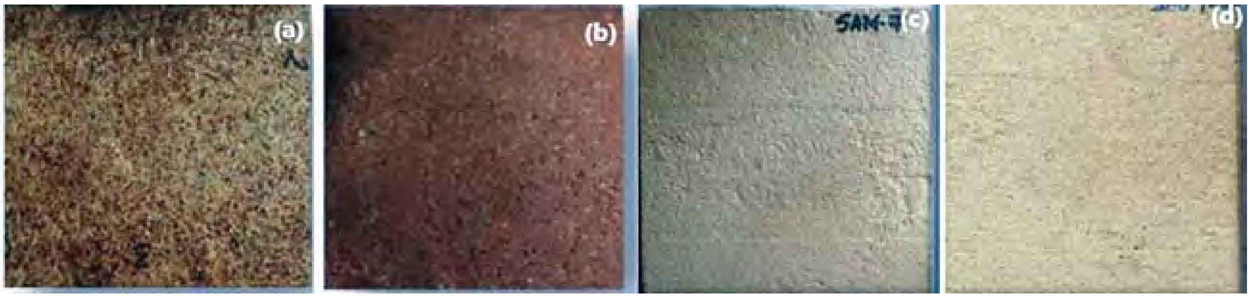


Fig. 89. Cassava stem based particle board with (a) urea formaldehyde as resin, (b) cassava stem-coir pith with urea-formaldehyde resin, (c) oxidised starch as binder, (d) starch succinate as binder

Economic analysis of corrugating adhesives based on cassava starch

The cost of production of three corrugating adhesives produced in the previous years under this project, from native as well as modified cassava starch instead of traditionally used dextrins, was worked out. The formulations included caustic free dry corrugating adhesive mix, moisture resistant corrugating adhesive and single phase corrugating adhesive. The cost of production of the various formulations was in the range of ₹39 to ₹44 per kg, which was on par with the cost of corrugating adhesives already present in the market.

Studies on post harvest physiological deterioration of cassava to enhance shelf-life of storage roots

The post harvest physiological deterioration (PPD) of fresh cassava roots is a severe constraint of cassava production, marketing and processing. Modified atmospheric storage of cassava roots with treatments such as waxing was tried to increase the shelf-life as well as to reduce the PPD intensity. Fresh cassava roots of Sree Swarna, H-226, Sree Vishakam, Sree Rekha, Sree Pavithra and Sree Apoorva were stored for 9 days in a well-ventilated room with specific and storage treatments to study the biochemical changes at 3, 6 and 9 days intervals. The treatments included wax coating and storage in polythene bags filled with carbon dioxide. In control, no treatment was given to the roots. The dry matter content was maximum (41.5%) on 3rd day of storage of Sree Apoorva variety, and this was 40.0% and 40.3%, respectively on 6th and 9th day of storage. There was an inverse relationship between dry matter content and PPD expression in fresh cassava roots. In all storage treatments, Sree Vishakam showed higher sugar content compared to other varieties. Sree Apoorva roots had the least sugar content of 4.98 mg g^{-1} on 9th day of storage. Among the different treatments, storage at elevated CO_2 resulted in higher phenol content in stored tubers. Sree Swarna had the maximum phenol content of 0.76, 0.72 and 0.70 mg g^{-1} respectively at 3rd, 6th and 9th day of storage. Wax coated cassava roots had the least peroxidase activity at 3rdday of storage compared to other periods. Catalase activity was stable during storage in other treatments including control during the sampling period. Among the treatments, storage of cassava roots at elevated CO_2 resulted in marginal decrease in catalase activity. Wax coated cassava roots had the least deterioration (Fig. 90). The wax coating of fresh cassava roots along with suitable pre-treatment for increasing the shelf life of cassava roots to 4-6 weeks was standardized. This method is suitable for retail and export of cassava roots.

Fig. 90. Storage treatments to enhance the shelf life of fresh cassava roots (A) wax coating and (B) storage at high CO_2

Development of functional sago/sago wafers using cassava based dry starch

Optimization of soaking time and concentration of reconstituted dry starch for sago production

Sago is primarily made from wet cassava starch. In order to operate small scale sago industries throughout the year, it is necessary to ensure the availability of cassava wet starch. Generally, the fresh cassava tubers are available only for six months (October to March) in a year for production of starch and sago. The starch used for sago production is to be kept under wet conditions for production of sago during off-season. Long term storage of wet cassava starch results in a number of adverse quality changes. These limitations could be overcome by the production of sago from dry cassava starch. The effect of different soaking time of dry starch in water (12, 24, 36, 48 h) and per cent of starch in slurry (10, 20, 30, 40, 50, 60% w/v) on moisture content and settling of reconstituted dry starch were analyzed to determine the conditions suitable for sago production. The cassava starch soaked in water at 30% (w/v) for 12 h with moisture content of 40% was found to be optimum for sago production (Fig. 91).

Production of sago from reconstituted dry starch

Sago was produced from the reconstituted dry cassava starch by different treatments *viz.*, T_1 – control (sago made from wet starch) (100:0); T_2 – sago made from reconstituted dry starch (100:0); T_3 – combination of dry starch + wet starch (25:75); T_4– combination of reconstituted dry starch +wet starch (50:50); T_5 – combination of reconstituted dry starch + wet starch (75:25); T_6 – combination of reconstituted dry starch + pre-gelatinized starch (99:1); T_7 – combination of dry starch + pre-gelatinized starch (97:3); T_8– combination of dry starch + pre-gelatinized starch (95:5). From the analysis of physico-chemical properties such as size, roundness, sphericity, bulk density, particle density, porosity, water activity, pH and functional properties such as swelling power, solubility, oil absorption index, rheological and pasting properties, the sago produced from the dry starch in combination with wet starch in the ratio of 75:25 (T_5) was found to be best (Fig. 91).

The effects of different operating time (10, 15, 20 min) and frequency (2.5 Hz-150 rpm, 3.5 Hz-210 rpm, 4.5 Hz-270 rpm) on sago globulation was studied using sago globulator with the help of VARIAC. The operating time of 15 min and frequency of 3.5 Hz (270 rpm) were found to be the best. The roasting temperature of 170°C and roasting time of 3 min was optimum for quality sago production.

Fig. 91. (a) Reconstituted starch and (b) sago made from reconstituted starch

Production of biochar from agricultural biomass and nutrient and biological enrichment

Biochar is obtained by pyrolysis of biomass in the absence or minimal supply of oxygen. Charcoal is used for soil amendment and can endure in soil for hundreds of years. Biochar is considered to be an effective method of carbon sequestration and potentially helps to mitigate climate change. Biochar is reported to increase soil fertility of acidic soils (low pH soils), increase agricultural productivity, and provide protection against some foliar and soil-borne diseases. Single barrel and double barrel kilns were designed for biochar production and tested using farm waste and tuber crop residues (Fig. 92). Of the two, double barrel kiln was more efficient for the biochar production. Double barrel kiln was tested with locally available crop residues such as cassava stems, yam vines, arrow root leaves and wood wastes. Co-composting, use of mineral fertilizers and crop residues are being studied for biochar enrichment.

Fig. 92. Biochar production using (A) single barrel kiln and (B) double barrel kiln

DEVELOPMENT OF CASSAVA STARCH BASED NOVEL PRODUCTS AND FUNCTIONAL FOODS FROM OTHER TUBER CROPS

Development of thermoplastic cassava starch composites based biodegradable films and foam type packaging products

Thermoplastic starch sheets from cross linked cassava starch

Thermoplastic starch sheets were prepared by cassava starch modified with epichlorohydrin using response surface Box-Behnken design to optimize the reaction conditions such as amount of glycerol (30, 40 and 50% of the starch), temperature of die plate (130, 140 and 150°C) and pressure of the die plate (120, 130 and 140 bar) with 5 min pressing time (Fig. 93). The physical and hydration properties of the sheets were analysed. The thickness of the sheets ranged from 0.27 cm to 0.09 cm and density from 912 kg cm^{-3} to 1619 kg cm^{-3}. The moisture content of the sheet varied between 14.41% and 27.48%. The yellowness index was maximum (41.91) for the sheet made at 150°C and 120 bar pressure with 40% glycerol while minimum (15.24) for the sheet at 150°C and 130 bar pressure with 50% glycerol. The total colour difference was in the range of 34.32 to 54.93. The water activity varied from 0.594 to 0.473 and solubility from 1.58% to 15.85%. The expansion index was maximum (52.63%) for the TPS containing 40% glycerol prepared at 150°C and 140 bar pressure. The absorption studies showed that at 75% relative humidity, maximum amount of moisture (13.68 g g^{-1}) was absorbed by the sheets made at 140°C and 130 bar pressure with 40% glycerol and the minimum of 5.34g g^{-1} for the sheets made at 150°C and 130 bar pressure with 50% glycerol. At 85% relative humidity, the value ranged from 24.38 g g^{-1} by the sheets made at 130°C and 130 bar pressure with 50% glycerol to 17.59 g g^{-1} for the sheets made at 150°C and 140 bar pressure with 40% glycerol. At 95% relative humidity, maximum of 31.95 g g^{-1} was absorbed by the sheets made at 140°C and 140 bar pressure with 50% glycerol and the minimum of 25 g g^{-1} for the sheets made at 130°C and 120 bar pressure with 40% glycerol.

Thermoplastic sheets from cassava starch succinate

Thermoplastic starch sheets were prepared by cassava starch modified with octenyl succinic anhydride employing Box-Behnken design by varying the amount of glycerol (30, 40 and 50% of the starch), temperature of die plate (130, 140 and 150°C) and pressure of the die plate (120, 130 and 140 bar) with 5 min pressing time (Fig. 93). The physico-mechanical and hydration properties of the sheets were analysed. The minimum moisture content of the sheet was 11.16% and was recorded with 30% glycerol at a temperature of 130°C and 130 bar pressure. Density of the sheet ranged from 1.11 g cm^{-3} to 1.40 g cm^{-3} and total colour difference from 12.70 to 55.33. Yellowness index was minimum for the sheets made at 130°C and 130 bar pressure with 30% glycerol. The hydration studies showed that the maximum diametrical expansion of the sheets after hydration was 78.94% for the sheets made at 140°C with 120 bar pressure and 30% glycerol. Solubility of the sheets in water ranged from 2.78% to 14.03%. The sorption studies showed that at different relative humidity, the moisture absorption ranged from 1.85g g^{-1}pressure to 36.01 g g^{-1}. Water activity was maximum (0.604) for the sheet containing 30% glycerol prepared at 150°C and 130 bar pressure and minimum (0.540) for the sheet containing 50% glycerol at a temperature of 130°C and 130 bar pressure. Maximum tensile strength of 0.39 Nmm^{-2} was obtained for the sample made at 140°C and 130 bar pressure with 40% glycerol. The elongation at break ranged from 32.54% to 16.65%. The maximum elastic modulus of the sheets was observed as 6653 Nm^{-1} for the sheets made at 140°C and 130 bar pressure with 40% glycerol.

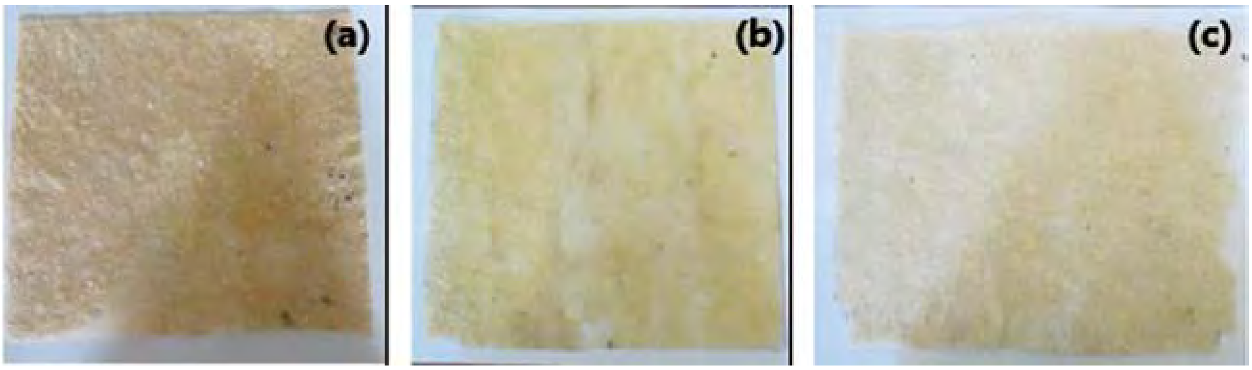


Fig. 93. Thermoplastic starch sheets made from (a) native starch, (b) cross linked starch, (c) starch succinate

Development of starch based functional biopolymers and bioactive compounds from tuber crops for food, pharmaceutical and agricultural applications

Synthesis of RS4 type resistant starch by octenyl succinylation

Potato, cassava, sweet potato, raw banana and lentil starches were esterified with the anhydride of long chain fatty acid, octenyl succinic acid, for enhancing the resistant starch (RS) and slowly digestible starch (SDS) fractions and to compare starches of diverse botanical origin. Among these starches, potato, raw banana and sweet potato are known for the presence of RS2 type resistant starch in their native form. However, cassava starch is highly digestible with only negligible amounts of RS in it. Native and modified starches showed significant differences in structure and properties including digestibility characteristics. The lower setback viscosity and percentage syneresis indicated that these modified starches have improved low temperature stability and can be used in frozen food products. Among the five native cooked starches, the maximum RS was in lentil starch (5.2%), followed by potato (3.6%), banana (3.4%) and sweet potato (3.3%) starches (Fig. 94). The modification caused significant enhancement in RS and SDS contents and reduction in RDS and glyceamic index in all the starches, compared to their respective native starches. The botanical origin of starch played a vital role in deciding the functionality of these modified starches.

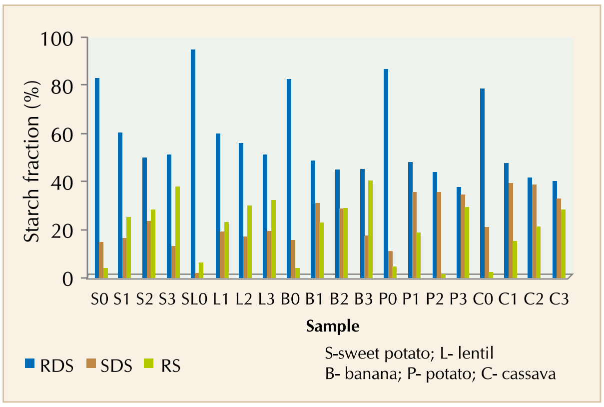


Fig. 94. Starch fractions in cooked native and modified sweet potato, lentil and banana starches

Synthesis of RS5 type resistant starch by enzymatic de-branching and complexation with GMS

The effect of de-branching of cassava and sweet potato starches by the enzyme, pullulanase at different hydrolysing times and the subsequent treatment with glycerylmonostearate (GMS) on the *in vitro* digestibility characteristics was studied. The treatment resulted in disruption of starch granules forming a non-homogeneous continuous surface morphology (Fig. 95). Both native cassava and sweet potato starches exhibited higher peak, breakdown and setback viscosities than the corresponding modified starches. No pasting happened with modified samples and this was confirmed by the 'zero pasting temperature'. De-branching of starch and complexation with GMS brought about increased RS (RS5) and reduced RDS fractions due to the formation of amylose-lipid inclusion complexes.

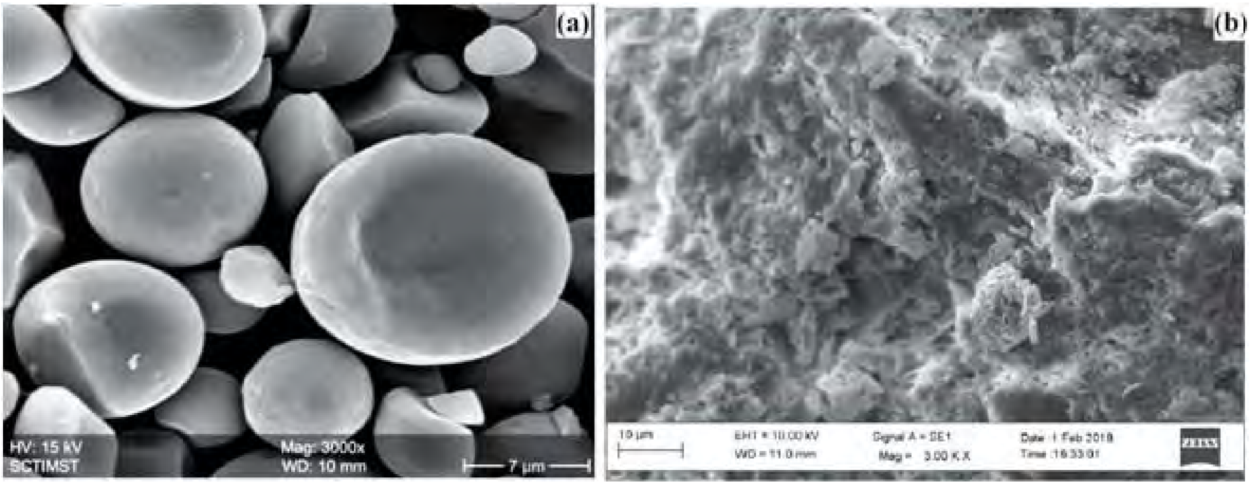


Fig. 95. SEM micrographs of (a) native sweet potato, (b) enzyme debranched complexed sweet potato starch with high RS5 content

Chemical Functionalization of cassava bagasse

The graft copolymerization reaction of cassava bagasse or thippi has been optimized for its functionalization and to make it suitable as a carrier for achieving slow release properties of the incorporated active compound. The grafting reaction has been carried out in aqueous medium with ceric ammonium nitrate as the free radical initiator and acrylonitrile as the grafting reagent. The reaction resulted in low level of grafting of the hydrophobic side chains on starch backbone, thereby altering the properties of the thippi.

Functional foods and nutritionally fortified snack food products, instant weaning food mixes for infants

The papad is one of the popular snack items and it is very tasty so it is used in every Indian diet since older days. Ready to fry/roast (RTF/RTR) papads were prepared from Elephant foot yam (EFY) (Jimikand) flour (30%), green gram (30%) and black gram (40%) and their proximate composition was analysed (Fig. 96). It contained crude protein in the range of 16.50 to 18.22%, crude fat 0.98 to1.73%, total ash 6.96 to 8.82%, moisture 13.10 to 14.75% and total carbohydrate

55.87 to 58.13%. The colour values of papads (L, a, b and YI) were 45.23, 7.41, 12.35 and 69.53. The proximate composition and characterisation of EFY flour (variety *Gajendra*) was analysed. The flour contained crude protein in the range of 9.45 to 11.24%, crude fat 0.87 to 1.99, total ash 3.77 to 4.56%, moisture 9.44 to 11.26%, starch 22.19 to 25.12 g 100 g^{-1}, pH 6.78 to 6.81, whiteness index 75.22 to 78.99, (% free radical inhibition by DPPH assay) 51 to 58.65, P 0.199 to 0.223 mg 100 g^{-1}, Fe 20.99 to 29.52 mg 100 g^{-1}, K 1.45 to 1.56 mg g^{-1} and Zn 2.53 to 3.16 mg 100 g^{-1}. The L, a, b and YI values of the flour were 75.18, 4.71, 9.08 and 29.67 respectively.

Response Surface Methodology (RSM) was used for formulation of ready to cook pasta from EFY flour, suji and finger millet flour. The cooking quality (cooking time, rehydration ratio and solid loss) of prepared pasta was analysed. The cooking time of pasta varied in the range of 4.45 to 5.4 minute, rehydration ratio varied from 1.50 to 2.85 and solid loss varied in the range of 7.57% to 8.85%, respectively. Sensory evaluation for overall acceptability (colour, texture, aroma and taste) of pasta was also carried out and it varied from 6.3 to 8.7.

Fig. 96. Pasta made from EFY flour, suji and finger millet flour

EXTENSION AND SOCIAL SCIENCES

IMPROVING KNOWLEDGE AND SKILL OF STAKEHOLDERS FOR SUSTAINABLE PRODUCTION OF TUBER CROPS

Longitudinal study on effects of tuber crops technologies intervention on their production and consumption in their users system

Value chain analysis of sweet potato in Karnataka

The study was conducted in Belagavi district which contributes 36% of total sweet potato production in Karnataka. A multi-level stratified sampling was used to select respondents from two taluks namely Belagavi and Khanapur. A total of 112 sweet potato growers from ten villages were intensively surveyed. A semi-structured questionnaire was used to interview 10 commission agents of APMC market, Belagavi and five wholesalers from Delhi, Maharashtra, Punjab and Gujarat who visited APMC for procuring sweet potato and 10 retailers in Belagavi town. The effects of various personal and production factors on the farm harvest price of sweet potato at the farmer's level were estimated through multiple regression analysis using Ordinary Least Square (OLS) method.

The model used:

$$Y = A+\beta_1 \ln x_1+ \beta_2 \ln x_2 + \beta_3 \ln x_3+ \beta_4 \ln x_4+ \beta_5 \ln x_5 +D_1 + D_2 + D_3 + D_4 + D_5 + D_6$$

Where,

Y=Price (₹kg^{-1}), x_1=Quantity sold (quintal), x_2=Age of the head of household (years), x_3=Size of the family (number), x_4=Distance to the market (Km), x_5= Area cultivated under sweet potato (ha) D_1=Immediate payment ('1' if yes or else '0'), D_2= September ('1' if yes or else '0'), D_3= October ('1' if yes or else '0'), D_4= November ('1' if yes or else '0'), D_5= January ('1' if yes or else '0'), D_6=Head of the household is literate ('1' if yes or else '0'). The statistical analyses were performed using SPSS software v.18.0 (IBM Corp., Armonk, NY, USA).

Mapping of the sweet potato value chain in Karnataka

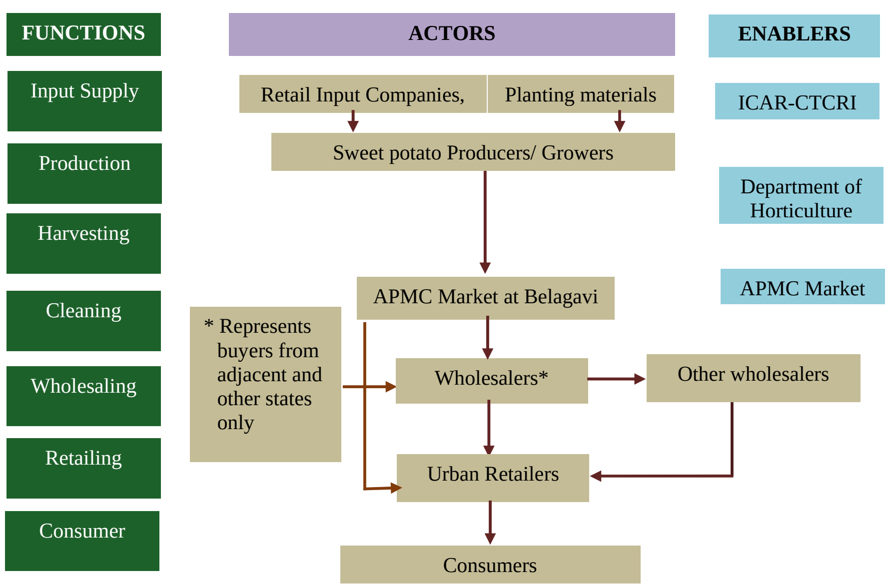


Fig. 97. Sweet potato value chain map in Belagavi district, Karnataka

The value chain of sweet potato in Belagavi district representing various actors at the upstream, midstream and downstream levels, along with their functions and interrelationships is given in Fig. 97.

Upstream actors in sweet potato value chain

The upstream level consists of primary farmer producers, who acquire information/ materials of new technologies for sweet potato from extension agents, retail input dealers and bankers/ agents who also provide finance. At this level, the primary farmer producers are considered important as they deliver the primary product of the value chain in the form of sweet potato tubers.

Household characteristics of producers

The average age of sweet potato growers was 51 years with the household size of 6.60. Twenty two of the sweet potato growers were literate. Over 97% of the farmers had farming as primary occupation while 21% had worked as wage labourers and this formed their secondary occupation. Sweet potato farmers had average landholding size of 2.49 ha, of which about 40% area was grown with sweet potato. The average production of sweet potato was 9.83 tons during *Kharif* season. It was found that more than 90% of the sweet potato produced was sold immediately after harvesting, thereby sweet potato was a commercial crop for the farmers while only 10% was retained for home consumption. Majority of the farmers in the study area were cultivating local varieties due to their better adaptability, good yield and better market price.

Economics of sweet potato production at producer level

The cost and return analysis of sweet potato based on primary survey is given in Table 5. The total cost for cultivating sweet potato was estimated to be ₹ 24, 262 ha^{-1} and the cost of production was ₹246 per quintal of tubers. The human labour and chemical fertilizers + farm yard manure were the major expenditure accounting to 32% and 26% respectively.

Table 5. Costs and returns of sweet potato cultivation for Kharif season during 2017

Operational costs	Mean	Share in total cost (%)
Input costs (₹)		
Planting materials	26.54	0.11
Chemical fertilizers + FYM	6336.95	26.12
Plant protection chemicals	343.36	1.42
Irrigation	7.61	0.03
Human labour	7862.38	32.41
Animal traction	1533.22	6.32
Tractor machine	2097.34	8.64
Interest on working capital	497.27	2.05
Rental value of owned land	5000.05	20.61
Rent paid for leased in land	0.00	0.00
Land revenue, taxes and cesses	16.80	0.07
Depreciation on implements and farm buildings	308.11	1.27
Interest on fixed capital	232.70	0.96
Total cost (₹)	**24262.33**	**100**
Land size, production and price (₹)		
Sweet potato area (ha)	1.00	-
Production (t)	9.83	-
Price (₹ Qtl^{-1})	598.66	-
Gross income	58848.27	-
Net income	34585.94	-
Benefit cost ratio (BCR)	2.42:1	-

On an average, net income of ₹34,585 was obtained from one hectare of sweet potato cultivation. The benefit cost ratio of sweet potato was estimated to be 2.42:1 which further reinforced in support of increasing of sweet potato acreage in order to enhance farmer's income.

Determinants of farm harvest price

The determinants of farm harvest price of sweet potato identified through multiple regression. During the estimation, the independent variables were checked for multicollinearity and no variance inflation factor was greater than 5. The logarithm of the price per kg was used as a dependent variable, and personal and production characteristics were included as independent/explanatory variables. The independent variables together explained 74% of the variation in the farm harvest price. The results of regression indicated that greater price realization was in the month of September ($r=0.48$; $p<0.01$), October ($r=0.26$; $p<0.01$) and November ($r=3.88$; $p<0.01$), if farmers sold their produce during these period.

Marketing behaviour of sweet potato farmers

It was found that all the farmers sold their produce through the Agricultural Produce Market Committee (APMC), indicating APMC's dominance in marketing of sweet potato in Belagavi district (Fig. 98). All the farmers sold their produce immediately after harvest due to satisfactory price realization. The reason for this peculiar trend was analysed and found that during this period demand for sweet potato was high due to coincidence of harvesting period with the Hindu festival during which consumption was considered to be auspicious. Furthermore, one of the major reasons why farmers settle on a particular buyer was immediate cash payments of about 83% of the transactions.

Fig. 98. APMC market yard at Belagavi district

Midstream actors in sweet potato value chain

The commission and wholesalers are two prominent actors involved in the midstream of the sweet potato value chain.

Commission agents

The commission agents are authorized traders in the APMC who facilitate the sales of sweet potato from producers to buyers, while the wholesalers procure the sweet potato from commission agents in bulk quantity for sale in local and distant markets. The method of sale of sweet potato in APMC market was open auction method as prescribed by the Govt. of India Act. The agents collect 6% of the total procurement cost as transaction commission from the buyers. On an average, per season transaction by commission agent was 3035 tonnes with an average sale price of ₹635 per quintal. Majority of the commission agents reported that base price of auction was determined by prevailing rates in other markets, quantity arrived at APMC on a specific day, estimated consumer demand, good size and shape of sweet potato tubers and free from sweet potato weevil infestations. Similarly, their network with buyers from distant markets helps them to sell farmers produce arrived in market. Many of the commission agents also act as local wholesalers in the market. The maximum transaction was observed in December (about 58%), while the peak period of demand was recorded during September, October and first week of November which led to good return to farmers as prices were much greater compared to the other months of arrival.

Wholesalers

The wholesaler survey was conducted with respondents from Delhi, Maharashtra, Punjab and Gujarat who come for buying sweet potato at APMC market in Belagavi district of Karnataka. It was found that 60% of them were trading multiple commodities including sweet potato due to seasonality of sweet potato. The wholesalers had an average experience of 17 years in sweet potato trade and considered it as the best business commodity than other agricultural commodities. The average quantity purchased by wholesalers during the *Kharif* season was 400 tonnes. The sweet potato procured from APMC, Belagavi was transported to wholesale markets in Delhi, Maharashtra, Punjab and Gujarat through trucks. The respondents reported over 10% of transportation and other post-harvest losses of sweet potato at the wholesale level. All the wholesalers had accessed information about sweet potato's prices and their arrival from APMC market at Belagavi and they considered it very reliable and authenticated.

Downstream actors in sweetpotato value chain

The downstream actors consist of retailers and consumers. All the retailer respondents sold sweet potato through unorganised retailing *i.e. kirana shops* and vegetable *mandis*. These shops served on an average 11 customers daily who purchased about 5 kg in a day. The retailers procured sweet potato from APMC market/wholesaler and sometimes directly from producers and sell it directly to the consumers. Further, it was estimated that all the respondents stored sweet potato after purchase for very short period and the maximum storage period on an average was 4.5 days. The average quantity sold during the season was 39 tons at the rate of ₹2,000 /quintal.

Price spread of sweet potato

Marketing channel I										
Producer	→	Commission agent/trader at APMC, Belagavi	→	Wholesaler in Maharashtra, Delhi etc.	→	Other wholesaler	→	Retailer	→	Consumer
Marketing channel II										
Producer	⟶			Commission agent/trader at APMC, Belagavi			→	Retailer	→	Consumer

Majority of the farmers were following the marketing channel I. The gross price received by the producers was ₹599/quintal and this constituted 20% of the retail price. The marketing cost incurred by producers, commission agents/traders at APMC market, wholesalers, other wholesalers and retailers were 4.12, 0.6, 11.73, 7.60 and 4% of the price paid by consumers. Furthermore, the wholesaler was having the maximum marketing cost (12%) followed by other wholesaler (8%) due to transportation of sweet potato for long distance. These marketing costs together account for 28% of the consumer price. Wholesaler (27%) has occupied major share among total margins of the consumer price followed by retailers (23%). It is therefore, the Marketing channel I being longer with more number of intermediaries involved, the producers share in consumers share was low (20%). The marketing channel II involves sale of sweet potato in Karnataka itself which was consumed locally. Producers share in consumer price on the sale of sweet potato through channel II was 30%. Retailers received the maximum margin of ₹ 1,253 per quintal which accounts about 63% of the consumer price.

Constraints in sweet potato value chain

The Garret's ranking technique was used to identify the constraints in the value chain of sweet potato. The major problem faced by the sweet potato farmers was incidence of pests and diseases during production besides unforeseen weather due to erratic rainfall which affects the production. Farmers reported low price for their produce and high commission fee charged by the commission agents at APMC market where farmers have to pay commission of around 7-8% of the total value of produce to commission agents. Many of the farmers opined that high marketing cost, long distance to the APMC market and lack of access to processing units as important constraints for marketing their produce. The major constraints faced by commission agents were; lack of cold storage facilities, price fluctuations, delay in receiving the payments from buyers and lack of processing units of sweet potato. Whereas, the constraints faced by the wholesalers and retailers were price fluctuations, high cost of transportation, lack of cold storage facilities and post-harvest loss due to weight loss and weevil infestation in tubers.

Consumption of cassava forecasted using ARIMA model

Time series data using autoregressive integrated moving average (ARIMA), popularly known as the Box–Jenkins methodology was used to forecast the variables for cassava commodity model. Time series data were used in Auto Regressive Integrated Moving Averages (ARIMA) model to forecast the consumption of cassava and starches in India for leading six years. The results showed that the total volume of consumption of cassava tubers are expected to reach 1.45 million tons by 2021 from 0.94 million tons in 2016, growing at a compound annual growth rate (CAGR) of 9% during 2016-2021. Similarly demand for cassava starches and starch products in India are expected to increase 1.7% by 2021 from 1.5% in 2016.

Table 6 shows the performance of cassava production in India from 1990-91 to 2016-17. The results showed that the domestic cassava production has generally increased. However, from the 2010-11 to 2016-17 the average cassava production decreased. This is attributed due to erratic rainfall which culminated in a severe drought during 2014-15 cropping season. There was an increase in sales of cassava by 8% due to decline in potato sales. Furthermore, adoption of improved varieties of cassava had a positive impact on cassava yields. This is evidenced by the increase in average yield of cassava from 23.6 t ha^{-1} in 1990-91 to 1994-95 to 33.6 t ha^{-1} in 2005-06 to 2009-10. Although acreage under cassava declined during 1995-96 to 1999-00, it increased steadily during 2005-06 to 2009-10. Cassava imports and exports in recent periods increased marginally. But the cassava price steadily increased over the years since 1990-91.

Table 6. Performance of cassava sector in India

Particulars	1990-91 to 1994-95	1995-96 to 1999-00	2000-01 to 2004-05	2005-06 to 2009-10	2010-11 to 2016-17
Area planted (x10^3 ha)	240.50	245.40	227.50	252.80	214.00
Yield (t ha^{-1})	23.60	24.40	26.80	33.60	30.10
Domestic production (x10^3 tons)	5631.3	5991.70	6117.10	8490.90	6506.60
Cassava exports (in tons)	1.60	16.80	31.00	522.20	1895.80
Cassava imports (in tons)	0.00	0.75	53.60	50.00	127.81
Cassava price (₹ t^{-1})	1715.08	2535.83	2755.19	3525.49	5306.62
Wholesale price index (WPI)	330	133	173	235	282

Pair wise correlation of cassava production with area, yield, price, export, import, Kerala WPI and Tamil Nadu WPI analysed showed that Pearson correlation coefficient (r) is positive except one variable (export) which indicated that increase in one variable will enhance other variable growth. Area of cassava and its price were negatively related and were significant which indicated that more area will increase production which will reduce the market price. Cassava one year lagged price was found to have negative correlation with the last year cassava area and positive correlation with its current prices.

Technological interventions in tuber crops

Fifty Frontline demonstrations of improved varieties of cassava, sweet potato, elephant foot yam, yams and taro were conducted in Tamil Nadu, Kerala, Karnataka and Manipur. Farmers were trained to adopt scientific agro-management practices for pests and diseases *viz.*, mealy bug, spiraling white fly and cassava mosaic disease in cassava and sweet potato weevil and leaf eating insects in sweet potato.

Improved varieties of cassava

Front line demonstrations of improved varieties of cassava (10 nos.) were conducted at Kanyakumari district of Tamil Nadu (Fig. 99). Sree Pavithra produced the maximum yield (36 t ha^{-1}) followed by Sree Jaya (35 t ha^{-1}), Sree Swarna (33 t ha^{-1}) and Sree Vijaya (32.5 t ha^{-1}). Average productivity of cassava from improved varieties was found to be 34.12 t ha^{-1} which is greater (17.7%) than the local varieties yield (29 t ha^{-1}).

Fig. 99. View of demonstration plots of improved varieties of cassava

Table 7. Economic impact of improved varieties of cassava

Variety	Yield (t ha^{-1})	Gross Income (₹ha^{-1})	Total Cost (₹ha^{-1})	Net Income (₹ha^{-1})	B: C ratio
Improved varieties*	34.12	2,73,000	79,650	1,93,350	3.43
Local varieties	29.00	2,32,000	75,495	1,56,505	3.06

Note: * - Sree Jaya, Sree Vijaya, Sree Pavithra and Sree Swarna

Gross income realized from improved varieties and local varieties of cassava were ₹ 2.73 lakhs ha^{-1} and 2.32 lakhs ha^{-1} respectively (Table 7). Overall, the productivity and profitability of cassava farming with improved varieties increased significantly over the existing local varieties.

Improved varieties of sweet potato

Twenty demonstrations on improved varieties of sweet potato *viz.*, Sree Arun, Sree Nandini and Sree Bhadra were conducted in Belagavi district of Karnataka (Fig. 100). Sree Arun produced the maximum yield (27 t ha^{-1}) followed by Sree Bhadra (20 t ha^{-1}) and Sree Nandini (19 t ha^{-1}). Average yield of improved varieties of sweet potato was found to be 21.3 t ha^{-1} which was (9.2%) greater than the yield of local varieties (19.5 t ha^{-1}).

Fig. 100. View of demonstration plots of improved varieties of sweet potato

Table 8. Economic impact of improved varieties of sweet potato

Variety	Yield (t ha⁻¹)	Gross Income (₹ ha⁻¹)	Total Cost (₹ ha⁻¹)	Net Income (₹ ha⁻¹)	B: C ratio
Improved varieties*	21.3	1,38,450	42,350	96,100	3.27
Local varieties	19.5	1,17,000	40,285	76,715	2.90

Note:* - Sree Arun, Sree Bhadra and Sree Nandini

Gross income realized from improved and local varieties of sweet potato were ₹ 1.38 and 1.17 lakhs ha^{-1} respectively (Table 8). The productivity and profitability of sweet potato with improved varieties increased significantly over the existing local varieties. Establishment of seed villages to ensure timely and continuous supply of improved varieties, promotion of participatory research and extension, organized marketing system and strengthening the linkages with other stakeholders of tuber crops will ensure sustainability of farming in the long run.

Sustainable livelihood analysis of tuber crops farmers

A sample of 60 sweet potato growers and 60 paddy growers were selected using snow ball sampling from two taluks *viz.*, Belagavi and Khanapur in Belagavi district for analyzing the sustainable livelihood of farmers. Data were collected using PRA tools, interview schedule and focus group discussions during July to November 2017. Livelihood sustainable index was worked out using the DFID methodology as given below.

Livelihood Sustainable Index (LSI) = HCI + SCI + FCI + NCI + PCI /5

HCI: Human Capital Index

SCI: Social Capital Index

FCI: Financial Capital Index

NCI: Natural Capital Index

PCI: Physical Capital Index

Capital Index: Actual Score/ Maximum Obtainable Score

Profile characteristics of sweet potato and paddy farmers

The sweet potato and paddy farmers do not differ significantly for most of their socio-economic attributes. The average age of sweet potato and paddy farmers is almost same (47 years). There is not much difference in the educational level of both the category of farmers. However, the average size of land holding for sweet potato and paddy growers differ significantly at 5% level. The average yield of sweet potato is greater than the paddy. There is no difference in the cost of cultivation between sweet potato and paddy. However, the higher yield realization makes sweet potato cultivation more remunerative. On an average, the sweet potato farmers realized 39% greater net profits than the paddy growers (Table 9).

Table 9. Cost and returns in sweet potato and paddy cultivation

Particulars	Sweet potato	Paddy	Difference	Difference (%)
Yield (t ha⁻¹)	11.04	4.05	6.99***	172.59
Price (₹quintal⁻¹)	573.33	1300	-726.66***	-55.89
Cost of cultivation (₹ha⁻¹)	21230.44	22363	-1132.56	-5.06
Cost of production (₹quintal⁻¹)	213.51	595.83	-382.31***	-64.16
Net Profit (₹ha⁻¹)	42178.76	30319.78	11858.98***	39.11

***-significance at 1% level

Livelihood Sustainable Index of sweetpotato and paddy growers

With respect to human capital index, training index was more for paddy growers (49.44) when compared to sweet potato growers (22.77). The other parameters like education, labour availability, health facilities and experience are more or less similar. The overall human index was 45.98 for sweet potato growers and 52.17 for paddy growers. Under the physical capital index regarding type of house, the index for sweet potato growers was 65.41 whereas it was 54.16 for paddy growers. The overall physical capital index was more for sweet potato growers (72.05) as compared to paddy growers (69.99). Social capital index was similar to both the farmers; in the case of sweet potato growers it was 63.32 and for paddy growers it was 63.43. Membership in organization was more for sweet potato growers (53.33) whereas it was 46.66 for paddy growers. In financial capital index, credit availability (51.11) was more for paddy growers than that of sweet potato growers (51.11). The overall financial index was 39.81 for paddy growers and 35.80 for sweet potato growers. The overall natural capital index was 62.98 for sweet potato growers and 64.47 for paddy growers.

The rural livelihood sustainable index was marginally more for paddy growers (57.97) than sweet potato growers 56.02 (Table 10). The association or similarities of different capitals between sweet potato and paddy growers is given in Fig. 101. Similarities between capitals of sweet potato and paddy growers are in the decreasing order with respect to social, natural, physical, financial and human capitals.

Table 10. Livelihood sustainable index of sweetpotato and paddy growers

Index	Sweet Potato growers (n = 60)	Paddy growers (n = 60)
Human Capital	45.98	52.17
Physical Capital	72.05	69.99
Social Capital	63.32	63.43
Financial Capital	35.80	39.81
Natural Capital	62.98	64.47
Overall LSI	**56.02**	**57.97**

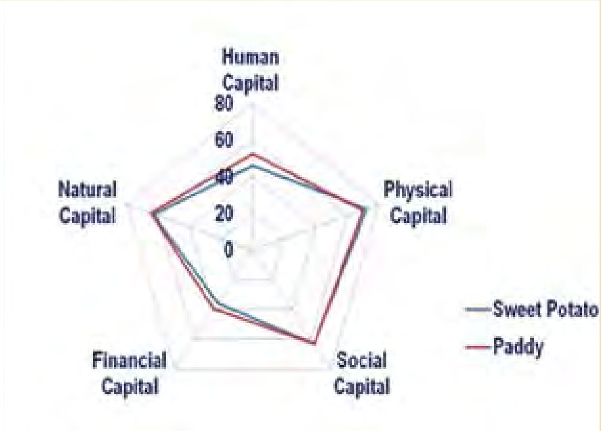


Fig. 101. Livelihood capital asset pentagon for Sweet Potato and Paddy growers

Major sources of livelihood as reported by both the farmers were, agriculture, employment in government/private sector and small business. The vulnerability factors were rampant inflation, price fluctuation, crop failure and labour cost. The trends observed were, price rise (input cost), drought and climate change. Major constraints reported by the sweet potato farmers were price fluctuation followed by incidence of pests and diseases, lack of storage facilities, scarcity of water and wild animals menace.

Development of ICT applications in tuber crops

Tuber Guru app

An Android app 'Tuber Guru app' is an information system on tropical tuber crops which provides information on cassava, sweetpotato, elephant foot yam, yams and taro in English and Malayalam (Fig. 102). Crop wise details on varieties, agro techniques, manures and fertilizers, intercultural operations, diseases and pests are available in this app.

VIT app (Variety Identification Tool)

Algorithm for VIT app (Variety Identification Tool) to identify the varieties of cassava, sweetpotato, yams and taro based on their morphological attributes like colour and shape of stem, leaf, petiole, tuber etc was developed. VIT app works in two major modes (a) Training mode and (b) Identification mode. In both the modes same morphological attributes of the crop in reference are used for identifying the varieties (Fig. 102).

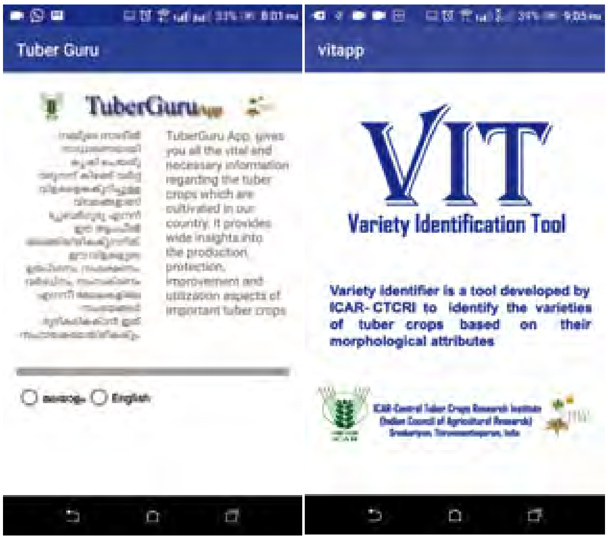


Fig. 102. View of TuberGuru app and VIT app

Generation and application of statistical tools and technologies for tuber crops research and development

Mapping of quantitative trait loci (QTL) in cassava using Markov chain Monte Carlo (MCMC) method

With the availability of inexhaustible supply of molecular markers there is considerable progress in detection of QTL for many agricultural importance traits. Many statistical methods have been well developed for QTL mapping such as ANOVA where the genotypes at particular location is grouped into two or three groups depending on the type of cross and the phenotypic means are compared using standard hypothesis test (t-test or F-test). Many of these methods are mainly for traits with a continuous distribution. However many agriculturally important traits such as cassava mosaic disease do have discrete distribution. Bayesian methods of QTL mapping are preferable for traits which are non-normal when multiple QTLs are considered. There are many statistical software packages that can perform Bayesian analysis using MCMC algorithm. MCMC procedure in SAS which draws variables using adaptive block random walk Metropolis algorithm was applied for QTL analysis for cassava mosaic disease. The parents were MNGA and CI-732 which are highly contrasting in the trait of interest. One hundred and fourteen seedlings were studied for the CMD resistance phenotype based on 1-5 scoring scale. Sixty five seedlings were symptomless, 8 seedlings had severe symptom with score of 5. One hundred and twelve SSR markers were used in the experiment. Different methods of QTL mapping were applied. To apply the Bayesian method of QTL mapping, the disease score was modelled as following poisson distribution and the expectation is connected to QTL effects through a log link function. The MCMC procedure in SAS particularly designed for Bayesian analysis using Markov chain Monte Carlo algorithm was used for carrying out the computations.

The model

Let $y_i=\{1, 2, 3, 4, 5\}$ be the observed disease score for the j^{th} plant for j=1, 2, …., n where n=114. Let μ_j be the expected score for the j^{th} plant, the poisson density for the data point is

$$f(y_i|\mu_j) = \frac{\mu_j^{\,y_j}}{y_j!}\exp(-\mu_j)$$

The expectation is connected to the QTL effects through a log-link function

$$\eta_j = \beta + \sum_{k=1}^{m} Z_{jk}\,\gamma_k$$

where Z_{jk} is the conditional expectation of the genotype indicator variable and γ_k is the QTL effect.

Z_{jk}= p(G_{jk}=A_1A_1|marker)-p(G_{jk}=A_2A_2|marker) for k=1, 2, …, 112 which can take values 1, 0 or -1. And the parameters estimated are

$$\theta=\{\beta, \gamma_1, \gamma_2, \gamma_3, \ldots\ldots, \gamma_{112}\}$$

The relationshipbetween μ_j and η_j is through the log link

$$\eta_j=\log(\mu_j)$$

Normal prior distributions were assumed and inverse chi square prior distribution was assumed for variance. The model is also known as Bayesian Shrinkage analysis. Under single marker analysis thirteen marker alleles (SSRY28a, SSRY28b, SSRY324d, SSRY59a, SSRY59b, SSRY43d, SSRY32c, SSRY32d, SSRY10b, SSRY30c, NS97c, NS185a and NS185b) have been found to be significantly associated with CMD resistance Table 11.

Table 11. SSR markers associated with CMD resistance predicted by single marker analysis

Linkage group	Markers	P-value
LG1	SSRY28[a]	0.020*
LG2	SSRY28[b]	0.020 *
Unlinked	SSRY324[d]	0.035 *
LG16	SSRY59[a]	0.015 *
LG9	SSRY59[b]	0.015 *
LG10	SSRY43[d]	0.003**
LG10	SSRY32[c]	0.017 *
LG19	SSRY32[d]	0.017*
LG9	SSRY10[b]	0.004 **
LG21	SSRY30[c]	0.004 **
LG9	NS185[a]	0.014*
LG16	NS185[b]	0.014*
LG21	NS97[c]	0.004**

*-5% level of significance, **-1% level of significance

Interval mapping identified two QTLs in chromosome 7 and chromosome 22 at LOD score above 8.0. QTL on chromosome 7 was flanked by NS97a and SSR38a, both marker alleles were contributed by the male resistant parent MNga-1. On the other hand, QTL on chromosome 22 was flanked by NS97c and SSRY30c, alleles contributed by the female parent. Composite interval mapping identified the same two QTLs as identified by SIM at LOD score above 8.0. The first QTL was found to be associated with marker NS97a and SSR38a with positive additive effect of 0.38 but the phenotypic variance explained by the QTL was very low. The second QTL was strongly associated with NS97c flanked by SSRY30c. R^2 value of 0.15 explained that this QTL on chromosome 22 is a major QTL which was responsible for the phenotypic variation for CMD.

With multiple interval mapping, three QTLs were identified, one in chromosome 6 at a position 6cM and other two QTLs in chromosome 7 at 0.1 cM and 60.4cM position. From these QTLs, main QTLs were identified by refine model and identified two main QTLs which were found in chromosome 7 at two different positions. First QTL was located at position 0.1cM with an additive effect of 0.56 and dominant effect of -2.61 and second QTL was located at position 60.4 with an additive effect of -0.0628 and dominant effect of 0.34. The convergence diagnostics for the parameters using MCMC procedure is shown in Fig. 103. The posterior summaries of the parameters estimated are shown in Table 12.

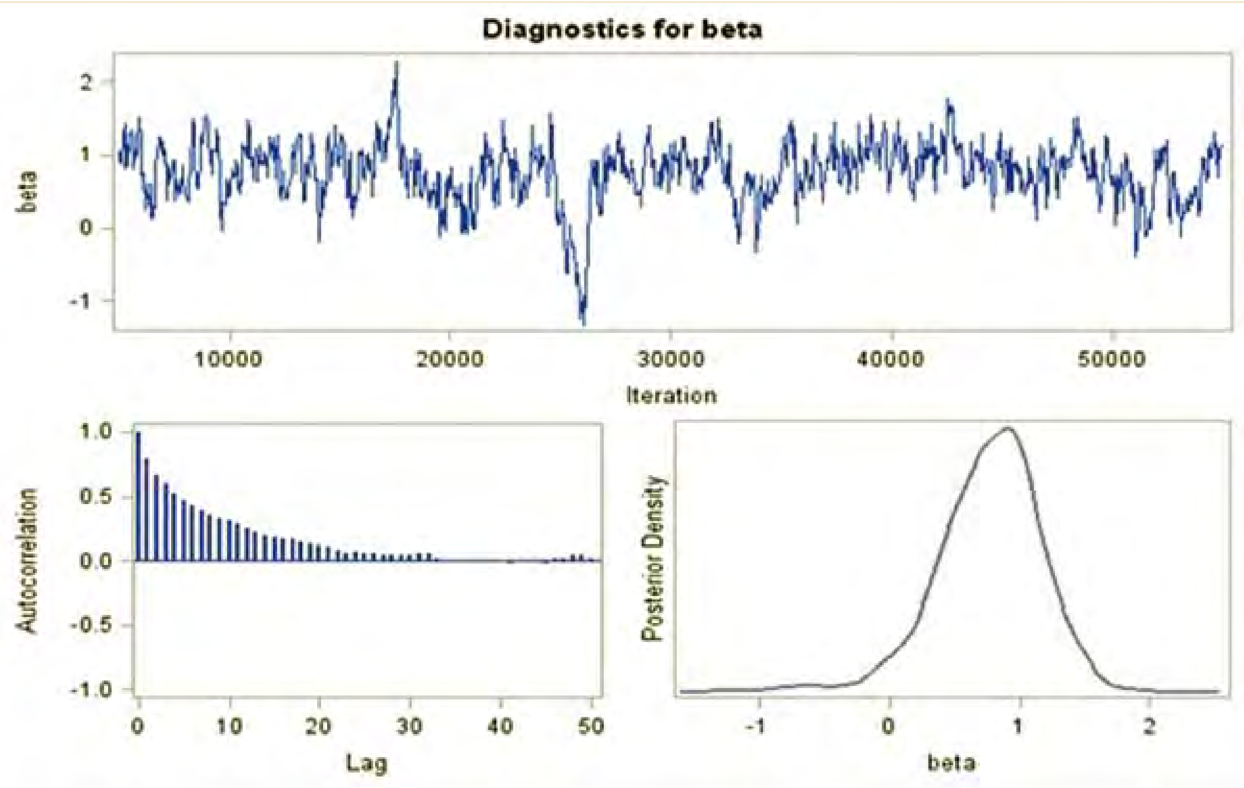


Fig. 103. Convergence diagnostics for the population mean

Table 12. Posterior sample summary statistics in PROC MCMC

Posterior Summaries										
Parameter	N	Mean	sd	Percentiles						
				1%	2.5%	5%	50%	95%	97.5%	99%
beta	1000	0.7628	0.4155	-0.6341	-0.1296	0.0498	0.8000	1.3419	1.4699	1.5671
gamma1	1000	-0.0370	0.0971	-0.4022	-0.3208	-0.2718	-0.00021	0.0320	0.0693	0.1199
gamma2	1000	0.0357	0.0979	-0.0941	-0.0284	-0.00886	-9.22E-6	0.2788	0.3604	0.4463
gamma3	1000	0.00485	0.0531	-0.1642	-0.0903	-0.0464	-1.96E-6	0.0909	0.1379	0.2170
sigmasqr1	1000	18.0609	450.2	3.06E-11	1.14E-10	3.26E-10	0.000033	0.6048	3.1024	19.1545
sigmasqr2	1000	10.6554	330.4	1.2E-11	1.5E-11	2.13E-11	1.341E-7	0.2890	0.7373	4.3996
sigmasqr3	1000	12.3269	382.8	1.23E-11	2.09E-11	5.11E-11	4.108E-6	0.0908	0.3472	2.9730

The Bayesian QTL effects estimated for predicted SSRs with chromosomal location is given in Table 13.

Table 13. SSR markers found associated with CMD resistance and the chromosomal location predicted by MCMC method.

Marker	Gamma	Chromosome
*SSRY32C	0.018311	10
*NS185A	0.021678	16
*SSRY27D	0.0235	13
*SSRY32D	0.0346	20
*SSRY28B	0.035726	2
*NS136A	0.0411	4
*SSRY44A	0.041496	4
*SSRY30C	0.103974	22
*NS-97C	0.128065	22
*SSRY43D	0.138414	10

EXTERNALLY AIDED PROJECTS

Adapting clonally propagated crops to climatic and commercial changes (EU funded INEA Taro Programme; PI: Dr. Archana Mukherjee)

The project is aimed at developing genotypes adapted to new environments (climate change, pest and disease outbreaks) and to satisfy market needs. Under the project, 50 exotic lines are maintained in the field and *in vitro*. Three hybrid lines were raised from the parental lines, *viz*., CE/IND/12 x Jhankri, CE/IND/06 x Jhankri and BL/SM/151 x Mukthakeshi which produced yields ranging from 300-600 g plant^{-1} and were resistant to blight. During the period, ten more hybrid lines were transplanted to the field. Seeds of three different combinations were inoculated *in vitro,* for germination. The transplanted hybrid lines are being evaluated for key morphological and valued characters like early maturity, blight resistance and other quality parameters.

Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro (PPV & FRA, New Delhi; PI: Dr. Archana Mukherjee)

DUS guidelines of taro and elephant foot yam were developed and approved.

Establishment of varietal gene bank and development of standards of DUS testing in yam bean (Pachyrrhizus erosus) and greater yam (Dioscorea alata) (PPV & FRA, New Delhi; PI: Dr. Archana Mukherjee)

The project was initiated with the objective to identify distinct, uniform and stable characteristics and standardise the DUS testing guidelines for yam bean and greater yam. A draft guideline of greater yam was prepared with 30 characteristics. It included six grouping traits *viz.*, leaf shape (Fig. 104), petiole colour (Fig. 105) and tuber shape, tuber colour of cortex, tuber colour of flesh and tuber length. The field genebank of 30 reference varieties of greater yam was conserved for conducting DUS testing trials in future.

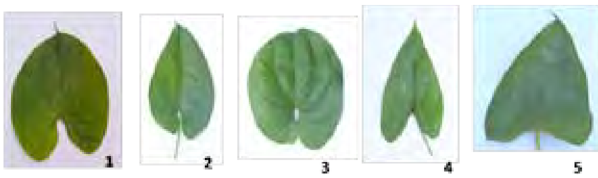


Fig. 104. Leaf shape characters: 1. cordate 2. cordate long 3. cordate broad 4. sagitate long 5. sagitate broad

Fig. 105. Petiole colour character 1. green 2. green with purple at both ends

In the case of yam bean, the draft DUS guidelines was prepared with various grouping characters *viz.*, leaf shape: terminal leaf [no of teeth] (Fig. 106); pod length (Fig. 107); tuber shape (Fig. 108) and seed shape (Fig. 109).

Fig. 106. Trifoliate teethed leaf, Less than 5 teeth (1), 5-7 teeth (2), More than 7 teeth (3)

Fig. 107. Pod length, small (1), medium (2), high (3)

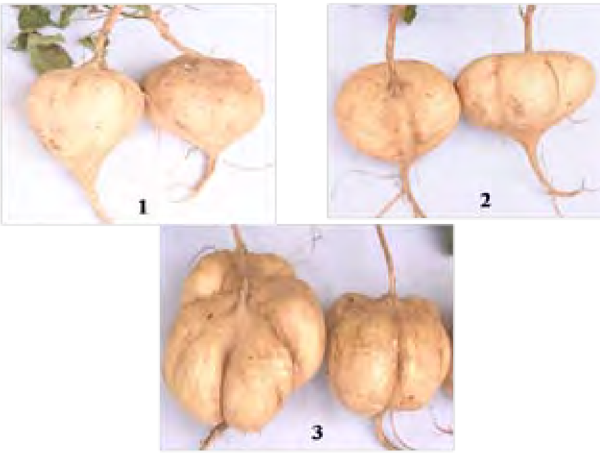


Fig. 108. Tuber shape, fusiform (1), round to fusiform (2), round with deep lobing (3)

Fig. 109. Seed shape, square inure (1), flattened (2)

Establishment of varietal gene bank and development of standards of DUS testing in cassava (*Manihot esculenta*) and sweet potato (*Ipomea batatas*)

(PPV & FRA, New Delhi; PI: Dr. Sheela, M.N.)

The gene bank of reference varieties of cassava (30) and sweet potato (40) are being conserved in the field. DUS testing guidelines of both cassava and sweet potato were standardised. DUS testing guidelines of cassava included thirty characteristics of which six traits, *viz.*, pubescence on apical leaves, predominant shape of central leaf lobe, petiole colour and colour of mature stem: exterior, tuber rind colour and tuber flesh colour, were selected as grouping traits. DUS testing guidelines for sweet potato included twenty five characteristics including six grouping traits *viz.*, plant growth habit, vine pigmentation, mature leaf shape, tuber shape, tuber: predominant skin colour and tuber flesh colour.

Development of tubers and Pulses

(Department of Agriculture, Govt. of Kerala; PI: Dr. James George)

The major objectives were to improve production and productivity of tuber crops and to popularize promising tuber crop varieties developed by ICAR-CTCRI. Twenty four seed villages were selected for multiplication of planting materials of cassava, elephant foot yam, greater yam and taro, covering 14 districts of Kerala. Of this, 4 are tribal villages in Palakkad, Wynad, Malappuram and Idukki districts. Planting materials of improved varieties developed by ICAR-CTCRI worth ₹ 1,04,000/-were distributed to all these seed villages for further multiplication.

Network Project on Organic Farming (NPOF)

(ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut; PI: Dr. G. Suja)

The major objectives were to evaluate organic, inorganic and integrated management practices in cropping systems involving tuber crops, to evaluate the response of cassava varieties to organic production system, to develop organic integrated farming system involving tuber crops and geo-referenced on-farm characterization of organic growers.

Evaluation of organic, inorganic and integrated management practices in cropping systems involving tuber crops

Four cropping systems, cassava-vegetable cowpea, cassava-groundnut, taro-black gram and taro-green gram, were evaluated under six management options, 100% organic, 75% organic, 100% inorganic, state recommendation (POP), 50% organic + 50% inorganic, 75% organic + 25% inorganic in large plots (18 m x 5.4 m) in strip plot design (unreplicated) with border fences of subabul between plots, border rows of lemon grass, karonda and lemon surrounding the experimental area and cowpea buffer strips in between plots as per the technical programme suggested by the lead centre.

Among the systems, cassava-groundnut was the most remunerative. Without premium price, cassava-vegetable cowpea and cassava-groundnut under 100% inorganic was the most profitable; 75% organic + innovative practice and 100% organic were the next profitable management options. With premium price, the above two organic practices were the most profitable in the two systems respectively.

In taro-black gram, 50% organic + 50% inorganic was the most profitable option when computed without premium price. When premium price was accounted, 100% organic was the most remunerative for this system. In taro-green gram, 50% organic + 50% inorganic were the most profitable when computed with or without premium price.

In both cassava-vegetable cowpea and cassava-groundnut systems, 100% inorganic resulted in the maximum energy equivalent. In taro-black gram and taro-green gram systems, the equivalent energy was the maximum for 75% organic + 25% inorganic and 50% organic + 50% inorganic respectively.

In all the cropping systems, the pH, organic C, exchangeable Ca, Mg, available S, Fe, Mn, Zn and Cu were higher in the organic (100% or 75%) or towards organic practices (75% organic + 25% inorganic). Available N, P and K were higher in inorganic or state POP.

Evaluation of response of different varieties of cassava to organic farming

Of the 12 varieties tested under organic mode, H-226 produced the maximum yield (46.70 t ha^{-1}) on par with the varieties Sree Reksha (CR-24-4) (45.81 t ha^{-1}), Sree Athulya (36.29 t ha^{-1}) and Sree Pavithra (33.43 t ha^{-1}). Cassava varieties H-226 and Sree Reksha also generated higher profit (₹5, 32, 229 ha^{-1} and ₹5,18,855 ha^{-1}, respectively) and B: C ratio (4.16 and 4.08) under organic mode (Fig. 110).

Fig. 110. Sree Reksha, good performer under organic mode

Geo-referenced on-farm characterization of organic growers

Geo-referenced survey of 33 farmers practicing organic farming was carried out in *Varkala, Neyyattinkara* and *Vamanapuram* blocks of Thiruuvananthapuram district (Fig. 111). The basic objective of this survey was to study the common organic farming practices adopted by the farmers, to identify the relative share of farmers involved in organic farming either individually or in clusters and the constraints in organic production.

Sixty one per cent of the farmers belonged to the small and marginal group with a land holding size less than 2 ha and majority were uncertified, but 6.06% were certified as safe-to-eat. Average land holding size was 0.79 ha. The entire farming situation surveyed was rainfed, but irrigated during summer. Farm animals and birds formed an integral part of organic farming. Animal wastes were converted to excellent manures using biogas and vermicompost units (with an average capacity to produce nearly 200 kg compost/annum).

Nutrient sources for organic farming constituted cow dung slurry, poultry manure, vermicompost, biogas slurry, bio-formulations like *Jaivavalachaya*, *Jeevamrutham*, *Amritapani*, *Ezhilakuttu*, egg amino acid, fish amino acid, *Panchagavya*, *Anchilavaratti*, groundnut cake and Gliricidia. Majority of farmers conducted soil testing before raising the crop. Pests and diseases were managed through application of neem cake, neem oil, garlic emulsion, *Beauveria*, *Trichoderma*, *Pseudomonas* and by cultural methods like intercropping, trap crops on field bunds.

Fig. 111. Glimpses of geo-referenced survey of organic growers

Climate smart natural resource management of cassava using geoinformatics tools (KSCSTE, Govt. of Kerala; PI: Dr. G. Byju)

Studies on climate suitability of crops in the changing climatic scenario are a pre-requisite to achieve sustainable utilization of available land resource for its production and to attain food security. This study attempts ensembled multi-model prediction of change in climate and climate suitability of cassava by 2030 and 2050 in major cassava growing regions of India based for 4.5 and 8.5 representative concentration pathways (RCP). The key findings of the study are (i) general warming of climate over the major cassava growing regions by 2030 and 2050 under RCPs 4.5 and 8.5 (Fig. 112). Change in annual average minimum temperature is 1.32 to 1.80°C under RCP 4.5 and 1.38 to 1.52°C under RCP 8.5 for 2030; 1.6 to 1.85°C under RCP 4.5 and 1.72 to 2.55°C under RCP 8.5 for 2050. Annual average change in maximum temperature predicted is 0.93 to 1.14°C under RCP 4.5 and 1.13 to 1.36°C under RCP 8.5 for 2030; 1.45 to 1.69°C under RCP 4.5 and 2.03 to 2.42°C under RCP 8.5 for 2050. The annual mean temperature change is 1.18 to 1.55°C under RCP 4.5 and 1.29 to 1.49°C under RCP 8.5 for 2030; 1.62 to 1.78°C under RCP 4.5 and 2.03 to 2.28°C under RCP 8.5 for 2050. (ii) change in total annual precipitation is 13.57 to 92.40 mm under RCP 4.5 and 25.27 to 103.70 mm under RCP 8.5 for 2030;-1.91 to 73.9 mm under RCP 4.5 and 5.31 to 56.60 mm under RCP 8.5 for 2050. (iii) Average suitability change in the major cassava growing regions is predicted as 4 and 4.78% under RCPs 4.5 and 8.5 by 2030; 8.36 and 7.6% under RCPs 4.5 and 8.5 by 2050. The results showed that there is no considerable change in the suitability of cassava in major growing areas by 2030 and 2050 which shows that cassava is resilient to climate change and is a promising future crop to alleviate hunger and malnutrition as well as to meet the energy needs as a biofuel crop.

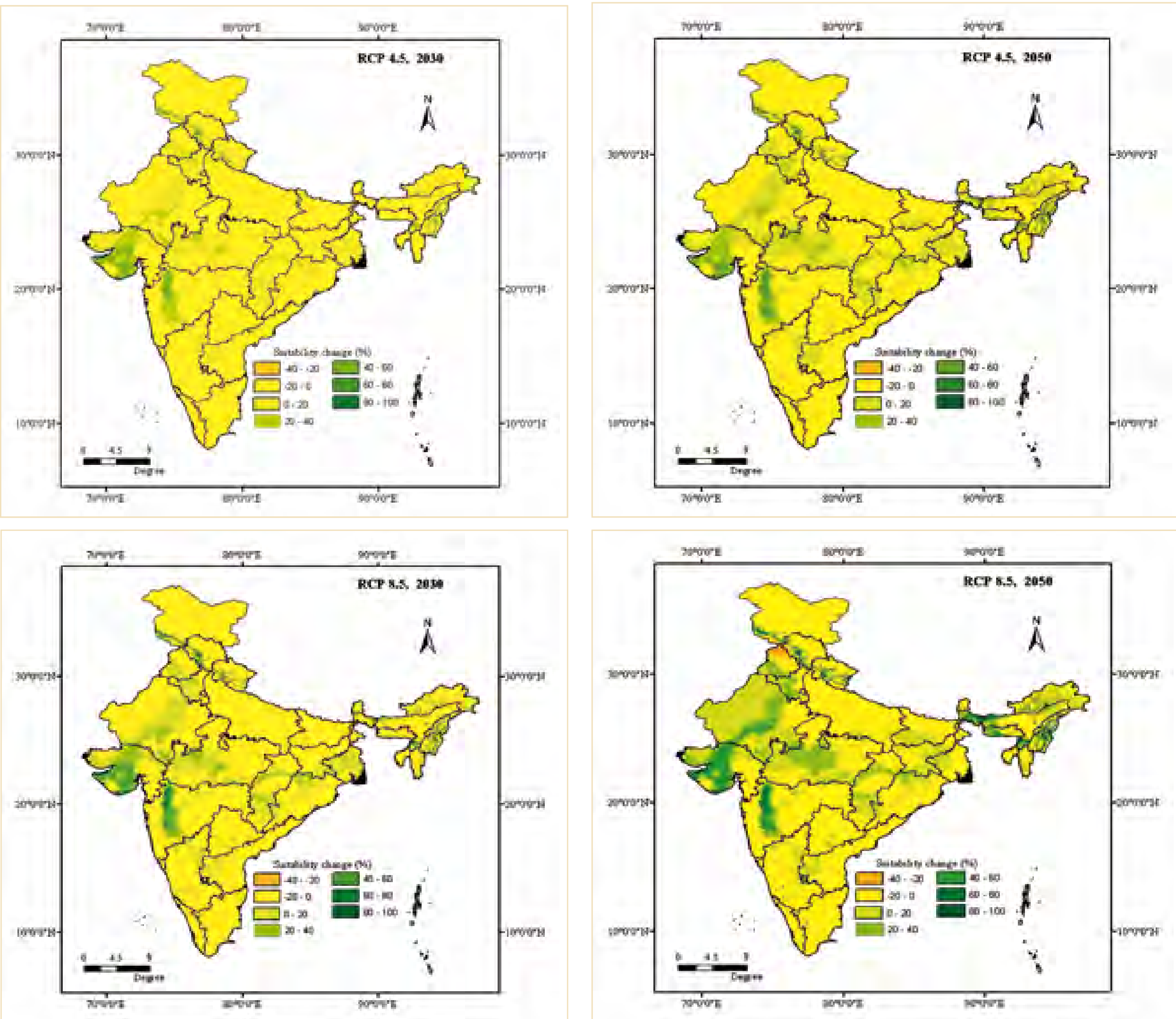


Fig. 112. GCM ensembled change in suitability of cassava (%) predicted under RCP 4.5 and 8.5 for 2030 and 2050

Enhancing the economic viability of coconut based cropping systems for land use planning in Kerala state

(Department of Agriculture, Government of Kerala; PI: Dr. Susan John K.)

The objectives of the project are to develop Best Management Practices (BMP) from the scientific study comprising of surface and subsoil acidity, soil available macro, secondary and micronutrients, plant nutrient content in tuber crops *viz*., EFY and cassava as intercrops in coconut garden for two agro-ecological units (AEU 3 and AEU 9) of Kerala, Validation and demonstration of the BMP for enhancing crop production in farmer's fields in the selected agro-ecological and development of a customized fertilizer (CF) formulation for the cultivation of EFY intercropped in coconut garden for better profit, soil and tuber quality for the two agro ecological units of Kerala (AEU3 and AEU 9).

Two trials each in cassava and elephant foot yam (EFY) in AEU3 and AEU9 were carried out with four treatments and four replications during the first year, for EFY with five treatments and four replications trials were carried out in three locations in AEU 3 and four locations in AEU 9 and in cassava, one location each in AEU3 and AEU 9 during the second year. In the third year, validation trials for BMP were conducted in five locations in the five districts of Kerala *viz.*, Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam and Ernakulam. During all these years, the BMP treatment comprised of application of liming materials *viz.*, lime @ 1 t ha^{-1}, dolomite @ 1.5 t ha^{-1} and gypsum @ 2 t ha^{-1} along with soil test based application of NPK (150:12.5:200 kg ha^{-1}) and FYM (25 t ha^{-1}) along with $MgSO_4$ @ 120 kg ha^{-1}, $ZnSO_4$ @ 20 kg ha^{-1} and borax @ 12.5 kg ha^{-1} did not produce any significant effect on tuber yield over PoP in the case of both cassava and EFY in both AEU's. The validation trials also confirmed the same trend. The three customized fertilizer formulations with grades as N: P_2O_5: K_2O: Mg: Zn: B @ 8: 11: 21: 3.5: 1: 0.3 (CF1), 7:12:24:2.5:1.25:0.4 (CF2), 7:3:25:3:1.25:0.4% (CF3), tested @ 625 kg ha^{-1} in the five districts of Kerala *viz.*, Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam and Ernakulam indicated CF2 as the best with a tuber yield of 62.623 t ha^{-1} and BC ratio of 8.49 (Fig. 113 and 114). Analysis of the tuber samples of the II season experiment indicated significant effect of treatments on crude fat, crude protein, oxalate, sugar and total phenol with CF's recording the highest fat, protein and sugar and lower oxalate content. However, CF1@ 625 kg ha^{-1} was found better with respect to all quality parameters and were comparable to farmers practice and PoP. Among the three CF's tried in cassava under intercropping in coconut, CF1 and CF2 with grades as N:P_2O_5:K_2O:Mg:Zn:B @ 8:11:21:3.5:1:0.3 (CF1), 7:12:24:2.5:1.25:0.4 (CF2) @ 500 kg ha^{-1} performed best with tuber yields to the tune of 53.77 and 53.47 t ha^{-1} respectively (Fig. 115).

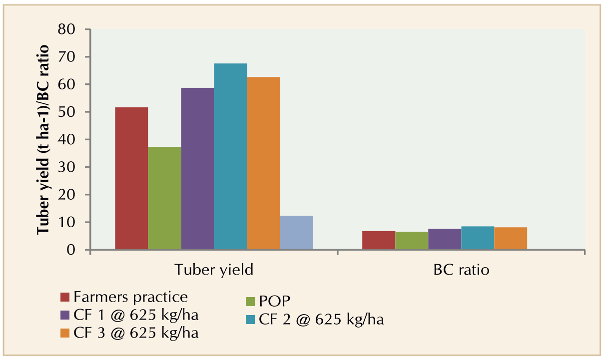


Fig. 113. Effect of customized fertilizer formulations on tuber yield and B:C ratio

Fig. 114. Field view of the BMP and CF experiments in elephant foot yam

Fig. 115. Testing of CF's in cassava under intercropping in coconut

Assessment of Soil Fertility and Preparation of Soil Fertility Maps for Various Agro-Ecosystems of Odisha

(RKVY, Dept. of Agriculture and Farmers' Welfare, Govt. of Odisha; PI: Dr. K. Laxminarayana)

The Directorate of Horticulture and Rashtriya Krishi Vikas Yojana (RKVY), Govt. of Odisha has released ₹84.53 and 88.53 lakhs, respectively in 4 instalments during 2014, 2015 and 2016 to assess the fertility status of soils and to prepare soil fertility maps under horticultural cropping systems representing 6237 Gram Panchayats of 30 districts of Odisha.The analytical works for physico-chemical properties (pH, EC, Organic C, available N, P, K, Ca, Mg, S, Fe, Cu, Mn, Zn, B and Mo) are in progress.

Indo-Swiss cassava network project

(Indo Swiss collaboration on Biotechnology (ISCB)-DBT; PI: Dr. T. Makeshkumar and Dr. M.N. Sheela)

On-farm trial was conducted in three different locations to evaluate the CMD resistant varieties (Fig. 116). In location 1 at Rajapalayam, Attur, Salem under irrigated conditions, the new CMD resistant variety 8S501-2 produced the maximum yield (124.9 t ha^{-1}) followed by White Thailand (70.4 t ha^{-1}), Kumkumarose (55.8 t ha^{-1}) and Sree Athulya (60.8 t ha^{-1}). In location 2 at Chandiyoor, CR-24-4 produced the maximum yield (132.1 t ha^{-1}) followed by CR 43-2 (74.7 t ha^{-1}) and 8S 501-2 (56.7 t ha^{-1}). In location 3 at Chandiyoor, under rainfed condition, CR 43-2 recorded the highest yield (69.2 t ha^{-1}), followed by 8S 501-2 (50.6 t ha^{-1}), and CR 24-4 (44.7 t ha^{-1}). In all the locations, the yield was significantly higher in resistant varieties than susceptible popular varieties (Fig. 117).

The maximum drymatter content was recorded in the variety White Thailand (49.4%) followed by Sree Athulya (45.8%). However, starch content of variety White Thailand (24.7%) was significantly lesser than the CMD resistant varieties *viz.*, CR43-2 (33.8%), 9S127 (33.55%), CR24-4 (33.7%) and 8S501-2 (28.9%). Among the varieties evaluated, three CMD resistant varieties were accepted by the farmers and these lines produced greater starch yield (>20 t ha^{-1}) as compared to Kumkumarose (15.9) and White Thailand (17.9), the popular varieties grown by the farmers. The variety 8S501-2 produced the maximum starch yield of 33.1 t ha^{-1} owing to its very high productivity under irrigated condition.

The cassava clones introduced from ETH Zurich were micropropagated, hardened and established in the field. The lines were screened for CMD resistance through grafting on highly susceptible varieties. Among the six lines, TME3, TME7, UMUCAS33, KBH2006/26 and KBH2006/18 were resistant while TME 14 was susceptible. TME3 and KBH 2006/18 were crossed with Vellayani Hraswa for developing new CMD resistant short duration hybrids.

Fig. 116. Field trial

Fig. 117. Tubers of CMD resistant cassava variety 8S501-2

Disease Diagnostics in Tropical Tuber Crops (ICAR-CRP on vaccines and diagnostics; PI: Dr. T. Makeshkumar)

Validation of Lateral flow device (LFD) based diagnosis of *Dasheen mosaic virus* in elephant foot yam was completed. The LFD kit was officially released in ICAR foundation day 2017. Validation of LAMP based diagnosis of *Sri Lankan cassava mosaic virus* (SLCMV) in cassava plants was completed. The presence of SLCMV was detected in whitefly collected from glass house through LAMP technique. Coat protein gene of SLCMV and DsMV were cloned in bacterial expression vector and confirmed by sequencing.

Development and evaluation of starch based functional polymers for controlled plant nutrient delivery (Kerala State Council for Science Technology and Environment, Govt. of Kerala; PI: Dr. A. N. Jyothi)

Synthesis of urea coated with cross linked cassava starch phosphate

Due to surface runoff, leaching and vaporization, synthetic fertilizers applied to the soil escape to environment to cause diseconomy and environmental problems. Nitrogen is highly leachable and hence the use efficiency of urea by crops is very low. Controlled release fertilizers (CRFs) are designed to improve the soil release kinetics of chemical fertilizers to address such problems. Various polymers are used for coating and encapsulating fertilizers to obtain slow release properties, but most of these coating materials are petro-chemical based and their cost is also very high. Use of natural biodegradable polymers such as starch assumes importance in this scenario. In the present study, urea, coated with cross-linked cassava starch phosphate, a completely biodegradable polymer, has been synthesised to attain sustained release of nitrogen in soil (Fig. 118). Also, coating with starch phosphate and wax layers has also been attempted to prepare double coated urea. These products exhibited high swelling potential and showed significantly higher sustained release of nitrogen in soil compared to uncoated urea. Wax coating could slightly increase the sustained release properties, but not in a very significant way.

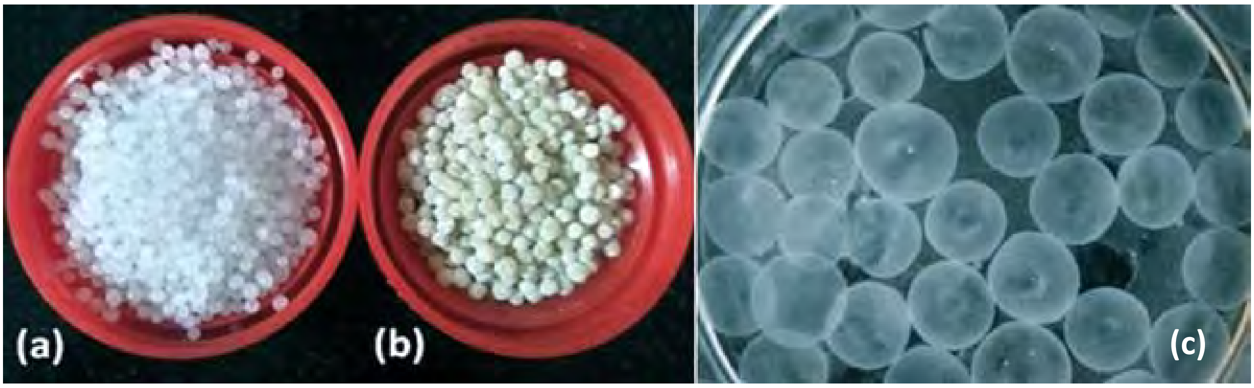


Fig. 118. (a) Urea, (b) urea coated with starch phosphate and (c) coated urea granules swollen in water

Incorporation of urea in cassava starch-layered silicate composite

Cassava starch – montmorillonite (MMT)-urea nanocomposites were prepared using MMT and citric acid modified MMT (CMMT) and nitrogen release studies were carried out in soil (Fig. 119). Release of nutrient was more sustained in MMT incorporated samples in comparison to CMMT as well as control urea. The release of nitrogen from urea incorporated in various starch-MMT composite samples was minimum in red soil, but fastest in laterite soil for all the samples. The citric acid modified MMT composite showed greater release of nitrogen from incorporated urea than native MMT composite. It was especially greater in black soil. In laterite soil, the release of nitrogen from MMT-starch incorporated urea was lesser than that of normal urea.

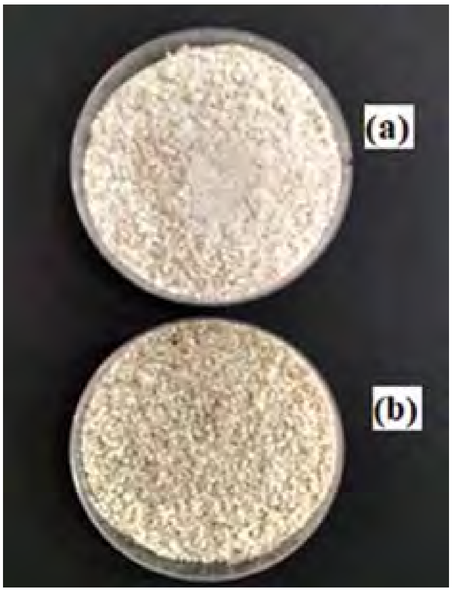


Fig. 119. (a) Cassava starch-MMT-urea composite and (b) cassava starch-CMMT-urea composite

Synthesis of urea coated with chemically modified cassava starch factory solid residue (*Thippi*)

The solid residue from cassava starch industries (cassava bagasse or *thippi*) was chemically functionalised by graft copolymerization reaction with acrylonitrile (Fig. 120). Urea was coated with the modified *thippi* and the product was characterized and nutrient release in soil was studied. The product could be effectively utilized as a coating material for urea in order to develop CRF and sustained release of N could be obtained from the coated samples.

Fig. 120. (a) Urea (b) grafted cassava bagasse (coating material) and (c) coated urea

High Value Compounds/Phytochemicals

(ICAR Network Project; PI: Dr. A. N. Jyothi)

Phyto-chemical analysis of Chinese potato tubers

Phytochemical screening of biochemical constituents in Chinese potato (*Plectranthus rotundifolius)* tubers with methanol, acetone, ethyl acetate, dichloromethane and water extracts showed the presence of important phytochemicals such as flavonoids, terpenoids, steroids, fatty acids, phenols, tannins and saponins. Methanolic extract was phytochemical rich and was superior in view of the presence of most of the phytochemicals except saponins in it. DPPH radical scavenging activity of the extracts followed the order methanol > ethyl acetate water > dichloromethane > acetone extract. The major compound, linoleic acid was purified from the methanolic extract of Chinese potato tubers by column chromatography and was characterized by spectroscopic techniques such as IR, Mass spectra, ^{1}H NMR, ^{13}C NMR, COSEY, DEPT, HMBC and HSQC analysis.

The antioxidant capacity and the interactions of the compounds in aqueous methanolic extract of Chinese potato tuber with various natural extracts were carried out by DPPH, ABTS and glucose inhibition assays. The DPPH and ABTS radical scavenging activity of the Chinese potato tuber extract showed synergistic/antagonistic effects depending on the type of natural extract used. However, the glucose inhibition capacity of all the combined extracts was antagonistic.

Co-pigmentation of anthocyanins with natural extracts and selected phenolic acids

Co-pigmentation is a solution phenomenon where natural pigments such as anthocyanins form molecular association or complexes with other organic compounds and it helps to reinforce the anthocyanins. The effect of co-pigmentation on the antioxidant activity (DPPH and ABTS) and glucose inhibition potential of purified anthocyanins from purple yam (Acc. Da-340*)* and purple sweet potato (*cv.* Bhu Krishna) tubers (Fig. 121) with Chinese potato tuber extract (in aqueous methanol) were investigated. The antioxidant activity showed antagonistic interaction at all the selected ratio and concentrations. However, after co-pigmentation, the glucose inhibition potential of anthocyanins and Chinese potato tuber extract was dramatically decreased. Co-pigmentation and antioxidant activity of purple yam and purple sweet potato tuber with natural extracts (in aqueous methanol) such as beet root (*Beta vulgaris*) root tuber, ginger (*Zingiber officinale)* stem tuber, red onion *(Allium cepa)* bulb, garlic (*Allium sativum*) bulb, pomegranate (*Punica granatum*) and turmeric (*Curcuma longa*) stem tuber were studied. Anthocyanins from sweet potato and purple yam tubers exhibited synergistic interaction with beet root and pomegranate extract, while ginger, garlic, turmeric and red onion extracts showed antagonistic effect. Co-pigmentation of anthocyanins from purple yam and purple sweet potato tuber with selected phenolic acids was also tested using the DPPH and glucose inhibition assay. Co-pigmentation of base hydrolysed anthocyanins with selected phenolic acids was also tested to identify the importance of acyl group in bioactivity. Synergistic interaction of both the anthocyanins (unhydrolysed) was observed with structurally similar ferulic and caffeic acid, but with P-coumaric acid, anthocyanins exhibited antagonistic effect which leads to decrease in antioxidant activity.

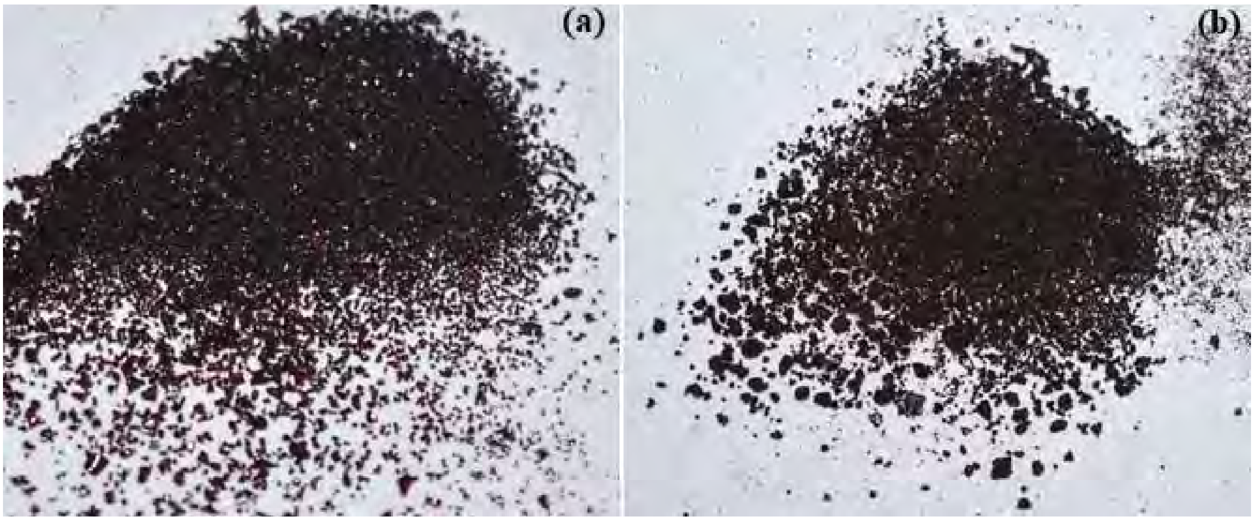


Fig. 121. Anthocyanins from (a) Purple yam (Acc. Da-340) and (b) purple sweet potato tubers (*cv* Bhu Krishna)

Techno Incubation Centre (SFAC, Govt. of Kerala; PI: Dr. M. S. Sajeev)

Thirty in campus training programmeson value addition and entrepreneurship development in tuber crops were organised at the Techno incubation centre of ICAR-CTCRI and 47 incubatees were provided with the incubation facilities for making various tapioca based products *viz*., pakkavada, sweet fries, muruku, crisps, hot crisps, pasta etc (Fig. 122). Six exhibitions were arranged *viz*., 2nd International Exhibition and Workshop on Agro Processing and Value Addition, Trichur, Kerala Agr. University, 27-31st December 2017; Machinery Expo Kerala 2018, Ernakulam in connection with, Dept of Industries, Kerala, 12-14 January 2018, CMFRI, Kochi, 15-17 January 2018, VAIGA 2017; Kerala Agro Food Pro 2018, Thrissur, Dept. of Industries, 10-13th March 2018 and Technology and Machinery Demonstration Mela, 21-22, March 2018, KCAET, Tavanur.

Fig. 122.Trainings at Techno Incubation Centre

Rural Entrepreneurship Development through Training cum Demonstration on Value-Added Products from Tuber Crops (Kerala State Council for Science Technology and Environment, Govt. of Kerala; PI: Dr. M. S. Sajeev)

Eight off campus training programees and exhibition of value added products and processing machineries in tuber crops were organized. Twenty four campus training programmes were organised at the Techno incubation centre of ICAR-CTCRI which was attended by about 441 people including 149 men and 292 women participants. Thirty incubatees were provided with the incubation facilities for making various tapioca based products *viz.*, pakkavada, sweet fries, muruku, crisps, hot crisps, pasta etc. They were provided with the printed covers made under the project. A Seminar on "Rural Entrepreneurship through Value Added Agriculture" was held on 22-12-2017 with Dr. S. Pradeep Kumar, Member Secretary and Director, KSCSTE, Thiruvananthapuram as a Chief Guest (Fig. 123). About 130 people participated in the programme and classes were held on various topics by eminent personalities from various reputed organisations as follows: Entrepreneurship developments in horticulture by Dr. K. P. Sudheer, National Professor and Director, Centre of Excellence in Post harvest Technology, KAU, Thrissur; Scope of under exploited agri-produce for micro enterprises by Dr. Geetha Lekshmi, Asst Professor, Dept. of Processing Technology, KAU, Vellayani; Organic farming for safe food and sustainable income by Dr. G. Suja, Principal Scientist, ICAR-CTCRI, Thiruvananthapuram; Central and State financial schemes for rural entrepreneurship by Ms. Usha K Pillai, Financial Literacy Councillor, Catholic Syrian Bank Ltd., Thiruvananthapuram and Food Safety-Rules and regulations by Ms. Reshmi Rajan, Food Safety Officer, Office of the Commissioner of Food Safety, Thiruvananthapuram.

Fig. 123. Activities under rural entrepreneurship development through training cum demonstration on value-added products from tuber crops

Assessment of roles and performance of agricultural enterprises of Agri Clinic and Agri-business Clinics Scheme in the emerging startup ecosystem (MANAGE, Hyderabad; PI: Dr. P. Sethuraman Sivakumar)

A survey of the status of AC and ABC ventures in Maharashtra, Kerala and Tamil Nadu was completed. During the survey the data were collected from a total of 110 entrepreneurs who established the unit and 120 trained entrepreneurs who didn't create an enterprise. A well-structured questionnaire representing all aspects of startup ecosystem-mentoring, funds, policy support, technology availability, entrepreneurial tendency etc., was developed and pre-tested with 30 samples and modified suitably.

A total of 20503 persons were trained in Maharashtra, Kerala and Tamil Nadu states of which 9826 established ventures indicating 47.92% success rate. The proportion of trainees creating a new venture is highest in Tamil Nadu (51.59%), followed by Maharashtra (46.49%) and Kerala (25.63%). Most entrepreneurs (91%) had medium level of Enterprising Tendency, and there is a need to enhancing their enterprising tendency through training. The sub-component wise analysis of enterprising tendency revealed that Kerala entrepreneurs had high level of enterprising components, which are significantly different from other states ($p<0.05$). The Maharashtra and Tamil Nadu entrepreneurs has similar creative tendencies, but significant different in other components ($p<0.05$)

The dimensions of entrepreneur's perception on the favourableness of startup ecosystem were derived through exploratory factor analysis. The analysis has revealed six latent factors such as favourable govt policy, entrepreneurial culture, availability of technical and business support, availability and access to funds, willingness to take risk and access to business mentoring.

National Agricultural Innovation Fund (NAIF): (Component 1 Innovation Fund)

(ICAR, New Delhi; PI: Dr. P. Sethuraman Sivakumar)

The technology commercialisation and entrepreneurship development activities of the Institute are executed by Intellectual Property Management Unit and Professional Services Cell (IPTMU&PSC) in collaboration with Divisions/ section and Techno-Incubation Centre (TIC). The following activities were conducted during 2017-2018.

Technology commercialisation

Six technologies including fried snacks and protein enriched pasta were commercialised to entrepreneurs from Kerala, Karnataka and Tamil Nadu and one contract research proposal for developing jackfruit based pasta was signed. Besides regular training programmes conducted by Techno-Incubation Centre, a special programme on social science research methodology was organised on payment basis. The revenue generated through various activities at the Institutional level in all modes is indicated in Table 14.

Table 14. Revenue generated through technology commercialisation and other professional service functions

Activity	Revenue generation (₹)
Technology licensing	2,06,500
Sale of technological products	13,10,910
Contract service	94,914
Professional training	1,20,000
Total	17,32,324

Entrepreneurship promotion

Considering the need for promoting agricultural technology-based entrepreneurship, the following programmes were organised. Two national level programmes (i) AGRISTARTup 1.0 – Tuber Crops Technology Conclave and Agristartup Meet 2017 at ICAR – CTCRI during Oct 27-28, 2018 and (ii) "Horti-Technology Incubation for Agristartup and Entrepreneurship Development in Odisha" meet at the Regional Centre of ICAR-CTCRI, Bhubaneswar on November 11, 2018, were organised. Two farmer-oriented entrepreneurship programmes (i) Entrepreneurship development programme on Cassava-based Agro-enterprises for Developing Sustainable Tribal Livelihoods at Pachamalai hills, Tamil Nadu on 02 February 2018 and (ii) Entrepreneurship Development Programme on Utilising Village Incubation Centre for Creating Sustainable Tuber Crops Based Enterprises at ICAR-CTCRI and ICAR RC NEH Village Incubation Centre, Riha Village, Ukhrul district, Manipur on 14 March 2018 were organised. One specialised student-oriented programme 'Entrepreneurship Development Programme' for B.Sc., Agricultural Students of KAU was conducted for final year B.Sc.(Ag.) students at ICAR-CTCRI during 16-17 November, 2017. The IPTMU and PSC under the guidance of IPTMC has organised a brainstorming on "Developing quality planting materials of tuber crops" on August 2, 2017 to finalise quality planting material production protocols of tuber crops.

ICAR-CTCRI-Tribal Sub Plan on Livelihood improvement of tribal farmers through tuber crops technologies

(ICAR, PI: Dr. M. Nedunchezhiyan)

During the year 2017-18 two tribal villages were selected one each from Odisha and Jharkhand states. Dadrisahi village in Chakapad block, Kandhamal district, Odisha and Burahkocha village in Angara block, Ranchi district, Jharkhand were selected. In Dadrisahi village 24 tribal households and in Burahkocha village 57 tribal households were adopted for conducting tuber crops demonstration (Fig. 124). Sweet potato 50, 000 vine cuttings, Cassava 3000 stems, yam bean 52.5 kg, other vegetable seeds 3.6 kg and greater yam 900 kg and vegetable seeds 2 kg were distributed to the farmers. A solar pumpset was installed in Burahkocha (village), Angara (block), Ranchi (district), Jharkhand for irrigating the crops during dry spells and rabi and summer seasons. Four numbers of on-farm trainings were conducted for capacity building of tribal farmers on tuber crops cultivation.

Fig. 124. Tuber crops cultivation in Dadrisahi village, Odisha

Establishment of Techno-Incubation Centre at the ICAR-Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar for the commercialization of value added products from sweet potato and other tuber crops (RKVY; PI, Dr. M. Nedunchezhiyan)

Techno-Incubation Centre was established at the Regional Centre of ICAR-CTCRI, Bhubaneswar with the financial support of RKVY, Odisha. Equipments related to production of pasta, extruded products, chips and snack foods as well as packing machines were procured and installed. Dr. Trilochan Mohapatra, Secretary (DARE) and Director General of ICAR, New Delhi inaugurated the Techno Incubation Centre in presence of Dr. Archana Mukherjee, Director, ICAR-CTCRI, Thiruvananthapuram and Dr. M. Nedunchezhiyan, Head (i/c), Regional Centre of ICAR-CTCRI, Bhubaneswar on 18.11.2017 (Fig. 125). More than 100 entrepreneurs participated in the inaugural programme apart from other dignitaries. A batch of 20 persons were trained on entrepreneurship development in tuber crops.

Fig. 125. Inauguration of techno incubation Centre

TECHNOLOGIES ASSESSED, TRANSFERRED, CONSULTANCY AND PATENT SERVICES

Technologies transferred

The Intellectual Property and Technology Management Unit & Professional Services Cell (IPTMU&PSC) under the guidance of the Intellectual Property and Technology Management Committee (IPTMC) has carried out the following technology transfer and contract activities during 2017-2018.

Technology commercialisation

Six technologies including fried snacks and protein enriched pasta were commercialised to entrepreneurs from Kerala, Karnataka and Tamil Nadu and one contract research proposal for developing jackfruit based pasta was signed. Besides regular training programmes conducted by Techno-Incubation Centre, a special programme on social science research methodology was organised on payment basis. The revenue generated through various activities at the Institutional level in all modes is indicated in Table 15.

Table 15. Revenue generated through technology commercialisation and other professional service functions

SNo	Activity	Revenue generated (₹)
1	Technology licensing	206500
2	Sale of technological products	1310910
3	Contract service	94914
4	Professional training	120000
	Total	1732324

Value added fried products and fried chips from tapioca and / or sweet potato on a technology licensing and consultancy mode to four firms/ individuals (i) Mr. Pradeep PS, TC/65/562, Prabhasadanam, Madathilnada, Thiruvallam PO, Thiruvananthapuram 695027; (ii) M/s Jaihari Food Products, Peringanadu P.O. Adoor, Pathanamthitta Dist, Pin 691551; (iii) M/s Chipsnco Pvt Ltd, 18, Teekay Grand, Krishna Nagar Industrial Layout, Koramangala, Bengaluru – 29 and M/s S.Ganesh & Nagendra Co, 396-B MS Road, Parvathipuram, Nagercoil, Tamil Nadu 629003; The firm M/S., Brahma Indic Nutriments Pvt Ltd (Formerly Planet Nutriments), Adat, Puranattukara PO., Thrissur – 680551, Kerala has licensed both Value added fried products and fried chips from tapioca and sweet potato along with protein enriched pasta.

Contract research

Smt. Rajasree, R., Harimangalaththekkathil, Panayil PO., Nooranad, Alapuzha (Dist.) – 690504, Kerala has entered into a contract research work for developing "A process for the production of cassava-jack fruit bulb flour based pasta".

Technologies/varieties developed:

Varieties

- High yielding varieties of cassava with CMD resistance viz., Sree Reksha, tolerant to post harvest physiological deterioration and PDP CMR1 tolerant to drought were released.
- Released Sree Nidhi, high yielding greater yam variety with good culinary quality and tolerance to anthracnose disease for cultivation in Kerala.
- Released one bushy white yam variety "Sree Swetha" with high yield (34 t ha^{-1}) and culinary quality for cultivation in Kerala.
- Released one white yam variety "Sree Haritha" with high yield (46 t ha^{-1}) and compact tuber shape for cultivation in Kerala.
- Identified one non trailing white yam hybrid, SD-15 with high yield and culinary quality.
- Identification of genotypes *viz.*, Sree Pavithra, 7 III E3-5, CI-905 and CI-906 as NPK efficient.

- Identified the salt tolerant variety Samrat of sweet potato for island ecosystem of Andaman.

Methodologies

- Predicted starch biosynthesis pathway in cassava.
- Predicted carotenoid biosynthesis pathway in cassava.

Production technologies

- *Five foliar liquid micronutrient formulations* for SSNM of cassava (2 products), sweet potato, elephant foot yam and yams.
- *Five foliar solid micronutrient formulations* for SSNM of cassava (2 products), sweet potato, elephant foot yam and yams.
- Soil test based soil application of B for cassava.
- Protocol for synthetic seed production in cassava has been developed.
- Rationalization of the existing NPK recommendation for sweet potato with INM strategy involving gypsum/dolomite @ 2 t ha^{-1} as the liming material, NPK @ 50:50:100 kg ha^{-1}, soil application of $MgSO_4$@ 80 kg ha^{-1} /$ZnSO_4$@ 20 kg ha^{-1} (depending upon the soil status) and foliar application of boron (0.1%) as solubor/$MgSO_4$ (1%)/ combination of KNO_3(1%) and solubor (0.1%)(depending upon the requirement).
- Production technology for rice-short-duration cassava + black gram system.
- Production technology for elephant foot yam + pulse system.
- In elephant foot yam, weed control ground cover 2 rounds of manual weeding (30 and 60 DAP)+Glyphosate (90 DAP) treatment may be recommended as alternate to farmers practice of 4 manual weeding (30, 60, 90 and 120 DAP).
- Assessed the heavy metals and micro nutrients in the polluted areas adjacent to mines and industrial areas.
- INM strategies for sweet potato, colocasia, yam bean and elephant foot yam in acid Alfisols were developed.
- Technologies on usage of graded doses of NPK, organic sources, secondary and micro nutrients on yield & proximate composition of tuber crops and its residual effect on soil quality were developed.
- Developed nutrient management strategies for sweet potato under island ecosystem of Andaman.

Protection technologies

- Tuber treatment with 0.1% Mancozeb+ Carbendazim+ 0.7% *Nanma* for post harvest rot in elephant foot yam.
- Developed loop mediated isothermal amplification technique (LAMP) for detecting *Phytophthora colocasiae.*
- Developed loop mediated isothermal amplification technique (LAMP) for detecting *Colletotrichum gloeosporioides.*
- Optimized metagenomic study of whitefly endosymbionts.
- Climate and suitability change predictions for major cassava growing regions of India.
- Among the three CF formulations developed for EFY under intercropping in coconut, CF2@625 kg ha^{-1} and CF1 and CF2 @500 kg ha^{-1} was found best for EFY and cassava respectively.
- LAMP based diagnosis of Sri Lankan Cassava mosaic virus (SLCMV) and Dasheen mosaic virus (DsMV).

Technologies for value added food products

- Preparation of papad from fresh cassava tubers and cassava flour.
- Production of pasta from Elephant Foot Yam (EFY) flour and multigrain.
- Development of sago (sabudana) from cassava based dry starch.

Technologies for industrial products

- Production of biochar from tuber crop residues such as cassava stems, yam and arrowroot crop residue was standardized.
- Particle board from cassava stems were prepared using modified starch and coir pith.
- Laboratory scale processes for single phase, moisture resistant and caustic alkali free corrugating adhesive formulations based on cassava starch.
- Method of cassava wax coating along with pretreatment was developed and tested.

Decision Support Systems/Bioinformatics Tools

- *Sree Poshini*, a mobile app for SSNM of tropical tuber crops
- Cassava commodity model
- Model on Value chain analysis of sweet potato
- VIT app and TUBERGURU app

EDUCATION AND TRAINING

Education

ICAR-CTCRI is recognized as an approved Research Centre by the University of Kerala, Kannur University and Manonmaniam Sundaranar University for undertaking Ph. D. programmes on tuber crops. During the period, the Institute has offered exposure training to students, imparted technical guidance for Ph.D. programmes and project work of M.Sc. students. Besides, the scientists of ICAR – CTCRI have handled courses at College of Agriculture, Vellayani for the students of M.Sc. Course on Integrated Biotechnology.

Particulars of the programme	Number of students
B.Sc. Project work	105
B.Sc. Internship	26
M.Sc. Project work	46
M.Sc. Integrated Biotechnology	13
Ph.D.	19
PDF	03

International training programmes

Three International training programmes were organized for the benefit of the participants from various countries who deal with tropical tuber crops.

Shri. Samuel Karicho, Minister at the Kenyan High Commission of India delivering inaugural address

- The Feed the Future–India Triangular Training Programme (FTF-ITT) sponsored by National Institute of Agricultural Extension Management (MANAGE), Hyderabad on "Production and processing technology for tuber crops" was organised at ICAR – CTCRI during April 4-18, 2017. The programme was inaugurated by Shri. Samuel Karicho, Minister at the Kenyan High Commission of India on April 5, 2017 in the presence of Smt. V. Usha Rani IAS, Director General, MANAGE, Dr. Archana Mukherjee, Director, ICAR-CTCRI and Dr. James George, Project Coordinator, AICRP TC. Twenty three executives from Botswana, Ghana, Kenya, Liberia, Malawi, Mozambique and Uganda participated in the programme. The training was imparted through interactive lectures, live demonstrations, hands on experiences and field visits to farmers' fields, industries and marketing agencies. An innovative "Tuber Crops Ethnic Food Festival" was also organised alongside a multicultural programme as a part of the training. Shri. A. M. Sunil Kumar, Additional Director, Department of Agriculture, Government of Kerala has delivered the Valedictory address and distributed certificates to the participants. ICAR-CTCRI team led by Dr. P. Sethuraman Sivakumar, Programme Coordinator has organised this training programme.

Participants of the training

- Training on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops sponsored by Ministry of External Affairs, Govt. of India was conducted during 28 February-09 March, 2018 at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram. Fifteen participants from Uganda, Ethiopia, Nigeria, Sudan and Addis Ababa attended the training programme. Lecture cum discussions, practical sessions on value addition, field visits and exposure visits to industries were organized.


Participants of the training

- Training programme on 'Genetic Improvement of Tropical Tuber Crops through Conventional and Biotechnological Approach' sponsored by the Ministry of External Affairs, Govt. of India was organized at ICAR-CTCRI during 1-15, March 2018. Eight participants from Kenya, Malawi and Ethiopia attended the training which included theory and practical classes on different aspects of germplasm conservation and genetic improvement of tropical tuber crops. The trainees were given practical training on breeding of cassava, sweet potato, yams, taro and elephant foot yam. The advanced topics on gene editing, genomics, cytology, and marker assisted breeding and development of transgenics were also covered. Field visits to innovative farmers and cassava based industries were also organized.


Participants of the training

Model training course

- Model training course on 'Post harvest processing and value addition in tuber crops' sponsored by Directorate of Extension, Ministry of Agriculture and Farmers Welfare was conducted during 4-11 December, 2017 at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram. Twenty participants from seven states *viz.*, Kerala, Karnataka, Tamil Nadu, Bihar, Jammu and Kashmir, Tripura and Delhi participated in the training programme.

Participants of the training


Demonstration on starch extraction

Training programmes

A total of 1653 farmers, 1933 students and 239 officials from different parts of the country visited the Institute. They were taught on the recent technologies of tuber crops for enhancing productivity and profitability in farming.

- Stakeholders interface programme was organized on 29 July 2017 in connection with 54^{th} Foundation day celebrations at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram. More than 150 farmers and other stakeholders participated.

- Scientist-farmers interface programme on coconut based tuber crops farming system was organized on 16 August 2017 in collaboration with ICAR-CPCRI, Kasaragod at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram for the benefit of 60 farmers.

Inaugural address by the Director, ICAR-CTCRI

- Inter-Media publicity coordination committee interface was organized on 23 August 2017 at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram.
- Training on Public Financial Management System (PFMS) for the staff members of ICAR-CTCRI was organized on 16 September 2017 at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram.
- Women farmers' day was celebrated on 17 October 2017 at ICAR-CTCRI, Sreekariyam, Thiruvananthapuram. Farmers' were felicitated with awards and certificates.

Women farmer felicitated by the Director, ICAR-CTCRI

- RAWE programme on improved technologies of tuber crops for B.Sc. (Agri) students at ICAR-Central Tuber Crops Research Institute, Sreekariyam Thiruvananthapuram organized during 06-12 November 2017.

RAWE students with Director and ICAR-CTCRI staff

- Entrepreneurship development programme for agricultural students was jointly organized by ICAR-CTCRI and College of Agriculture, KAU, Vellayani during 16-17 November, 2017 at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram.
- Stakeholders interface programme was organized on 04 December 2017 as part of Tuber crops day celebrations 2017 at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram.
- Stakeholders interface programme was organized on 04 December 2017 as part of Agricultural Educational Day celebrations 2017 at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram.
- Entrepreneurship development programme on Cassava-based agro-enterprises for developing sustainable tribal livelihoods was organized on 02 February 2018 at Pachamalai hills, Trichy district, Tamil Nadu.
- Entrepreneurship development programme on Utilising Village Incubation Centre for Creating Sustainable Tuber Crops Based Enterprises was organized on 14 March 2018 at ICAR-CTCRI and ICAR RC NEH Village Incubation Centre, Riha Village, Ukhrul district, Manipur in which more than 100 farmers participated.
- Stakeholders interface programme was organized on 17 March 2018 as part of Hon'ble Prime Minister's live telecast programme from Krishi Unnati Mela, Pusa at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram.

- **In house training for skilled supporting staff:** Refresher training on improved technologies of tuber crops for 25 Skilled Supporting Staff for knowledge and skill enhancement was conducted during 26 – 27 March 2018 at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram. The classes were handled by the scientists and other staff of the Institute. Exposure was given to them in all the activities undertaken by the Institute.

Participants of the training

Trainings organized by Techno Incubation Centre, ICAR-CTCRI

Thirty four on campus training programmes on **“**Practical demonstration of value added products and entrepreneurship development in tuber crops” were organized at Techno Incubation Centre, ICAR-CTCRI. Eight off campus training on ‘Value added products and entrepreneurship development on tuber crops’ were also organised.

On campus training programmes

Off campus training programmes

Resource person in training programmes

More than 160 classes on production, protection, processing and value addition aspects were handled by scientists of various divisions under different programmes within and outside the Institute beneficial to department officials, subject matter specialists, students and farmers all over the country. The specific topics covered were improved varieties, tissue culture, agro-techniques with special focus on organic management, INM, IPM, vermi–composting, bio–pesticides and bio-control strategies, post – harvest management and value addition.

Tribal Sub Plan Scheme at Regional Centre, ICAR-CTCRI

- Four numbers of on-farm trainings were conducted for capacity building of tribal farmers on tuber crops cultivation for the tribal people of Dadrisahi village in Chakapad block, Kandhamal district, Odisha and Burahkocha village in Angara block, Ranchi district, Jharkhand.

Exposure visit cum training programme

- Twenty one-day exposure visit cum training on improved technologies of tuber crops was organized at ICAR-CTCRI, HQ for the benefit of 703 farmers from Kerala, Tamil Nadu, Puducherry, Maharashtra and Andhra Pradesh.

Farmers from Thiruvananthapuram, Kerala

Farmers from Kanyakumari, Tamil Nadu

Farmers from Tirunelveli, Tamil Nadu

Farmers from West Godavari, Andhra Pradesh

- Twenty seven one-day exposure visit cum training on improved technologies of tuber crops were organized at ICAR-CTCRI, RC Bhubaneswar for the benefit of 995 farmers from eastern part of India.

Trainings attended by ICAR – CTCRI staff

a. Scientific staff

Sl. No.	Name of scientist	Particulars of the training	Period
1.	Mrs. Sirisha Tadigiri	Quarantine Pests, Detection and Identification at National Institute of Plant Health Management, Hyderabad	4 – 25 April 2017
2.	Dr. D. Jaganathan	Agricultural Innovation Systems: Multi–Stakeholder Partnership and Convergence in Extension at National Institute of Agricultural Extension Management, Hyderabad	3 – 5 May 2017
3.	Dr. C. Visalakshi Chandra, Dr. P. Arun Kumar	Experimental Approaches for the Utilization of Genomic Resources of Horticultural Crops at College of Horticulture, University of Horticultural Sciences, Bengaluru	5 – 25 July 2017
4.	Dr. G. Suja	Stability/Combined Analysis of NPOF Experimental Data at ICAR – Indian Institute of Farming Systems Research, Modipuram, Meerut	25 – 26 July 2017
5.	Mr. P. Prakash	Good Practices in Quantitative Social Science Research: A Journey from Conceptualization to Research Application at ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram	7 – 12 August 2017

Sl. No.	Name of scientist	Particulars of the training	Period
6.	Dr. Sanket J. More	Recent Advances in Abiotic Stress Management for Climate Smart Agriculture at ICAR – National Institute of Abiotic Stress Management, Pune, Maharashtra	8 – 28 September 2017
7.	All Scientists	Public Financial Management System (PFMS) at ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram	16 September 2017
8.	Dr. T. Krishnakumar	Food Safety and Quality Management Systems for a Farm to Fork Approach at Department of Agricultural Microbiology, Directorate of Natural Resource Management, Tamil Nadu Agricultural University, Coimbatore	1 – 21 November 2017
9.	Mr. R. Arutselvan	Use of Biotechnological and Conventional Tools for Understanding Virus – Host Interactions at ICAR – Indian Agricultural Research Institute, New Delhi	7 – 27 November 2017
10.	Dr. K.M. Senthilkumar	Next Generation Sequencing (NGS) and Its Application in Crop Science at ICAR – National Research Centre on Plant Biotechnology, New Delhi	1 – 21 December 2017
11.	Dr. P. Murugesan	Assessors Programme, Agriculture Skill Council of India, Bengaluru, Karnataka	9 – 10 December 2017
12.	Dr. D. Jaganathan Mr. P. Prakash Dr. H. Kesava Kumar Dr. T. Krishnakumar	Hindi Prabodh class at All India Radio, Vazhathacaud, Thiruvananthapuram	18 – 19 December 2017
13.	Dr. Sangeetha B. G.	Whole Genome Sequencing of Plant Pathogens: Methods and Applications at Division of Plant Pathology, ICAR – Indian Agricultural Research Institute, New Delhi	29 December 2017 - 18 January 2018
14.	Dr. P. Murugesan	Exploitation and Conservation of Plant Genetic Resources of Major, Minor and Under Exploited Horticultural Crops at University of Horticultural Sciences, Bagalkot, Karnataka	3 – 23 January 2018
15.	Dr. A.V.V. Koundinya	Computational and Statistical Advances for Analysis of Biological Data in Agriculture at ICAR – Indian Agricultural Statistics Research Institute, New Delhi	24 March – 13 April 2018

b. Technical Staff

Sl. No.	Name	Particulars of the training	Period
1.	Mrs. T. K. Sudhalatha, Assistant Chief Technical Officer	Hindi Workshop of TOLIC, Vikram Sarabhai Space Centre, Town Official Language Implementation Committee, Thiruvananthapuram, Kerala	23 February 2018
		Conference on Official Language, HLL Lifecare Ltd., Inter TOLIC, Town Official Language Implementation Committee, Thiruvananthapuram, Kerala	9 March 2018

c. Administrative Staff

Sl. No.	Name	Particulars of the training	Period
1.	Shri. S. Sreekumar, Upper Division Clerk	CPC-TDS, One day Awareness Programme at Thycaud Thiruvananthapuram	24 July 2017
2.	Shri. P. C. Noble, AAO	General FR at Institute of Secretariat Training and Management (ISTM), New Delhi	30 August to 1 September 2017
3.	Shri. M. Padmakumar, Personal Assistant	Enhancing Efficiency and Behavioural Skills at ICAR–National Academy of Agricultural Research and Management, Hyderabad	25 – 31 October 2017

d. Skilled Supporting Staff

Sl. No.	Name	Particulars of the training	Period
1.	Shri. D. Arun Raj Shri. S. Abhishek Shri. P. Aswin Raj Shri. A. Chandran Shri. T. Lawrence Shri. K. Sivadas Smt. P. Vidhya Smt. S. Ushakumari Shri. P. Udaya kumar Smt. J. Thenmozhi Shri. S. Sudhish Shri. Stiphin George Shri. Sreenath Vijay Smt. S. D. Saritha Shri. K. Sarathchandra Kumar Shri. L. Samynathan Ms. Rohini K. Nair Smt. Rini Alocious Smt. V. S. Remya Shri. G. Madhu Smt. S. L. Jyothy Ms. C. P. Gayathri Smt. C. T. Chellamma Shri. K. Chandran Ms. S. S. Sneha	Refresher Training on Improved Technologies of Tuber Crops at ICAR - Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram	26 – 27 March 2018

AWARDS AND RECOGNITIONS

Awards

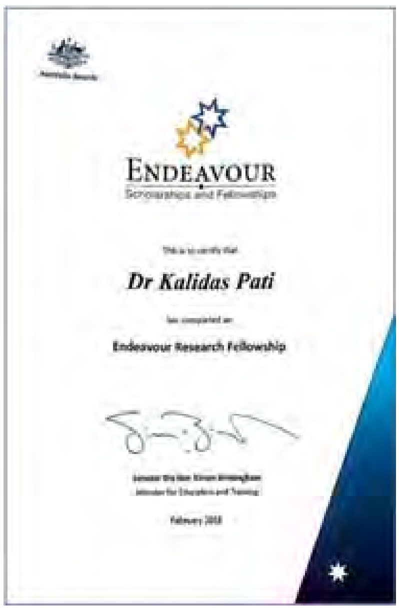
- Dr. Archana Mukherjee has won the prestigious National award 'Panjabrao Deshmukh Outstanding Woman Scientist award 2016' for her meritorious research work on developing climate resilient nutrient rich tuber crops *viz.,* sweet potato and taro for the upliftment of under-privileged and under-nourished tribal population in India. The Director of ICAR - CTCRI received the award from Shri. Radha Mohan Singh, Honourable Union Minister for Agriculture and Farmers' Welfare in the presence of Dr. Trilochan Mohapatra, Secretary DARE and Director General, Indian Council of Agricultural Research and other dignitaries on 16 July 2017 on the occasion of Foundation Day Celebrations of the Indian Council of Agricultural Research (ICAR), New Delhi.

Dr. Archana Mukherjee receiving the Panjabrao Deshmukh outstanding woman scientist award from Shri. Radha Mohan Singh, Hon'ble Union Minister for Agriculture and Farmers' Welfare

- Dr. K. Susan John received the prestigious 'International Zinc Association (IZA)-Fertilizer Association of India (FAI) award – 2017' for promoting the use of zinc in agriculture for enhancing crop productivity from Shri. Ananth Kumar, Honourable Union Minister for Chemicals and Fertilizers on 5 December 2017 at New Delhi. The award carried gold medal, citation and prize money of ₹ 1.00 lakh.

Dr. K. Susan John receiving the 'IZA – FAI' award – 2017

- Dr. Kalidas Pati was awarded the 'Endeavour Research Fellowship' for post-doctoral research at the University of Western Australia, Perth, Australia under 'Australia Award' from Honourable Minister for Department of Education and Training, Australian Government.



- Dr. R. Muthuraj received best poster award in the 'National Conference on New Vistas in Vegetable Research towards Nutritional Security under Changing Climate Scenario' organised by Department of Vegetable crops, Horticultural College and Research Institute, TNAU, Coimbatore during 6 – 12 December, 2017.

Dr. R. Muthuraj receiving the best poster award in NCVR – 2017 at TNAU

- Dr. Sirisha Tadigiri received best poster award on '*In-vitro* evaluation of potential bio-agents against root knot nematode, *Meloidogyne incognita*' at the 5th International Conference on Agriculture, Horticulture and Plant Science at Rishikesh, Uttarakhand during 24-25 June 2017.

- Dr. Visalakshi Chandra C. secured second position in the competition of poem recitation (*Kavitha Paat*) organized by Town Official Language Implementation Committee (TOLIC) at Thiruvananthapuram, Kerala.

- Basketball team consisting of Dr. Sanket J. More, Shri. V. R. Sasankan, Shri P.C. Noble, Shri. R. Bharathan, Dr. S. Shanavas, Shri. C. Chandru, Shri. A. Chandran bagged the first prize at the ICAR – Inter Institutional Tournament (South Zone) held at Coimbatore during 9–13 October 2017 and bagged second prize at ICAR Inter-Zonal Sports Meet – 2017 held at Hyderabad during 21–25 February 2018.

- ICAR- Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram bagged first prize in the category of 'Best Exhibition Stall Award' in Agricultural exhibition at VFPCK, Anchal, Kollam during 07-11 December 2017.

- ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram bagged second prize in the category of 'Best Exhibition Stall Award' in National Banana Festival 2018 at Vellayani Devi Temple ground, Kalliyoor, Thiruvananthapuram held during 17-21 February 2018.

- Shri Arun Raj, D., Shri Aswin Raj, P. and Shri Stiphin George bagged best trainee awards in the refresher training on 'Improved technologies of tuber crops' organized during 26-27 March 2018 at ICAR- CTCRI, Sreekariyam, Thiruvananthapuram.

Award of Ph. D.

- Mrs. Soumya B. Nair was awarded Ph.D. in Chemistry from University of Kerala for the thesis entitled 'Investigations on the preparation, characterization and applications of starch based composites and blends' under the guidance of Dr. A. N. Jyothi.

- Ms. Krishna Radhika N., Scientist, (Agricultural Biotechnology) was awarded Ph. D. in Biotechnology under the faculty of Applied Science and Technology from the University of Kerala for her thesis entitled 'Prospecting of *Cheilanthes farinosa* (Forsk.) Kaulf. for its Anti-angiogenic and Anti-Hepatocellular Carcinoma Activities.

- Ms. Shanida Beegum S.U. was awarded Ph.D. in Environmental Sciences for thesis entitled 'Low input management strategy for cassava (*Manihot esculenta* Crantz): Implications of rhizosphere dynamics and carbon sequestration under global climate change' from the University of Kerala, Thiruvananthapuram, Kerala under the guidance of Dr. Susan John K.

- Dr. E. R. Harish, Scientist, (Agril. Entomology) was awarded Ph. D. in Agricultural Entomology from College of Horticulture, Kerala Agricultural University, Vellanikkara for the thesis entitled 'Characterisation of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), for genetic variability, endosymbionts and vector-virus interactions in cassava' under the guidance of Dr. Mani Chellappan, Kerala Agricultural University.

- Dr. Mithun Raj was awarded Ph.D. in Biotechnology from the University of Kerala, Thiruvananthapuram for the thesis entitled 'Characterisation and Diagnosis of *Colletotrichum gloeosporioides* causing anthracnose/die-back in greater yam (*Dioscorea alata*)' under the guidance of Dr. Vinayaka Hegde, ICAR - CPCRI and co - guidance of Dr. M. L. Jeeva, ICAR-CTCRI.

M. Sc. Biotechnology/B.Sc.-M.Sc. Integrated Biotechnology/M.Sc. Microbiology

- Ms. Anjali Sabu C. was awarded B.Sc.–M.Sc. in Integrated Biotechnology from Kerala Agricultural University. The project work was done on the topic 'Characterization of selected accessions of cassava germplasm using morphological and molecular markers' at ICAR-CTCRI under the guidance of Dr. Asha K. I.
- Ms. Gayathri P. Nair was awarded M.Sc. in Biotechnology from the University of Kerala. The project work was done on the topic 'Molecular Characterisation of Chinese potato (*Plectranthus rotundifolius* Spreng.) Germplasm Using ISSR Markers' at ICAR-CTCRI under the guidance of Dr. Asha K. I.
- Ms. Asha Poorna T. was awarded M.Sc. in Biotechnology from the University of Kerala for the project work entitled, 'Cloning of *gbssI* gene fragment into pMD-T vector' at ICAR-CTCRI under the guidance of Dr. Krishna Radhika N.
- Ms. Anjumol Abraham was awarded M. Sc. in Biotechnology from the University of Kerala for the project work entitled 'Somatic Embryogensis in Selected Cassava (*Manihot esculenta* Crantz) Genotypes' at ICAR-CTCRI under the guidance of Dr. Krishna Radhika N.
- Ms. Aishwarya Nair was awarded M.Sc. in Biotechnology from the University of Kerala. The project work was done on the topic 'Evaluation for Post-harvest Physiological Deterioration tolerance in Cassava (*Manihot esculenta* Crantz)' at ICAR-CTCRI under the guidance of Dr. Visalakshi Chandra C.
- Ms. Swathy A.S. was awarded M.Sc. in Biotechnology from the University of Kerala. The project work was done on the topic 'Comparative analysis of DNA isolation methods in lesser yam (*Dioscorea esculenta*)' at ICAR-CTCRI under the guidance of Dr. Visalakshi Chandra C.
- Ms. Sree Vidya M.R. was awarded B.Sc.–M.Sc. in Integrated Biotechnology from Kerala Agricultural University. The project work was done on the topic 'Molecular characterization of taro [*Colocasia esculenta* (L.) Schott] and its conservation *in vitro*' at ICAR - CTCRI under the guidance of Dr. Asha Devi A.
- Ms. Gopika, M. was awarded M.Sc. in Biotechnology from the the University of Kerala. The project work was done on 'Assessment of genetic diversity in tannia (*Xanthosoma sagitiifolium*) by using ISSR marker' at ICAR - CTCRI under the guidance of Dr. Asha Devi A.
- Ms. Akshara George was awarded B.Sc. – M.Sc. in Integrated Biotechnology from the Kerala Agricultural University. The thesis work was done on 'Genetic Diversity analysis of *Phytophthora colocasiae* using SSR markers' at ICAR - CTCRI under the guidance of Dr. M. L. Jeeva.
- Ms. Aarathy M.B. was awarded B.Sc. – M.Sc. in Integrated Biotechnology from Kerala Agricultural University. The project work was done on 'Molecular characterization of Taro bacilliform virus (TABV)' ICAR – CTCRI under the guidance of Dr. T. Makeshkumar.
- Ms. Ashna N. K. was awarded B.Sc. – M.Sc. in Integrated Biotechnology from Kerala Agricultural University. The project work was done on 'Molecular characterization of Sweet potato feathery mottle virus' ICAR – CTCRI under the guidance of Dr. T. Makeshkumar.
- Ms. Aparna Prakash awarded M.Sc. in Microbiology from Gandhi University, Kerala. The project work was done on 'Secondary and micronutrients on soil health and plant growth under sweet potato' at ICAR-CTCRI under the guidance of Dr. K. Susan John.
- Ms. Jaseela Farbeen P. was awarded M.Sc. in Microbiology from Mahatma Gandhi

University, Kerala. The project work was done on 'Phosphorus and liming materials on soil health and plant growth under sweet potato' at ICAR - CTCRI under the guidance of Dr. K. Susan John.

- Mr. Md. Wazid awarded M.Sc. in Biotechnology from Utkal University, Bhubanewar, Odisha. The project work was done on '*In vitro* screening for drought tolerance in sweet potato, at ICAR-CTCRI under the guidance of Dr. Hanume Gowda.

Recognitions

Dr. Archana Mukherjee

- Participated as Panelist and delivered lecture on 'Tropical Tuber Crops: Sustainable Option for Food and Nutrition in the Technical Session IV: Role of Technology in Farming System for Nutrition at International Conference on Farming System for Nutrition held at MSSRF, Chennai on 9 August 2017.
- Delivered lecture on 'Conservation of Future Smart Tropical Tuber Crops for Adaptive Food, Nutrition and Livelihood' in the National Seminar on Modern Trends in Conservation, Utilisation and Improvement of Plant Genetic Resources organized by Department of Botany, University of Kerala, Karyavattom on 23 November 2017.
- Delivered a lead lecture on 'Wide Adaptive Tropical Tuber Crops for Food, Nutrition and Livelihood' in the Conference 'Farming System Innovation' at Bidhan Chandra Krishi Vishwa Vidyalaya, Kalyani, Kolkata held during 12 – 13 January 2018.
- Member of State Level Project Screening Committee (SLPSC) for RKVY, Govt. of Kerala.

Dr. M. N. Sheela

- Resource person for the Seminar on 'Provisions of PPV&FR Act 2001' organized at ICAR – Indian Institute of Spices Research, Kozhikode on 19 January 2018 and delivered a lecture on 'Conservation and registration of tuber crops under PPV&FRA with special emphasis on farmers' varieties'.
- Resource person for the National Science Day celebrations at the Department of Zoology, University of Kerala and delivered a talk on 'Medicinal tuber crops and conservation' on 27 February 2018.
- As external examiner conducted the final viva voce of M.Sc. (Ag.) Plant Biotechnology student at College of Agriculture, Vellayani.

Dr. C. A. Jayaprakas

- ASRB Nominee for the recruitment/ promotion of Technical staff.
- President of Indian Society of Root Crops.
- Joint Secretary of Association of Advancement of Entomology.

Dr. Sheela Immanuel

- Subject expert in the discipline of Agricultural Extension for Career Advance Scheme (CAS) promotions under UGC 2006, Kerala Agricultural University, Vellanikkara, Thrissur.
- External examiner for thesis evaluation of 3 M.Sc. (Ag.) students of Kerala Agricultural University, Kerala.
- Served as expert in the scientific advisory committee meeting of the KVK, Kollam on 27 July 2017.
- Invited as resource person to deliver a lecture on 'Improved technologies of tuber crops' during the annual celebrations of the Green Agri farmers club at Nagercoil on 2 September, 2017.
- Served as expert in the scientific advisory committee meeting at KVK, Mitraniketan, Thiruvananthapuram on 9 February 2018.

Dr. G. Suja

- Nominated as Subject expert (Agronomy) for Career Advance Scheme (CAS) Promotions under UGC 2006, Kerala Agricultural University, Thrissur.
- Member, Advisory Committee, Ph.D. Programme and External examiner of M.Sc. Agronomy students of Kerala Agricultural University.
- Resource person to deliver a lecture entitled 'Climate change and food security' at the XXVI Refresher Course in Environmental

Sciences at the UGC-Academic Staff College, University of Kerala, Thiruvananthapuram, on 10 January 2018.

- Expert for evaluation of research papers for 30th Kerala Science Congress 2018 and Expert for evaluation of research papers for Dr. J.S. Pruthi Award of Honour, Indian Society for Spices, Journal of Spices and Aromatic Crops, Volume 24 (1 and 2), 2015.
- Reviewer of papers (6 nos.): 1 in international journal, International Journal of Vegetables, Taylor and Francis and 5 in national journals.
- Resource person and delivered lecture on 'Organic farming in tropical tuber crops: Scope, prospects and practices' at Summer School on 'Modern Concepts and Practices of Organic Farming for Safe, Secured and Sustainable Food Production' organized by ICAR-IIFSR, Modipuram, Meerut.

Dr. S. Sunitha

- Member in Expert committee of NABARD to finalise the estimate and unit cost of drip irrigation of various crops on 5 July 2017 at NABARD, Thiruvananthapuram.
- Acted as an external examiner and conducted viva voce for three M.Sc. (Ag.) students and one Ph.D. (Ag.) student at Kerala Agricultural University, Vellayani, Kerala.

Dr. K. Susan John

- Acted as convenor for Technical Session – VI on 'Advances in potassium Research-IV' of the International K Conference held at NASC, New Delhi during 28-29 August 2017.
- Acted as convenor for Plenary Session of the 'International K Conference' held at NASC, New Delhi during 28-29 August 2017.
- Acted as Co-Chairman during Brainstorming/ Panel Discussion on 'Reshaping of the Extension System in ICAR' at the 'National Workshop on Reshaping Agricultural Research, Education and Extension Systems Management for 2030' held at ICAR-NAARM on 31 August 2017.
- Delivered a lecture on 'Soil fertility status of Kerala state: Management measures' at the programme organized by Fertilizer Association of India (FAI) at College of Agriculture, Vellayani on 10 April 2017.
- Chief Guest on the World Environment day – 2017 celebration of Bharatiya Vidya Bhavan School, Thiruvananthapuram on 5 June 2017 and delivered a talk on 'Protection of Environment with special emphasis on tuber crops'.
- Expert in the scientist – extension – farmer interface of Ernakulam district on 10 May 2017 for the session on Tuber crops and delivered a talk on 'Tropical Tuber crops'.
- External examiner for one Ph.D. thesis evaluation on 'Phyto remediation of inorganic contaminants in Vellayani wet land ecosystem' and qualifying viva-voce of two M.Sc. (Ag.) students of the Kerala Agricultural University, Kerala.
- Expert for the face to face program of farm and home during the Golden Jubilee Celebration of Farm and Home of AIR on 3 May 2017 at Nishagandhi Auditorium, Thiruvananthapuram, Kerala.
- External expert in interview board for the selection of sales officers at FACT, Aluva.
- External expert in interview board for the selection of programme assistant, ICAR-CARD, KVK, Pathanamthitta, Kerala.
- Chief Guest at Senior Citizens Forum, Thiruvananthapuram and delivered a lecture on 'Health Rejuvenating Climate Resilient Tropical Tuber Crops' on 16 November 2017.
- Resource person for the block level Karshika seminar of Erattupetta block, Kottayam district on 22 November 2017.
- Expert at Karshaka Samvadam organized by the Agri-Horti Society, Alappuzha on 27 December 2017.

Dr. V. Ramesh

- External examiner for one M.Sc. (Ag.) and one Ph.D. (Ag.) students at Kerala Agricultural University, Kerala.
- Nominated as IMC member for ICAR-Sugarcane Breeding Institute by ICAR for a

period of 3 years and attended the first meet on 20 December 2017 at Coimbatore, Tamil Nadu.

Dr. K. Laxminarayana

- Delivered a lecture on 'Agro-techniques and value addition in tuber crops' to a group of 20 graduates from Orissa organized by Nodal Officer, CYSD, Bhubaneswar on 08 February 2018.
- Delivered a lecture on 'Agro-techniques and value addition in tuber crops' to a group of 40 horticulture scientists from different KVKs of Orissa under a training programme on 'Cutting edge technologies for horticultural crops under climate change scenario', organized by Directorate of Extension Education, OUAT, Bhubaneswar on 20 November 2017.
- Expert in the mid-term evaluation of R&D Projects in Bio-technology of Department of Science and Technology, Govt. of Odisha, organized by Odisha Bigyan Academy, Bhubaneswar.
- Judge for evaluation and selection of candidates for Rashtriya Prestigious Balashree Honor – 2016 award organized by State Jawahar Bal Bhavan, affiliated unit of National Bal Bhavan, an Autonomous institution under Ministry of HRD.
- Member of Potato seed verification committee under which visited different cold storages at Paschim Midnapore and Burdwan Districts of West Bengal; Jalandhar district in Punjab and verified potato seed stock and submitted the reports to the Director, Horticulture Department for procurement of seed potato during 2017-18.
- External member for selection of vocational trainees for one year apprenticeship training at CHES, ICAR-IIHR, Bhubaneswar on 11 January 2018.
- Resource person and attended the 'RKVY Review meetings at IMAGE, Bhubaneswar at different intervals, SLPSC meetings at Rajiv Bhavan under the Chairmanship of Principal Secretary, Agriculture and Farmers' Empowerment, Govt. of Odisha and SLSC meetings at Secretariat under the Chairmanship of Chief Secretary, Govt. of Odisha.

Dr. P. Murugesan

- Resource person in a training programme on 'Seed Processing Worker' and delivered a talk on 'Upgrading and advances in seed processing techniques in important horticultural crops' organized at ICAR – Indian Institute of Oil Palm Research, Regional Station, Palode, Kerala on 16 March 2018.
- External examiner for evaluation of M.Sc. (Ag.) thesis entitled 'Seed production aspect in cluster bean var. MDU-1 by Ms. S. Jayasree, Agricultural College and Research Institute, Madurai, Tamil Nadu.
- Resource person for setting question paper for the course SST-321 Seed production techniques in horticultural crops (1+1) of Horticultural College and Research Institute, Coimbatore, TNAU, Tamil Nadu.
- Resource person in the brainstorming session on Seed, field and procedural standards for oil palm held at ICAR-Indian Institute of Oil Palm Research, Pedavegi and delivered an invited lecture on 'Status of seed standards in the world and experts finalised seed and field standards for oil palm seed for Indian seed gardens' on 24 January 2018.
- Resource person for the UGC-SAP Sponsored National Seminar on 'Abiotic Stress Agriculture: Constraints and Strategies' by the Department of Genetics and Plant Breeding, Annamalai University during 6-7 March 2018 and delivered an invited lecture on 'Genetic resources of unexploited tuber crops-Constraints and utilisation strategies for abiotic stress'.
- Resource person for the Skill training programme on Hybrid seed production in plantation crops conducted at ICAR-IIOPR Regional Station, Palode and delivered an invited lecture entitled 'Hybrid seed production in plantation crops' on 01 November 2017
- Resource person for the PMKVY training programme on Vegetable cultivation sponsored by Agriculture Skill Council of India and organised by Kerala Agro Industry Corporation Ltd and delivered theory and

practical lecture to the participants during 03 to 04 February 2018

- As a nominated member of OPIL (Joint venture of Govt. of India and Kerala) Workers Wage fixation Committee, participated in 2nd combined meeting held at Inspection Bungalow, Kulathupuzha during 09 to 10 May 2017.

Dr. Asha K.I.

- Reviewer of Journal of Root Crops.
- Member of the Judging Panel for Spectrum 2018 at L'ecole Chempaka, Edavacode during the annual science exhibition, '*Spectrum* 2018' held on 13 January 2018.

Dr. Asha Devi A.

- Reviewer of Journal of Root Crops.
- External Expert and conducted the first annual presentation of the Ph.D. programme of Shri Jaychand, J., Ms. Sakthipriya, M. and Deepa, J.M., on 20 November 2017 at the Department of Biotechnology, University of Kerala, Karyavattom.
- Member of the Judging Panel for Spectrum 2018 at L'ecole Chempaka, Edavacode during the annual science exhibition, '*Spectrum* 2018' held on 13 January 2018.
- Resource person for the National Seminar on Versatility of Plants at Department of Botany, Women's Christian College, Nagercoil and delivered a talk on the topic, 'Breeding techniques for the improvement of climate resilient tuber crops' on 1 February 2018.
- Resource person for the Pedestal-2018 Seminar Series at the Department of Botany, VTMNSS College, Dhanuvachapuram and delivered a talk on the topic, 'Breeding Methods for the Improvement of Tuber Crops' on 21 February 2018.

Dr. M. L. Jeeva

- Subject expert in the discipline of Plant Pathology for Career Advance Scheme (CAS) promotions under UGC 2006, Kerala Agricultural University, Vellanikkara, Thrissur.
- External expert for CAS interview board for promotion of Assistant professors and Associate professors in Plant Pathology at KAU, Vellanikkara.
- Evaluator for thesis and external examiner for final viva-voce of Ph.D. thesis at Anna University, Tamil Nadu.
- Examiner for Ph.D. thesis evaluation at Bharathidasan University, Tiruchirapalli, Tamil Nadu.
- Examiner for thesis evaluation and external examiner for final viva-voce of M.Sc. (Pathology) at College of Agriculture, Vellayani and College of Horticulture, Vellanikara.

Dr. S. S. Veena

- Member of DPC of ICAR-Sugarcane Breeding Institute, Coimbatore, Tamil Nadu.
- ICAR nominee for CAS (DPC) for promotion of Scientist (Plant Pathology), Sugarcane Breeding Institute Coimbatore.
- Acted as Treasurer for Indian Society of Root Crops.
- Thesis evaluation and external Examiner for final viva of M.Sc. (Plant Pathology) at College of Agriculture, Vellayani.
- Acted as reviewer for various National and International journals.

Dr. T. Makeshkumar

- Resource person in CAFT training at Division of Plant Pathology, IARI, New Delhi and delivered a lecture on 'Use of biotechnological and conventional tools in understanding virus-host interactions' on 14 November 2017.
- Resource person in ICAR sponsored short course on 'Nanotechnological approaches in pest and disease management' at ICAR-NBAIR, Bengaluru on 15 November, 2017.
- Resource person in ICAR sponsored short course on 'Breeding for Resistance to pest and diseases of plantation crops' at ICAR-CPCRI, Kayamkulam on 29 November 2017.
- Resource person during Indo-African Forum Summit (IAFS)-III and delivered a lecture on 'Cutting edge molecular diagnostic

techniques for viruses affecting banana and plantains' at ICAR-National Research Centre for Banana, Tiruchirapalli, Tamil Nadu on 29 March 2018.

- DBT Nominee in Institute Bio safety committee of ICAR-IISR, Kozhikode (2016-2019).
- Member in Institute Bio safety committee of Kerala Agricultural University (2016-2019).
- Member, Institute Management Committee, ICAR-CPCRI, Kasaragod (2018-2020).
- Expert for project evaluation in Kerala Biotechnology Commission, KSCSTE, Thiruvananthapuram, Kerala.
- Ph.D. thesis evaluator and conducted viva-voce examination at Tamil Nadu Agricultural University, Coimbatore, Bharathiar University, Coimbatore, JNTUH, Hyderabad and Madurai Kamaraj University, Madurai.

Dr. M. S. Sajeev

- Advisory Committee Member of M.Sc. (Processing Technologies) course at Kerala Agricultural University, Vellanikkara, Kerala.
- Curriculum Committee Member of the B.Tech (Food Technology), Kerala Technological University, Thiruvananthapuram.
- FRC Member, B.Tech (Food Engineering), Kerala Agricultural University, Thrissur, Kerala.
- External Examiner for Ph.D. at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Dr. A. N. Jyothi

- Technical Committee member for finalising the quotations of GC and FT-IR instruments at State Pesticide Testing Laboratory, Department of Agriculture, Govt. of Kerala.
- Evaluator for a project proposal for funding by AYUSH Department, Govt. of India.

Dr. V. S. Santhosh Mithra

- Resource person and delivered a lead lecture on 'Climate change and food safety' during the technology week celebration of KVKs at KVK, Thrissur on February 5, 2018.

Dr. P. Sethuraman Sivakumar

- External examiner for evaluation of thesis of three M.Sc. (Ag.) students of College of Agriculture, Kerala Agricultural University, Vellayani, Kerala.
- Resource person to deliver a talk/ lead lecture in 13 Summer/Winter Schools/ Trainings/ Workshops/ Seminars /Conferences organised by MANAGE and ICAR-NAARM, Hyderabad; SAMETI, Ludhiana; ICAR-CPCRI, Kasaragod; ICAR-NDRI, Bengaluru; TNAU, Coimbatore and KAU, Vellayani.

Dr. J. Sreekumar

- Editorial board member of the Journal of Tropical Agriculture, Kerala Agricultural University, Kerala.
- Adjudicator of the thesis and chairman of the committee for conducting viva voce of two M.Sc. (Agricultural Statistics) students, College of Agriculture, Kerala Agricultural University, Vellayani, Kerala.

Dr. Saravanan Raju

- External examiner for the conduct of qualifying examination and for evaluation of M.Sc. (Ag.) thesis of 5 students of College of Agriculture, Vellayani, Kerala Agricultural University.
- Guest faculty for M.Sc. (Integrated Biotechnology), College of Agriculture, Vellayani, Thiruvananthapuram for handling the course on Enzymology and Enzyme Technology and Metabolomics.

Dr. D. Jaganathan

- Resource person and delivered a lecture on 'Tuber crops based cropping systems' at KVK MYRADA, Erode, Tamil Nadu on 12 October 2017.
- Resource person and delivered lectures on 'Farmers' participatory demonstration on arecanut based cropping system – A success story' and 'Participatory rural appraisal tools and techniques' in Model training course on Participatory technology approaches at ICAR-CPCRI, Kasaragod during 13-14 December 2017.

- Resource person and delivered a lecture on 'Tuber crops for entrepreneurship development' in the Workshop on Tuber Crops Technology based Enterprise Development in Manipur: Scope and Opportunities at ICAR – Research Complex for NEH, Manipur Centre, Imphal on 15 March 2018.

Dr. Harish, E. R.

- Member in executive committee of the Journal 'Entomon'.

Dr. Krishna Radhika N.

- Editor for Journal of Root Crops.

Shri V. Bansode

- Question paper setter and evaluator for the B.Tech (Food Technology) course of Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan for the academic year 2017-18.
- External examiner for the M.Sc. (Nutrition) course of Orissa University of Agriculture and Technology, Orissa.

Shri V.B.S. Chauhan

- External examiner for evaluation of thesis of Shri Mohd Talha Ansari, M.Sc. (Horticulture), College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh.
- External examiner for evaluation of thesis and viva-voce of 2 M.Sc. (Ag.) students of Department of Vegetable Science, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa.

Dr. Kalidas Pati

- Invited as a member of task force meeting on 19 March 2018 at PPV & FRA, New Delhi for Development of DUS testing guidelines for greater yam and yam bean.

Dr. T. Krishnakumar

- Technical committee member, Equipments Purchase committee for establishing NABL lab in SAGOSERVE, Salem, Tamil Nadu.
- External Examiner for M.Tech (Food Technology) viva-voce programme, College of Food and Dairy Technology (CFDT), TANUVAS, Chennai.
- Question paper setter for B.Tech (Food Engineering) course for Agricultural Engineering College and Research Institute (AEC&RI), TNAU and College of Food and Dairy Technology (CFDT), TANUVAS, Chennai.

LINKAGES AND COLLABORATIONS IN INDIA AND ABROAD

The Institute has established international collaborations with International Potato Centre (CIP), Lima, Peru; International Centre for Tropical Agriculture (CIAT), Cali, Columbia; CIRAD, France and EMBRAPA, Brazil. Presently the Institute has international collaborations through external funded projects, Cassava Gmarkets funded by European Commission and Indo-Swiss Project on cassava mosaic disease funded by Swiss Agency for Development and Co-operation, Bern and Department of Biotechnology, Govt. of India, New Delhi. The national and state funding agencies are: ICAR, National Agricultural Innovation Foundation (NAIF), Govt. of India, Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA), DST, DBT, Coconut Development Board and Govt. of Odisha-Rashtriya Krishi Vikas Yojana (RKVY) and Govt. of Kerala – Department of Agriculture, Kerala State Planning Board, Small Farmers Agri-business Consortium (SFAC), Kerala State Council for Science, Technology and Environment (KSCSTE) and KSCSTE – BIRD.

Research and extension activities of ICAR-CTCRI are conducted in collaboration with many ICAR Institutes and SAUs *viz.*, ICAR-Indian Institute of Horticultural Research, Bengaluru; ICAR-Central Potato Research Institute, Shimla; ICAR-Central Institute of Women in Agriculture, Bhubaneswar; ICAR-Central Institute of Fisheries Technology, Cochin; ICAR-Central Institute of Freshwater Aquaculture, Bhubneshwar; ICAR-Central Marine Fisheries Research Institute, Kochi; ICAR-Central Plantation Crops Research Institute, Kasaragod; ICAR-National Rice Research Institute, Cuttack; ICAR Research Complex for NEH Region, Barapani; ICAR-National Academy of Agricultural Research and Management, Hyderabad; ICAR-Indian Institute of Spices Research, Kozhikode; Indian Institute of Water Management, Bhubaneswar; Agricultural Technology Application Research Institute, Hebbal, Bengaluru; Kerala Agricultural University, Thrissur; Orissa University of Agriculture and Technology, Bhubaneswar and Tamil Nadu Agricultural University, Coimbatore.

The section of Extension and Social Sciences along with the Intellectual Property and Technology Management Unit and Professional Services Cell (IPTMU & PSC) has developed collaboration with National Institute of Agricultural Extension Management (MANGE), Hyderabad and Centre for Research on Innovation and Science Policy (CRISP), Hyderabad and conducted a training programme on Social Science Research Methodology. Besides MANAGE, Hyderabad along with Veterinary College and Research Institute, TANUVAS, Namakkal and ICAR-CTCRI were involved in equipping cassava farmers of Pachamalai in critical skills of managing cassava value chains. Collaborations were also developed with public sector agencies like Kerala State Industrial Development Corporation (KSIDC), Kerala Start-up Mission, Department of Agriculture, Govt of Kerala; ICAR Research Complex for North Eastern Hills, Umiam for promoting agricultural entrepreneurship in the country. ICAR–CTCRI was an Eco-system partner for the "Ipitch" – a national level business plan competition organised by Villgro, Chennai. Functional collaborations were developed with College of Agriculture, Kerala Agricultural University, Vellayani to conduct Entrepreneurship Orientation Programmes for B.Sc.(Ag.) final year students. Under Tribal Sub Plan, linkages were developed with research organizations, NGOs and Department of Agriculture in Koraput, Kandhamal and Ranchi districts for the livelihood improvement of tribal farmers. Demonstrations on tuber crops based farming systems were conducted in farmers fields.

The Institute has MoU with College of Agriculture, Kerala Agricultural University, Vellayani for conducting courses and carrying out project work of M.Sc. Integrated Biotechnology students. Kerala University and Kannur University are approved research centres for Ph. D programmes. MoU had been signed with Indian Institute of Crop Processing Technology, Thanjavur for mutual utilization of research facilities.

All India Coordinated Research Project on Tuber Crops (AICRP TC) located at ICAR-CTCRI has collaboration with twenty two centres spread over eighteen States and one Union Territory. The Regional Centre has established collaboration with Directorate of Horticulture and Department of Agriculture and Farmers Empowerment, Govt. of Odisha, RKVY, through external funded projects, for soil mapping, establishment of Techno-Incubation Centre at Regional Centre, Bhubaneswar and popularization of climate resilient nutrient rich varieties.

The Institute is collaborating with various ICAR Institutes in different projects. The ICAR-Central Potato Research Institute (CPRI), Shimla is associated in two projects, *viz.*, 'Integrated crop, water and nutrient management for improving productivity of tropical tuber crops' and 'Studies on the impact of climate change and devising mitigation and adaptation strategies for sustaining productivity of tuber crops'. In the PPV&FRA funded projects on development of standards of DUS testing for varietal gene bank in different tuber crops, the Institute is collaborating with the AICRP centres at BCKV, Kalyani, West Bengal and Dholi, Bihar. In the ICAR Network Project on Organic Horticulture, the Institute has collaboration with ICAR-CPCRI, Kasaragod. The Institute is associating with ICAR-Indian Institute of Water Management (IIWM), Bhubaneswar, Odisha for the preparation of soil fertility maps for various agro-ecosystems.

ALL INDIA CO-ORDINATED RESEARCH PROJECT ON TUBER CROPS

Headquarters: ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala.

The All India Coordinated Research Project on Tuber Crops (AICRP TC), functioning since 1968 is the largest national network of tropical tuber and root crops spread over eighteen states and one union territory covering north-eastern, eastern, western and southern parts of India. Presently the AICRP TC is having 22 centres, located in 12 State Agricultural Universities, 5 ICAR Institutions and two Central Agricultural Universities. The details of the centres are mentioned below:

Sl. No.	Name	Year of start
1.	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala	1968
2.	Rajendra Prasad Central Agricultural University, Dholi, Muzaffarpur (Dt.), Bihar	1968
3.	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu	1968
4.	Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh	1969
5.	Assam Agricultural University, Jorhat, Assam	1971
6.	Dr.Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri (Dt), Maharashtra	1975
7.	ICAR Research Complex for NEH Region, Barapani, Meghalaya	1975
8.	Bidhan Chandra Krishi Viswavidyalaya, Nadia, Kalyani, West Bengal	1976
9.	Regional Centre of ICAR-CTCRI, Bhubaneswar, Odisha	1983
10.	Birsa Agricultural University, Kanke, Ranchi, Jharkand	1987
11.	Indira Gandhi Agricultural University, Kumharwand, Jagdalpur (Bastar), Chhattisgarh	1987
12.	Narendra Dev University of Agriculture and Technology, Faizabad, Uttar Pradesh	1987
13.	Navsari Agricultural University, Navsari, Gujarat	1994
14.	ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands	2000
15.	Central Agricultural University, Iroisemba, Imphal, Manipur	2006
16.	Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan	2006
17.	University of Agricultural Sciences, Dharwad, Karnataka	2007
18.	Chaudhary Sawan Kumar Himachal Pradesh Krishi Viswavidyalaya, Palampur, Himachal Pradesh	2014
19.	Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, Telangana	2015
20.	Regional Station-ICAR Research Complex for NEH Region, Lembucherra, Tripura	2015

Achievements of ICAR-AICRP on Tuber Crops during 2017-2018

Collection, conservation, cataloguing and evaluation of genetic resources of tuber crops

A total of 122 new germplasm collections were made by different centres during 2017-18. Altogether 4328 different accessions of root and tuber crops are being maintained as gene bank for improvement of major crops including cassava, sweet potato, aroids, yams and minor tuber crops at 21 centres. A total of 4328 accessions of different tuber crops are being maintained in the National Repository for Tuber Crops at ICAR-Central Tuber Crops Research Institute (CTCRI) and RC, CTCRI Bhubaneswar maintains a total of 1342 accessions of tuber crops. Among the centres, maximum accessions of twelve tuber crops (1335) were maintained at RPCAU, Dholi. IC numbers were obtained for a total of 2032 germplasm collections at different centres.

Testing of genetic resources at various agro climatic environments

Varietal evaluation trials in cassava, sweet potato, yams, aroids and yam bean with coded entries are in progress at different centres. New IET on cassava mosaic resistant lines indicated that the entry TCa 16-4 performed best at Yethapur (45.55 t ha^{-1}), TCa 16-5 at Peddapuram (54.59 t ha^{-1}) and Thiruvananthapuram (30.50 t ha^{-1}). Pooled data analysis of URT on K-efficient cassava lines for the last two years indicated that, TCa 14-6 is superior at Yethapur, Sree Athulya at Peddapuram and TCa 14-3 at Thiruvananthapuram. Under MLT on cassava for culinary uses, TCa 13-3 (47.78 t ha^{-1}) recorded maximum tuber yield at Thiruvananthapuram, TCa 13-4 at Jagdalpur and TCa 13-7 at Imphal. The maximum tuber yield (46.23 t ha^{-1}) was recorded in TCa 12-6 at Yethapur, TCa 12-9 (35.05 t ha^{-1}) at Peddapuram, and TCa 12-5 at Thiruvananthapuram (42.78 t ha^{-1}) under MLT on short duration cassava entries based on the pooled data analysis.

Under the new IET on orange flesh sweet potato, TSp 16-2 produced maximum marketable tuber yield at Dholi and Ranchi, TSp 16-8 at Peddapuram and Kalyani, TSp 16-1 at Jagdalpur and Rajendranagar, TSp 16-6 at Navsari and Udaipur. Among the entries evaluated in MLT on sweet potato for weevil resistance, TSp 12-6, performed well (16.8 t ha^{-1}) coupled with less weevil infestation at Dholi and at Rajendranagar, TSp 12-4 performed well. Under MLT on sweet potato, maximum marketable tuber yield was recorded from Sree Bhadra at Kalyani and TSp12-12 at Barapani.

Among the fourteen entries evaluated under the new IET on Colocasia, TTr 17-4 produced maximum cormel yield at Kalyani, TTr 17-7 at Jorhat, TTr 17-3 at Dapoli and Dholi, TTr 17-5 at Jagdalpur, TTr 17-14 at Imphal and Lembucherrah, TTr 17-1 at Kovvur, TTr 17-6 at Ranchi and TTr 17-8 at Coimbatore. Under first year of MLT on colocasia, TTr 12-4 produced maximum yield at Kalyani and Coimbatore centres. The entry TTr 12-8 produced maximum yield at Ranchi, Dholi and Port Blair. The evaluation of colocasia entries against *Phytophthora* blight in MLT indicated that TCbl 12-4 is field resistant to leaf blight and also gave very good cormel yield at Kalyani, and Dholi, whereas TCbl 12-5 was found superior at Dapoli and Rajendranagar.

Under new IET on Bunda, TBd 17-3 produced maximum yield at Kalyani, TBd 17-2 at Jorhat, TBd 17-1 at Jagdalpur, TBd 17-7 at Barapani, TBd 17-4 at Dholi and Ranchi. Under URT on Tannia, among the six entries TTn 14-6 performed well and produced maximum tuber yield at Rajendranagar, TTn 14-5 at Thiruvananthapuram and Jagdalpur, TTn 14-1 at Kalyani. Under URT on swamp taro, the highest corm yield was recorded in BCST-3 (24.74 t ha^{-1}) at Kalyani, BCST-13 at Jorhat (17 t ha^{-1}) and BCST-1 at Imphal.

Under the new IET on greater yam TGy 17-10 produced maximum tuber yield at Thiruvananthapuram and Dapoli, TGy 17-8 at Kovvur, TGy 17-3 at Udaipur, TGy 17-6 at Jagdalpur and TGy 17-5 at Jorhat. Under URT on greater yam TGy 14-6 produced maximum yield at Dapoli (30.13 t ha^{-1}), TGy 14-11 at Kovvur (51.27 t ha^{-1}) and at Imphal (19.80 t ha^{-1}), TGy 14-8 at Udaipur, TGy 14-9 at Jagdalpur (35.27 t ha^{-1}), TGy 14-5 (40.9 t ha^{-1}) at Thiruvananthapuram and TGy 14-7 at Jorhat. Under MLT on greater yam, TGy 12-3 produced maximum tuber yield at Kovvur and Thiruvananthapuram, TGy 12-6 at Jagdalpur and Udaipur. One variety in greater yam *i.e* IGDa-2 was recommended for release for the states of Chhattisgarh and Gujarat. Maximum bulbil yield and total yield was recorded in TDb 13-1 at Dapoli, TDb 13-5 at Ranchi and TDb 13-6 at Jagdalpur under MLT on aerial yam. Under new IET on elephant foot yam among the entries TEy 17-2 produced maximum corm yield at Kovvur and the national check Gajendra recorded maximum yield at other centres. Pooled data analysis of URT on yam bean showed the superiority of TYb14-8 at Bhubaneswar and TYb14-9 at Dholi.

Greater yam genotype IGDa2

Agro techniques

The farming system studies involving tuber crops introduced in Birigaon (village), Kandhamal (District), Odisha state generated a gross income of ₹ 1, 50, 180 ha^{-1} with B: C ratio of 2.69 and employment generation of 280 man-days ha^{-1} in place of the gross income of ₹ 90, 750 ha^{-1} with B: C ratio of 1.96 and employment generation of 200 man-days ha^{-1} before intervention. The gross income and net income increased at four locations of Jharkhand after interventions of different components under tuber crops based farming system studies from the year 2012-13 to 2017-18. Average B: C ratio of the famers increased from 1.31 to 2.41. The model created an additional employment of 69 man days. Farming system introduced in Jorhat district of Assam increased farm net income from ₹ 2070 to ₹ 2, 72, 802 ha^{-1} after four years of intervention. The benefit cost ratio increased from 1.05 to 3.19. The employability also increased from 212 days to 632 days ha^{-1}. Tuber crops based farming system introduced in Gumiyapal village of Bastar district of Chhattisgarh increased the farm net income from ₹ 56, 850 to ₹ 4, 03, 720 and created 61 man-days of additional employment. Under micro nutrient studies in sweet potato, positive response in terms of tuber yield was recorded with the application of micro nutrients. Tuber yield as well as B:C ratio was maximum with the application of micronutrients *viz.*, $MgSO_4$, $ZnSO_4$ and Borax at Rajendranagar, Kalyani, Ranchi and Dholi. At Dharwad, the response of Boron was more pronounced.

Validation of organic farming technologies in elephant foot yam indicated its positive response over conventional methods, however the conventional method resulted in maximum B:C ratio at Dholi and Kalyani. In greater yam, organic package resulted in maximum tuber yield and net income in all the centres except Jagdalpur and Kovvur where conventional and traditional package respectively resulted in maximum yield. Organic farming resulted in superior performance of taro in most of the centres. At Rajendranagar conventional method and at Kalyani traditional method of cultivation resulted in more cormel yield. Under the new experiment on "Integrated weed management in elephant foot yam" maximum growth and corm yield was recorded with weed control ground cover at Coimbatore (45.72 t ha^{-1}), Kalyani (47.93 t ha^{-1}), Port Blair (23.5 t ha^{-1}) and Dapoli (34.94 t ha^{-1}).

Pest and disease management

IPM treatment in sweet potato field was found to be the best to manage weevil infestation and the second best treatment was the pheromone trap (1 trap 100 m^{-2}) at Kalyani. At Dholi chemical control was found to be effective, whereas at Rajendranagar and Dapoli, sex pheromone trap was found to be effective. For anthracnose management in greater yam, soil application and tuber treatment with *Trichoderma* followed by carbendazim spray three times showed minimum disease intensity and maximum tuber yield at Jagdalpur and Rajendranagar, whereas *Trichoderma* treatment along with carbendazim spray seven times resulted in maximum tuber yield at Udaipur. Under collar rot management in EFY, chemical control resulted in best results compared to organic management in most of the centres. Application of *Trichoderma* and vermicompost @ 150-200 gm per pit after intercultural operations also could reduce the disease incidence.

Planting material production

Planting materials of improved varieties of tuber crops were multiplied and distributed to farmers by all the centres. The centres produced a total of 1, 58, 635 stems of cassava, 38, 64, 916 vine cuttings of sweet potato, 28.6 tons of elephant foot yam, 14.81 tons of taro, 19.97 tons of yams and 265 kg of yam bean as part of planting material production programme.

Research extension interface

CAU, Imphal organized four training programmes on "Importance and scientific cultivation of tuber crops" in four different districts of Manipur. A field day cum farmers interaction meeting was organised for nearly 400 members at HRS, Peddapuram on 01.02.2018 to create awareness on improved package of practices in cassava and other horticultural crops. ICAR-CIARI, Port Blair, organized two field days on "Organic cultivation of elephant foot yam" at Sipighat on 25th April and 25th October, 2017 in which a total of 70 farmers participated. CIARI, Port Blair participated and displayed the tuber crops and tuber dishes in the Regional Agricultural Fair for Southern Region conducted during 15-17th February, 2018. The Fair was inaugurated by Shri. Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers' Welfare, Govt. of India.

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Sajeev, M.S. and Krishnakumar, T. 2017. Tuber crops based extruded products. In: *Post harvest Processing and Value Addition in Tuber Crops/Horticulture,* 4-11 December 2017, ICAR – Central Tuber Crops Research Institute, Thiruvananthapuram.

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Sheela Immanuel. 2017. A talk on 'Tuber crops day celebrations and its importance' at AIR, Thiruvananthapuram on 4 December 2017.

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Susan John, K. 2018. A talk on 'Soil testing and soil health card scheme' at AIR, Thiruvananthapuram on 4 March 2018.

TV Talks

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Suja, G. 2018. A talk on 'Planting time of tuber crops' at Doordarshan, Thiruvananthapuram on 23 February 2018.

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ONGOING PROJECTS

Institute Projects

Sl. No.	Project code	Project title	PI	Co-PIs
1.	HORTICARCTCRI SIL2015001 01457	Conservation and utilization of germplasm of tuber crops for sustaining production	M.N. Sheela	Archana Mukherjee K.I. Asha C. Mohan A. Asha Devi Shirly Raichal Anil P. Murugesan N. Krishna Radhika Kalidas Pati T. Makesh kumar M.L. Jeeva S.S. Veena H. Kesava Kumar V.B.S. Chauhan K. Hanume Gowda Vivek Hegde Visalakshi Chandra C. J. Sreekumar A.N. Jyothi A.V.V. Koundinya P. Arun Kumar K.M. Senthilkumar
2.	HORTICARCTCRI SIL2015 001 01458	Genetic improvement of tuber crops through conventional breeding and molecular approaches	Archana Mukherjee	M.N. Sheela K.I. Asha C. Mohan A. Asha Devi Shirly Raichal Anil N. Krishna Radhika Kalidas Pati T. Makeshkumar M.L. Jeeva S.S. Veena R.C. Ray M. Nedunchezhian K. Lakshminarayana V.B.S. Chauhan K. Hanume Gowda Vivek Hegde Visalakshi Chandra C. J. Sreekumar A.N. Jyothi S. Sunitha G. Suja Saravanan Raju P. Arun Kumar K.M. Senthilkumar A.V.V. Koundinya V. Ravi P. Prakash

Sl. No.	Project code	Project title	PI	Co-PIs
3.	HORTICARCTCRI SIL2015 003 01459	Integrated crop, water and nutrient management for improving productivity of tropical tuber crops	G. Byju	James George V. Ravi R. Muthuraj G. Suja M. Nedunchezhiyan S. Sunitha K. Laxminarayana V. Ramesh T. Makeshkumar M.N. Sheela Archana Mukherjee A. Asha Devi Susan John K. Saravanan Raju S.S. Veena J. Sreekumar V. Ravi Jyothi A.N. Santhosh Mithra V.S. V.K. Dua (ICAR-CPRI Shimla) Madhumita Das (ICAR-IIWM) Prakash, P. Sanket J. More Visalakshi Chandra C. J.Suresh Kumar
4.	HORTICARCTCRI SIL2015 004 01460	Studies on impact of climate change and devising mitigation and adaptation strategies for sustaining productivity of tuber crops	V. Ravi	Saravanan Raju Krishna Radhika N. R. Muthuraj Prince Kumar (RS CPRI) G. Byju V. S. Santhosh Mithra M.N. Sheela G. Suja V. Ramesh Sanket J. More J.Suresh Kumar K.L. Laxminarayana James George
5.	HORTICARCTCRI SIL2015 005 01461	Eco-friendly strategy for the management of insect pests in tuber crops	C.A. Jayaprakas	Archana Mukherjee E.R. Harish H. Kesava Kumar T. Sirisha S.S. Veena J. Sreekumar Shirly Raichal Anil Sangeetha B.G.
6.	HORTICARCTCRI SIL2015 006 01462	Development and refinement of integrated disease management and forecasting system for improved tuber crop production	M.L. Jeeva	S.S. Veena M. Nedunchezhiyan G. Byju A.N. Jyothi J. Sreekumar K.I. Asha V.S. Santhosh Mithra T. Makeshkumar Arutselvan R. T. Sirisha Sangeetha B.G.

Sl. No.	Project code	Project title	PI	Co-PIs
7.	HORTICARCTCRI SIL2015 009 01465	Cassava mosaic disease-variability, diagnostics, vector relation and management	T. Makeshkumar	M.L. Jeeva M.N. Sheela B.G. Sangeetha E.R. Harish C. Mohan J. Sreekumar C.A. Jayaprakas K. Susan John S. Sunitha R. Muthuraj Vivek Hegde Saravanan Raju James George
8.	HORTICARCTCRI SIL2013 012 01451	Development and refinement of post-harvest handling, storage and processing techniques for minimization of losses in tropical tuber crops and production of value added products	M.S. Sajeev	A.N. Jyothi P. S. Sivakumar S.S. Veena K.I. Asha Shirly Raichal Anil T. Krishnakumar N.A. Giri Saravanan Raju Pradeepika Chintha
9.	HORTICARCTCRI SIL2015 010 01466	Development of cassava starch based novel products and functional foods from other tuber crops	A.N. Jyothi	M.S. Sajeev Venkataraman V. Bansode Susan John K. Nedunchezhiyan M. T. Krishnakumar
10.	HORTICARCTCRI SIL2015 008 01464	Developing Methodologies and Tools for Assessment and Transfer of Tuber Crops Technologies	Sheela Immanuel	J. Sreekumar V.S. Santhosh Mithra P. Sethuraman Sivakumar D. Jaganathan P. Prakash V. Ramesh R. Muthuraj H. Kesava Kumar Sanket J. More M. Nedunchezhiyan M. S Sajeev G. Byju C. Mohan T. Makesh Kumar E.R. Harish G. Suja A.N.Jyothi CA Jayaprakas V. Ravi M. N. Sheela P. Murugesan K. Venkatesan (NAARM, Hyderabad)

Externally aided projects

Sl. No.	Project title	PI	Co-PIs	Funding agency
1.	Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro	Archana Mukherjee	J. Tarafdar Kalidas Pati	PPV & FRA, New Delhi
2.	Establishment of Varietal Gene Bank and Development of Standards of DUS Testing in Yam bean (*Pachyrrhizus erosus*) and Greater Yam (*Dioscorea alata*)	Archana Mukherjee	P.P. Singh M.N. Sheela Kalidas Pati M. Nedunchezhiyan	PPV & FRA, New Delhi
3.	Adapting clonally propagated crops to climatic and commercial changes	Archana Mukherjee	J. Sreekumar	European Union
4.	Network Project on Organic Farming (NPOF)	G. Suja	G. Byju S. Sunitha S.S. Veena A.N. Jyothi M.N. Sheela	ICAR – Indian Institute of Farming Systems Research, Modipuram
5.	Climate smart natural resource management of cassava (*Manihot esculenta* Crantz) using geoinformatics tools	G. Byju	-	KSCSTE, Govt. of Kerala
6.	Higher productivity and profitability from coconut gardens through soil health management in tuber crops	G. Byju G. Suja	Archana Mukherjee D. Jaganathan	Coconut Development Board, Govt. of India
7.	Enhancing the economic viability of coconut based cropping systems for land use planning in Kerala State	Susan John K.	Sunitha S. Veena S.S.	Kerala State Planning Board
8.	Assessment of soil fertility and preparation of soil fertility maps for various agro-ecosystems of Odisha	K. Laxminarayana	M. Madhumita Das (ICAR-IIWM)	Department of Agriculture and Farmers' Welfare, Rashtriya Krishi Vikas Yojana (RKVY), Govt. of Odisha
9.	ICAR-CTCRI-Tribal Sub Plan 'Livelihood improvement of tribal farmers through tuber crops technologies'	M. Nedunchezhiyan	Archana Mukherjee R.C. Ray K. Laxminarayana Kalidas Pati M.S. Sajeev Ramakrishna Mission Ashrama Ranchi Jharkhand Brijesh Pandey Ajeet Kumar Singh Ramakrishna Mission Ashrama Narayanpur Chhattisgarh ORRISSA PRAGATI SOVA	ICAR – CTCRI

Sl. No.	Project title	PI	Co-PIs	Funding agency
10.	Establishment of Techno-Incubation Centre at the ICAR – Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar for the commercialization of value added products from sweet potato and other tuber crops	M. Nedunchezhiyan	R.C. Ray M.S. Sajeev V. Bansode	RKVY, Govt. of Odisha
11.	High Value Compounds/ Phytochemicals	A.N. Jyothi	J. Sreekumar Shirly Raichal Anil	ICAR (Network Project)
12.	Development and evaluation of starch based functional polymers for controlled plant nutrient delivery	A.N. Jyothi	M.S. Sajeev Susan John K.	Kerala State Council for Science, Technology and Environment, Govt. of Kerala
13.	Rural entrepreneurship development through training cum demonstration on value-added products from Tuber Crops	M.S. Sajeev	G. Padmaja	Kerala State Council for Science, Technology and Environment, Govt. of Kerala
14.	Techno-Incubation centre	M.S. Sajeev	G. Padmaja T. Krishnakumar	Small Farmers Agribusiness Consortium, Govt. of Kerala
15.	Indo – Swiss Cassava Network	T. Makeshkumar M.N. Sheela	Harish E.R. B.G. Sangeetha Visalakshi Chandra C.	Indo Swiss collaboration on Biotechnology(ISCB)-DBT, Govt. of India
16.	Disease diagnostics in tropical tuber crops	T. Makeshkumar	M.L. Jeeva R. Arutselvan R. Muthuraj	ICAR-CRP on Vaccines and Diagnostics
17.	Assessment of roles and performance of agricultural enterprises of Agri Clinic & Agri-business Clinics Scheme in the emerging startup ecosystem	P. Sethuraman Sivakumar	Sheela Immanuel	MANAGE, Hyderabad
18.	XIIth Plan IP & TM Scheme: National Agricultural Innovation Foundation (NAIF)	P. Sethuraman Sivakumar	V. Ravi M. S. Sajeev M. L. Jeeva V. S. Santhosh Mithra R. Bharathan	ICAR – NAIF

PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS WORKSHOPS

Programme	Particulars of the Programme	Name of the participants
Participatory Interface Meeting – Decades of Protection of Plant Variety and Farmers' Rights Act	ICAR-Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar, 22 April 2017	Dr. Kalidas Pati Dr. V.B.S. Chauhan
17th Annual Group Meeting of All India Coordinated Research Project on Tuber Crops	University of Horticultural Sciences, Bagalkot, 26-30 April 2017	Dr. Archana Mukherjee Dr. James George Dr. M.N. Sheela Dr. Sheela Immanuel Dr. S. Sunitha Dr. R. Muthuraj Dr. M. L. Jeeva Shri Suresh Kumar J.
Scientist-Farmers-Extension Interface of Ernakulam District	Muvattupuzha, Kerala, 10 May 2017	Dr. K. Susan John
National Conference on Sustainable Development Goals (SDG's) Preparedness and Role of Agriculture	International Food Policy Research Institute, South Asia Office, New Delhi 10 – 11 May 2017	Shri Prakash P.
Inter Media Publicity Co-ordination Committee Meeting	Press Information Bureau, Thycaud, Thiruvananthapuram, 18 May 2017	Dr. Sheela Immanuel
Sree Visakham Thirunal Endowment lecture	ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, 18 May 2017	All Scientists
23rd Meeting of the ICAR Regional Committee Meeting Zone –III	ICAR Research Complex for NEH Region, Imphal, 30-31 May 2017	Dr. Archana Mukherjee
22nd RKVY State Level Sanctioning Committee Meeting	Department of Agriculture and Farmers Empowerment, Odisha, 6 June 2017	Dr. Kalidas Pati Dr. V.B.S. Chauhan
Conference on Krishi Unnati – Making Farming an Attractive Livelihood Opportunity	Confederation of Indian Industry, Bhubaneswar, 8 June 2017	Dr. K. Laxminarayana
Inter Media Publicity Co-ordination Committee Meeting	All India Radio, Thiruvananthapuram, Kerala 13 June 2017	Dr. Sheela Immanuel
5thInternational Conference on Agriculture, Horticulture and Plant Science	Anandam Resort, Rishikesh, Uttarakhand, 24 – 25 June 2017	Mrs. Sirisha Tadigiri
Directors' Conference	National Agricultural Science Complex, Indian Council of Agricultural Research, New Delhi 15 – 16 July 2017	Dr. Archana Mukherjee
Seminar on Towards a Diversified Food System:Emerging Opportunities in Odisha	Tata Cornell Institute (TCI) – Technical Assistance & Research on Indian Nutrition & Agriculture (TARINA), Xavier University, Bhubaneswar, 19 July 2017	Dr. Archana Mukherjee

Programme	Particulars of the Programme	Name of the participants
Hindi Workshop on Official Language and Management	ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala 29 June 2017	All Scientists
Rural Advisory Committee Meeting of All India Radio	St. Marys school, Pattom, Thiruvananthapuram, Kerala 19 July 2017	Dr. Sheela Immanuel
Inter Media Publicity Co-ordination Committee Meeting	Press Information Bureau, Doordarshan Kendra, Thiruvananthapuram, Kerala 20 July 2017	Dr. Sheela Immanuel
54th ICAR – CTCRI Foundation day	ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala 29 July2017	All Scientists
Brainstorming Workshop on Developing Guidelines for Producing Quality Planting Materials of Tuber Crops	ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala 2 August 2017	Dr. Archana Mukherjee Dr. James George Dr. Sheela Immanuel Dr. P.S. Sivakumar Dr. V. Ravi Dr. P. Murugesan Dr. M.N. Sheela Dr. Asha Devi A. Dr. Shirly Raichal Anil Dr. R. Muthuraj Dr. G. Suja Dr. Sanket J. More Dr. D. Jaganathan Shri P. Prakash Dr. C.A. Jayaprakas Dr. M. L. Jeeva Dr. T. Makeshkumar Dr. H. Kesava Kumar
International Conference on Farming System for Nutrition	M.S. Swaminathan Research Foundation, Chennai, 7 – 9 August 2017	Dr. Archana Mukherjee
Inter Media Publicity Co-ordination Committee Meeting	ICAR – Central Tuber Crops Research Institute, Thiruvananthapuram, 23 August 2017	Dr. Archana Mukherjee Dr. James George Dr. Sheela Immanuel
International Potassium Conference	ICAR – National Agricultural Science Complex, New Delhi, 28 – 29 August 2017	Dr. K. Susan John
Indo-Swiss Cassava Network Review Meeting	ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, 28 August 2017	Dr. Archana Mukherjee Dr. M.N. Sheela Dr. T. Makeshkumar Dr. Visalakshi Chandra C. Shri R. Arutselvan Shri Prakash P.

Programme	Particulars of the Programme	Name of the participants
New India Manthan: Sankalp Se Siddhi Programme	Krishi Vigyan Kendra, Thirupathisaram 29 August 2017	Dr. M.N. Sheela
National Workshop on Reshaping of Agricultural Research, Education and Extension Systems Management for 2030	ICAR-National Academy of Agricultural Research and Management, Hyderabad 31 August 2017	Dr. K. Susan John
61st Meeting of Town Official Language Implementation Committee	Indian Institute of Technology, Argul Campus, Bhubaneswar 31 August 2017	Dr. V.B.S. Chauhan
ICAR – NAARM Foundation Day	ICAR-National Academy of Agricultural Research and Management, Hyderabad 1 September 2017	Dr. K. Susan John
World Coconut Day	IMAGE & Asian & Pacific Coconut Community and Coconut Development Board, Bhubaneswar 2 September 2017	Dr. V.B.S. Chauhan
Young Entrepreneurship Summit – 2017	Le Meridien, Kochi, 12 September 2017	Dr. P. S. Sivakumar Dr. D. Jaganathan
Trivandrum Biotechnology Industries Conclave – 2017	Mascot Hotel, Thiruvananthapuram 30 September 2017	Dr. P. S. Sivakumar Dr. D. Jaganathan Shri P. Prakash
Meeting of Implementation of Collaborative Action Plan between CIAT and ICAR – CTCRI	Department of Agricultural Research and Education, Indian Council of Agricultural Research, New Delhi, 4 October 2017	Dr. Archana Mukherjee
Agri-startup 1.0 and Tuber Crops Technology Conclave cum Technology Meet – 2017	ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala 27-28 October 2017	All Scientists
Vigilance Awareness Week	ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 30 October-4 November 2017	All Scientists
19th Organic World Congress	India Expo Centre and Mart, Greater Noida, Uttar Pradesh 9-11 November 2017	Dr. G. Suja
Hindi Workshop cum Valedictory Function of the Hindi Fortnight Celebrations-2017	ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 15 November 2017	All Scientists
Regional Workshop and Agro-Biodiversity Exhibition	ICAR–National Rice Research Institute, Cuttack, November 2017	Dr. Archana Mukherjee
Review Meeting of Foreign aided Project	Krishi Anusandhan Bhawan II, Indian Council of Agricultural Research, New Delhi 20 November 2017	Dr. Archana Mukherjee

Programme	Particulars of the Programme	Name of the participants
Brainstorming Workshop on Converting Extreme Rainfall Events into Opportunities	ICAR – Indian Institute of Water Management, Bhubaneswar 22 November 2017	Dr. K. Laxminarayana
Inter Media Publicity Co-ordination Committee Meeting	Press Information Bureau, Thiruvananthapuram 24 November 2017	Dr. Sheela Immanuel
9th Scientific Advisory Committee Meeting	ICAR – Krishi Vigyan Kendra, Thirupathisaram, Nagercoil 30 November 2017	Dr. R. Muthuraj
Agricultural Educational Day–2017	ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 4 December 2017	All Scientists
Indo-US Symposium–2017 on Curbing Whitefly-Plant Virus Pandemics: The Departure from Pesticides to Genomics Solutions	Punjab Agricultural University, Ludhiana, 4 – 5 December 2017	Dr. E. R. Harish
World Soil Day	ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 5 December 2017	All Scientists
Annual Seminar – Fertilizer Association of India	Hotel Pullman and Novotel, New Delhi, 5 – 7 December 2017	Dr. K. Susan John
National Conference on New Vistas in Vegetable Research towards Nutritional Security under Changing Climate Scenario	Department of Vegetable crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore 6 – 9 December 2017	Dr. Sheela Immanuel Dr. R. Muthuraj Dr. Visalakshi Chandra C.
National Conference on Viruses to Viromes in Health and Disease – Virocon 2017	Mangaluru, Karnataka 7–9 December 2017	Shri R. Arutselvan
Meeting of the State Seed Sub Committee for Variety Release	Department of Agriculture, Government of Kerala, Thiruvananthapuram 12 December 2017	Dr. M.N. Sheela
XII Annual Group Meeting of the Network Project on Organic Farming (NPOF)	ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, 17-19 December 2017	Dr. G. Suja
District Planning Committee Meeting	Collectorate Office, Thiruvananthapuram, Kerala 4 January 2018	Dr. Sheela Immanuel
Kerala State Industrial Development Corporation Meeting	Kerala State Industrial Development Corporation, Thiruvananthapuram, Kerala, 5 January 2018	Dr. Sheela Immanuel Dr. C. A. Jayaprakash Dr. P. S. Sivakumar
Workshop on Startup Green-2018 on Agribusiness Ventures	ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala, 7 January 2018	Dr. P. S. Sivakumar Dr. D. Jaganathan

Programme	Particulars of the Programme	Name of the participants
2nd Meeting of Technical Advisory Committee of the Project – Farming System for Nutrition: A Pathway for Addressing Malnutrition in India	M.S. Swaminathan Research Foundation, Chennai 8 January 2018	Dr. Archana Mukherjee
Conference on Farming system innovation	Bidhan Chandra Krishi Vishwa Vidyalaya, Kalyani, West Bengal 12–13 January 2018	Dr. Archana Mukherjee
Seminar on Provisions of PPV&FR Act 2001	ICAR-Indian Institute of Spices Research, Kozhikode 19 January 2018	Dr. M.N. Sheela
Brainstorming Session on Seed, Field and Procedural Standards for Oil Palm	ICAR-Indian Institute of Oil Palm Research, Pedavegi, West Godavari, Andhra Pradesh 24 January 2018	Dr. P. Murugesan
Kerala Science Congress	Thalassery, Kerala 28–30 January 2018	Dr. Sangeetha B. G.
Kerala State Industrial Development Corporation Meeting	Kerala State Industrial Development Corporation, Thiruvananthapuram, Kerala, 2 February 2018	Dr. Sheela Immanuel Dr. C. A. Jayaprakash Dr. P. S. Sivakumar
Entrepreneurship Development Programme on Cassava based Agro-enterprises for Developing Sustainable Tribal Livelihoods	Pachamalai hills, Trichy, Tamil Nadu, 2 February 2018	Dr. R. Muthuraj Dr. V. Ramesh Dr. P.S. Sivakumar Dr. D. Jaganathan
Krishi Vigyan Kendra Technology Week	Krishi Vigyan Kendra, Thrissur 5 February 2018	Dr. V. S. Santhosh Mithra
National Banana Fest	Kalliyoor, Thiruvananthapuram 16 February 2018	Dr. Archana Mukherjee Dr. Sheela Immanuel Dr. M. N. Sheela Dr. V. Ravi Dr. C. A. Jayaprakas Dr. M. S. Sajeev Dr. G. Byju Dr. D. Jaganathan Dr. Sanket J. More
Divisional Meeting for Monitoring and Reviewing of Progress of Foreign Aided Projects of Horticultural Science Division of ICAR	Krishi Anusandhan Bhavan – II, Pusa, New Delhi 21 February 2018	Dr. M.N. Sheela
National Science Day – 2018	ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 23–24 February 2018	All Scientists
National Science Day – 2018	Department of Zoology, University of Kerala, 27 February 2018	Dr. M.N. Sheela
Krushi Odisha – 2018	Govt. of Odisha, Bhubaneswar 6–9 March 2018	Dr. K. Laxminarayana

Programme	Particulars of the Programme	Name of the participants
Directors' Conference	National Agricultural Science Complex, Indian Council of Agricultural Resaerch, New Delhi 8–9 March 2018	Dr. Archana Mukherjee
Inter TOLIC Official Language Conference	Thiruvananthapuram Town Official Language Implementation Committee and HLL Lifecare Limited, Thiruvananthapuram Kerala, 9 March 2018	Dr. Sanket J. More
International Conference on Invigorating Transformation of Farm Extension towards Sustainable Development: Futuristic Challenges and Prospects	Tamil Nadu Agricultural University, Coimbatore, 9 – 10 March 2018	Dr. P. S. Sivakumar Dr. D. Jaganathan
Entrepreneurship Development Programme on Utilizing Tuber Crops based Village Incubation Centre for Creating Sustainable Development	Village Incubation Centre, Riha Village, Ukhrul, Manipur 14 March 2018	Dr. R. Muthuraj Dr. D. Jaganathan Dr. T. Krishnakumar
Stakeholders Workshop on Tuber Crops Based Entrepreneurship: Scope and Opportunities in Manipur	ICAR –Research Complex for North Eastern Hill Region, Manipur Centre, Lamphelpat, Imphal, Manipur, 15 March 2018	Dr. R. Muthuraj Dr. D. Jaganathan Dr. T. Krishnakumar
Workshop cum Brainstorming Session on Revisiting FOCARS: Reflections and Feedback of Trained Scientists	ICAR-National Academy of Agricultural Research Management, Hyderabad, 15-16 March 2018	Dr. A.V.V. Koundinya
Task Force meeting of PPV & FRA	PPV & FRA, New Delhi 20 March 2018	Dr. Archana Mukherjee
National Environment and Climate Change Congress (NECCC – 2018)	Directorate of Environment and Climate Change, Thiruvananthapuram 20-22 March 2018	Dr. Sanket J. More
Task Force Meeting on Greater Yam and Yam Bean	Protection of Plant Varieties & Farmers' Rights Authority, NASC complex, 21 March 2018	Dr. M.N. Sheela
62nd Meeting of Town Official Language Implementation Committee	Indian Institute of Technology, Bhubaneswar, 28 March 2018	Dr. V.B.S. Chauhan

VISITS ABROAD

Name of the Scientist	Period	Place of visit	Purpose
Dr. Kalidas Pati	22 August 2017 to 21 February 2018	University of Western Australia, Perth, Australia	Post Doctoral Research Programme – Endeavour Research Fellowship-2017
Dr. G. Byju	10 – 11 October 2017	University of Brawijaya East Java, Indonesia	International Conference on Root and Tuber Crops for Food Sustainability 2017 (ICRTC-2017)
Dr. M.N. Sheela	3– 7 December 2017	Kasetsart University, Bangkok, Thailand	3rd Asian Cassava Breeders Meeting

DISTINGUISHED VISITORS

- Shri. Samuel Karicho, Minister at the Kenyan High Commission of India.
- Smt. V. Usha Rani, Director General, MANAGE, Hyderabad.
- Shri. A. M. Sunil Kumar, Additional Director, Department of Agriculture, Govt. of Kerala.
- Prof. R. R. Hanchinal, Chairperson, PPV&FRA, New Delhi.
- Dr. R. C. Agarwal, Registrar-General, PPV&FRA, New Delhi.
- Dr. Ravi Prakash, Registrar, PPV&FRA, New Delhi.
- Dr. S. Pasupalak, Vice Chancellor, OUAT, Bhubaneswar, Odisha.
- Dr. Jan Low, Leader, Sweet Potato for Profit and Health Initiative, International Potato Center, Kenya.
- Shri. L. Radhakrishnan IAS., Chairman, Kerala State Innovation Council, Thiruvananthapuram.
- Dr. S.K. Malhotra, Agricultural Commissioner, Ministry of Agriculture and Farmers Welfare, Government of India.
- Shri. A. Somadethan, Retd. Assistant Director (OL), Income Tax Department, Thiruvananthapuram.
- Shri. Teeka Ram Meena, Principal Secretary (Agriculture) and Agricultural Production Commissioner, Government of Kerala.
- Smt. K. C. Rugmini Devi, Managing Director, Small Farmers Agri-Business Consortium (SFAC), Government of Kerala.
- Shri. Ravinderjit Singh, Chief Executive Officer, Agri-Innovate, ICAR, New Delhi.
- Dr. Lilian Gilgen, Program Manager, Indo-Swiss Collaboration in Biotechnology, EPFL, Switzerland.
- Dr. Herve Vanderschuren, Network Coordinator, Indo-Swiss Cassava Network Project, ETH, Zurich, Switzerland.
- Dr. Simon E Bull and Dr. Vasudevan Kumar, ETH, Zurich, Switzerland.
- Dr. Alessandra Guilliani, Dr. Karim Zbinden and Ms. Rahel Wyss, HAFL, Bern, Switzerland.
- Dr. P.G. Chengappa, JAC member, Indo-Swiss Collaboration in Biotechnology.
- Prof. (Dr.) K. Veluthambi, Madurai Kamaraj University, Madurai, Tamil Nadu.
- Dr. Partha Dasgupta, Syngenta Foundation, Kolkata.
- Dr. Rajalakshmi and Dr. Prathibha Singh, Department of Biotechnology, New Delhi.
- Adv. Shri. V. S. Sunil Kumar, Hon'ble Minister for Agriculture and Farmers' Welfare, Govt. of Kerala.
- Dr. Trilochan Mohapatra, Secretary DARE & Director General, ICAR, New Delhi.
- Shri. Bhaskarjyoti Sharma, Special Secretary of Agriculture, Government of Odisha.
- Dr. Christy Fernandes, Chairman, KSIDC, Govt. of Kerala.
- Dr. Sanjeev Saxena, ADG, IP&TM, ICAR, New Delhi.
- Dr. Ajay Parida, Director, Institute of Life Sciences, Bhubaneswar, Odisha.
- Dr. Subhrendu Sekhar Dey, Managing Director, The Agricultural Promotion & Investment Corporation of Odisha Limited, Bhubaneswar, Odisha.
- Dr. L.N. Gadanayak, Dean, College of Agriculture & Vice Chancellor (Acting), Orissa University of Agriculture and Technology, Bhubaneswar, Odisha.
- Dr. Gopakumar G. Nair, Ex-Dean, Institute of Intellectual Property Studies, Mumbai.
- Shri. Mohan Choudhari, Assistant Director (OL) and Member Secretary (TOLIC), Office of the Chief PMG, Thiruvananthapuram.

- Dr. S. Pradeep Kumar, Director, KSCSTE, Thiruvananthapuram.
- Dr. Purnachandra Rao, Director, NCESS, Thiruvananthapuram.
- Dr. Asha Kishore, Director, SCTIMST, Thiruvananthapuram.
- Dr. Ajay Ghosh, Director, NIIST, Pappanamcode, Thiruvananthapuram.
- Dr. Renuka Leslie, Senior Consultant, Women & Children Hospital, Thycaud, Thiruvananthapuram.

Dr. T. Mohapatra, Secretary DARE & DG ICAR visiting the Institute museum of ICAR – CTCRI

Shri. Adv. V. S. Sunil Kumar, Hon'ble Minister for Agriculture, Govt. of Kerala Inaugurating Agri Startup Meet 1.0 at ICAR – CTCRI

MANAGERIAL PERSONNEL

Director	:	Dr. Archana Mukherjee
Project Coordinator	:	Dr. James George
Head, Regional Centre, Bhubaneswar	:	Dr. M. Nedunchezhiyan (i/c)
Senior Administrative Officer	:	Shri. Davis Joseph (Rtd. on 30.09.2017)
Finance and Accounts Officer	:	Smt. R. Sari Bai (Rtd. on 30.09.2017)
	:	Shri. P. Krishnakumaran (w.e.f. 30.12.2017)
Central Public Information Officer	:	Dr. C.A. Jayaprakas
Vigilance Officer	:	Dr. Saravanan Raju

Head of Divisions/Section

Crop Improvement	:	Dr. M. N. Sheela (i/c)
Crop Production	:	Dr. V. Ravi
Crop Protection	:	Dr. C.A. Jayaprakas (Acting)
Crop Utilisation	:	Dr. J.T. Sheriff (upto 26.06.2017)
	:	Dr. M. S. Sajeev Head (i/c) w.e.f. 27.06.2017
Extension and Social Sciences	:	Dr. Sheela Immanuel (i/c)

PERSONNEL

HEADQUARTERS, Thiruvananthapuram	
Director	**Dr. Archana Mukherjee**
AICRP on Tuber Crops	
Dr. James George	Principal Scientist & Project Coordinator
Dr. S. Sunitha	Principal Scientist
Shri. Suresh kumar J.	Scientist
Division of Crop Improvement	
Dr. M. N. Sheela	Principal Scientist & Head (i/c)
Dr. P. Murugesan	Principal Scientist
Dr. Asha K. I.	Principal Scientist
Dr. C. Mohan	Principal Scientist
Dr. A. Asha Devi	Principal Scientist
Dr. Shirly Raichal Anil	Principal Scientist
Dr. N. Krishna Radhika	Scientist
Dr. Vivek Hegde	Scientist
Dr. Visalakshi Chandra C.	Scientist
Dr. P. Arunkumar	Scientist
Dr. A.V.V. Koundinya	Scientist
Dr. Senthilkumar K.M.	Scientist
Division of Crop Production	
Dr. V. Ravi	Principal Scientist & Head

HEADQUARTERS, Thiruvananthapuram	
Dr. G. Byju	Principal Scientist
Dr. G. Suja	Principal Scientist
Dr. K. Susan John	Principal Scientist
Dr. V. Ramesh	Principal Scientist
Dr. R. Muthuraj	Principal Scientist
Dr. Sanket J. More	Scientist
Division of Crop Protection	
Dr. C.A. Jayaprakas	Principal Scientist & Head (Acting)
Dr. M.L. Jeeva	Principal Scientist
Dr. S.S. Veena	Principal Scientist
Dr. T. Makeshkumar	Principal Scientist
Dr. Harish. E.R.	Scientist
Dr. H. Kesava Kumar	Scientist
Dr. Sangeetha B.G.	Scientist
Ms. Sirisha Tadigiri	Scientist
Shri. Arutselvan R.	Scientist
Division of Crop Utilization	
Dr. M. S. Sajeev	Principal Scientist & Head (i/c)
Dr. A.N. Jyothi	Principal Scientist
Dr. Saravanan Raju	Senior Scientist
Smt. Namrata Ankush Giri	Scientist
Ms. Pradeepika Chintha	Scientist
Dr. Krishnakumar T.	Scientist
Section of Extension and Social Sciences	
Dr. Sheela Immanuel	Principal Scientist & Head (i/c)
Dr. T. Srinivas	Principal Scientist
Dr. V. S. Santhosh Mithra	Principal Scientist
Dr. J. Sreekumar	Principal Scientist
Dr. P. Sethuraman Sivakumar	Principal Scientist
Dr. D. Jaganathan	Scientist
Shri. Prakash P.	Scientist
Library / PME Unit / Photography	
Shri. R. Bharathan	Chief Technical Officer
Smt. T. K. Sudhalatha	Assistant Chief Technical Officer
Shri. V. S. Sreekumar	Senior Technical Officer
Smt. B. S. Deepa	Technical Assistant
Field/Farm/Lab. Technical Staff	
Smt. Sujatha Kumari N.	Chief Technical Officer
Dr. L.S. Rajeswari	Assistant Chief Technical Officer
Shri. A. Madhu	Assistant Chief Technical Officer
Shri. I. Puviyarasan	Assistant Chief Technical Officer
Shri. M. Kuriakose	Assistant Chief Technical Officer

HEADQUARTERS, Thiruvananthapuram	
Shri. C.S. Salimon	Assistant Chief Technical Officer
Shri. L.V. Ajithkumar (Rtd. on 30.11.2017)	Senior Technical Officer
Shri. V. R. Sasankan	Senior Technical Officer
Shri. B. Renjith Kishor	Senior Technical Officer
Shri. V. Ganesh	Technical Officer
Shri. Patric M. Mascrene	Technical Officer
Shri. S. Natarajan	Technical Officer
Shri. A. S. Manikuttan Nair	Technical Officer
Shri. G. Suresh	Senior Technical Assistant
Dr. S. Shanavas	Senior Technical Assistant
Shri. B.S. Prakash Krishnan	Senior Technical Assistant
Shri. G. Shajikumar	Senior Technical Assistant
Shri. Luke Armstrong	Technical Assistant
Dr. S. Karthikeyan	Technical Assistant
Smt. Pallavi Nair K.	Technical Assistant
Shri. K. Sunil	Technical Assistant
Shri. T. Raghavan	Senior Technician
Shri. B. Satheesan	Senior Technician
Shri. D.T. Rejin	Senior Technician
Shri. Shinil T.M.	Senior Technician
Shri. C. Krishnamoorthy	Technician
Shri. K.Velayudan	Technician
Shri. T. Manikantan Nair (w.e.f. 24.03.2018)	Technician
Administration and Accounts	
Shri. Davis Joseph (Rtd. on 30.09.2017)	Senior Administrative Officer
Smt. R. Sari Bai (Rtd. on 30.09.2017)	Finance and Accounts Officer
Shri. T. Jayakumar (Rtd. on 30.11.2017)	Assistant Administrative Officer
Shri. T. Vijayakumara Kurup (w.e.f. 01.12.2017)	Assistant Administrative Officer
Smt. Jessymol Antony	Assistant Finance and Accounts Officer
Smt. K. Padmini Nair	Personal Assistant
Shri. S. Sasikumar	Personal Assistant
Shri. M. Padmakumar	Personal Assistant
Smt. S. Sunitha	Stenographer Grade – III
Smt. B. Presanna	Assistant
Shri. P. S. Suresh Kumar	Assistant
Shri. J. Unni	Assistant
Shri. K. Unnikrishnan Nair	Assistant
Shri. S. Hareendrakumar	Assistant
Shri. Arjun Murali (w.e.f. 20.07.2017)	Assistant
Smt. V. Sathyabhama	U. D. C.
Shri. O.C.Ayyappan	U. D. C.
Shri. S. Sreekumar	U. D. C.

HEADQUARTERS, Thiruvananthapuram	
Shri. R.S.Adarsh (w.e.f. 18.12.2017)	U. D. C.
Shri. C. Chandru	L. D. C.
Shri. N. Jayachandran	L. D. C.
Smt. C.G. Chandra Bindhu	L. D. C.
Canteen Staff	
Shri. S. Radhakrishnan Nair	Skilled Support Staff
Skilled Support Staff	
Smt. S. Ushakumari	Skilled Support Staff
Shri. P. Udayakumar	Skilled Support Staff
Shri. K. Saratchandra Kumar	Skilled Support Staff
Shri. G. Madhu	Skilled Support Staff
Shri. A. Chandran	Skilled Support Staff
Smt. C.T. Chellamma	Skilled Support Staff
Smt. M. Syamala	Skilled Support Staff
Shri. T. Lawrence	Skilled Support Staff
Shri. K. Sivadas	Skilled Support Staff
Smt. J.Thenmozhi	Skilled Support Staff
Shri. L. Samynathan	Skilled Support Staff
Shri. S. Sreekumaran	Skilled Support Staff
Shri. K. Chandran	Skilled Support Staff
Ms. Rohini K. Nair	Skilled Support Staff
Ms. Sneha S.S.	Skilled Support Staff
Smt. Rini Alocious	Skilled Support Staff
Ms. Gayathri C.P.	Skilled Support Staff
Smt. Nijamol R.	Skilled Support Staff
Shri. Abhishek S.	Skilled Support Staff
Smt. Jyothi S.L.	Skilled Support Staff
Shri. Stiphin George	Skilled Support Staff
Smt. Vidya P.	Skilled Support Staff
Shri. Arunraj D.	Skilled Support Staff
Shri. Sreenath Vijay	Skilled Support Staff
Ms. Anjitha S.	Skilled Support Staff
Shri. Sudhish S.	Skilled Support Staff
Shri. Aswin Raj P.	Skilled Support Staff
Smt. Saritha S.D.	Skilled Support Staff
Smt. Remya V.S.	Skilled Support Staff
Smt. Lekshmi S. Nair (upto 02.02.2018)	Skilled Support Staff
REGIONAL CENTRE, Bhubaneswar	
Scientists	
Dr. M. Nedunchezhiyan	Principal Scientist & Head (i/c)
Dr. R.C.Ray (Rtd. on 30.11.2017)	Principal Scientist
Dr. K. Laxminarayana	Principal Scientist
Dr. Kalidas Pati	Scientist

Regional Centre, Bhubaneswar	
Dr. Vijay Bahadur Singh Chauhan	Scientist
Shri. Venkatraman V. Bansode	Scientist
Shri. Hanume Gowda K.	Scientist
Field / Farm / Lab. Technical Staff	
Shri. N. C. Jena	Technical Officer
Shri. Niranjan Pattnaik	Technical Officer
Shri. Pramod Kumar Mati	Technical Officer
Shri. Bibhudi Bhusan Das	Technical Officer
Shri. Bharat Kumar Sahoo	Senior Technical Assistant
Shri. Sushanta Kumar Jata	Senior Technical Assistant
Shri. Keshab Paikaray	Senior Technician
Administration and Accounts	
Shri. P. C. Noble	Assistant Administrative Officer
Shri. P. K. Acharya	Private Secretary
Shri. K. Lakshamana Rao	Assistant
Skilled Support Staff	
Shri. Ramachandra Das	Skilled Support Staff
Shri. Bijoykumar Nayak	Skilled Support Staff
Shri. Akshayakumar Nayak	Skilled Support Staff
Shri. Purna Samal	Skilled Support Staff
Shri. Bhajaman Malik	Skilled Support Staff
Shri. Sauri Pradhan	Skilled Support Staff
Shri. Ramesh Nayak	Skilled Support Staff
Shri. Babuli Sethi	Skilled Support Staff
Shri. Fakirchandran Bhoi	Skilled Support Staff
Shri. Samsudin Khan	Skilled Support Staff

OTHER INFORMATION

Annual Group Meeting of AICRP on Tuber Crops

The 17th Annual group Meeting of AICRP on Tuber Crops for the year 2016-17 was held at University of Horticultural Sciences, Bagalkot, Karnataka during 28th to 30th April, 2017. Dr. Archana Mukherjee, Director, ICAR-CTCRI formally inaugurated the event, which was presided over by Dr. D.L. Maheswar, Vice Chancellor, University of Horticultural Sciences, Bagalkot. The Best Centre Award during 2016-17 was presented to Ranchi centre of Birsa Agricultural University, Jharkhand. The meeting recommended one variety in greater yam for release for the states of Chhattisgarh and Gujarat.

Dr. Archana Mukherjee, Director, ICAR-CTCRI inaugurating 17th Annual Group Meeting of AICRP on Tuber Crops

H.H. Sree Visakham Thirunal Endowment Lecture 2017

The seventh H. H. Visakham Thirunal Endowment lecture organized by the Indian Society for Root Crops (ISRC) in collaboration with ICAR-CTCRI was held on 18 May 2017. The lecture was delivered by the World Food Prize laureate Dr. Jan Low, Leader, Sweet Potato for Profit and Health Initiative, International Potato Center, Kenya on the topic "Developing and Disseminating Biofortified Sweet Potato in Sub-Saharan Africa: Technical and Social Perspectives". Scientists and staff members of ICAR – CTCRI participated in the programme.

Foundation Day Celebrations 2017

Fifty fourth foundation day of ICAR-CTCRI was celebrated on 29 July, 2017. Shri. Teeka Ram

Meena, IAS, Principal Secretary (Agriculture) and Agricultural Production Commissioner, Government of Kerala was the Chief Guest. Smt. K. C. Rugmini Devi, Managing Director, Small Farmers Agri-Business Consortium (SFAC), Government of Kerala and Shri. Ravinderjit Singh, Chief Executive Officer, Agri-Innovate, ICAR, New Delhi were the guests of honour. The online soil health card system was launched during the function and the soil health cards were distributed to four farmers of the *Mera Gaon Mera Gaurav* scheme. The staff who retired from service were felicitated during the function.

Foundation day celebrations 2017

Brainstorming on Developing Standards for quality planting materials of tuber crops

Considering the need for developing quality planting material standards for cassava and other tubers, the ICAR–Central Tuber Crops Research Institute had organised a brainstorming on "Developing standards for quality planting materials of tuber crops" on August 2, 2017. The meet was inaugurated by Shri M. Subramonian, Joint Director, Directorate of Agriculture, Govt. of Kerala. Shri M. Subramonian has indicated that developing planting material production standards is the need of the hour and lauded the efforts of ICAR-CTCRI for initiating this process. He assured that the State Agriculture department will provide necessary help in institutionalizing the standards and also sought CTCRIs help in educating the seed certification officers in implementing these standards for quality seed production in the state. Dr. Archana Mukherjee, Director of ICAR – CTCRI indicated that the demand for quality planting materials of tuber crops is increasing especially from non-traditional states like Maharashtra and Gujarat, there is an urgent need to develop quality planting material production standards for tuber crops. She sought cooperation and help from the State Agriculture department in developing and institutionalising these standards for improving the quality of output from tuber crops. Dr. James George, Project Coordinator (Tuber Crops) who played a key role in developing rapid quality planting materials from tubers and Dr. V. Ravi, Head, Crop Production also addressed the gathering. This brainstorming was organized by Dr. P. Sethuraman Sivakumar, Chairman of Intellectual Property Technology Management Unit of ICAR – CTCRI to address the gap in seed certification standards as well as create a battery of seed entrepreneurs or seed villages for benefit of the farmers in Kerala and other states. About 30 scientists, academicians, Subject Matter Specialists from KVKs, officials from state Agriculture Department took part in this event.

Mr. M. Subramonian, Joint Director, Directorate of Agriculture delivering inaugural address

Collaborative Workshop on "Good Practices in Quantitative Social Science Research"

The ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), in collaboration with the Centre for Research on Innovation and Science Policy (CRISP), Agricultural Extension in South Asia (AESA) and National Institute of Agricultural Extension Management (MANAGE) under the aegis of Agricultural Extension in South Asia (EASA), had organised a workshop on "Good Practices in Quantitative Social Science Research: A Journey from Conceptualization to Research Application" at ICAR-CTCRI during August 7-12, 2017. The workshop was inaugurated by an eminent scholar and development planner Prof. Sunil Mani, Director, Centre for Development Studies, Thiruvananthapuram on August 7, 2017. Dr. James George, Project Coordinator – AICRP, TC and Director (In charge), ICAR-CTCRI has delivered the presidential address. Dr. James George has explained the need for conducting quality social science research for designing sound approaches for technology transfer and commercialisation. Dr. Sheela Immanuel, Head – Extension & Social Sciences, ICAR-CTCRI. was the Guest of Honour at the inaugural and narrated the intentions and motivations behind this collaborative workshop. While Dr. P. Sethuraman Sivakumar, Principal Scientist & Programme Director welcomed the participants with a brief note on AESA and its collaborators, Dr. D. Jaganathan, Scientist & Programme Coordinator, proposed vote of thanks. A total of 38 participants comprised of 17 practicing professionals and 21 research scholars from seven states representing diverse domains like agricultural extension, agricultural economics, rural management, agribusiness management,

Workshop on GPQSSR

Participants of the Workshop

home science, library science and social work had actively participated in the workshop.

Indo-Swiss Cassava Network Project Meeting

The third year review meeting of the Indo-Swiss Cassava Network Project was held at ICAR-CTCRI during 28-31 August 2017. This meeting was inaugurated by Dr. Archana Mukherjee, Director, on 28 August 2017. Dr. Lilian Gilgen, Program Manager, ISCB, EPFL, Switzerland briefed about the activities of Indo-Swiss Collaboration in Biotechnology (ISCB) and expectations from this review meeting. It was attended by all the scientists of the participating centres. The salient achievements of biotech components includes, transgenic cassava (H 165 and TMS 60444) having Sri Lankan Cassava Mosaic virus RNAi constructs were developed, confirmed through molecular analysis and cassava mosaic disease resistant cassava lines were evaluated in farmers' fields at Salem, Tamil Nadu. In the socio-economic studies, different cassava production systems in India, their economics of cultivation, value addition and awareness of genetically modified cassava were documented. The project was extended for one more year.

Participants of the Indo – Swiss Meet

AGRISTARTup 1.0: Tuber Crops Technology Conclave & Agri-Startup Meet 2017

The startup culture is gaining new ground in Kerala due to the efforts of State Government and its national share stands at 15% of all the total start-ups in the country. Despite the resurgence of startup culture in Kerala especially in IT sector, only 8% of start-ups are focusing on agriculture and food processing sector. Considering the need to promote agristartups in the state, the ICAR–Central Tuber Crops Research Institute, Thiruvananthapuram along with Kerala State Industrial Development Corporation (KSIDC), IPTM Central Unit, ICAR; AgriInnovate India (a Central Govt company) and National Institute of Agricultural Extension Management (MANAGE), Hyderabad had organised a two day Tuber Crops Technology Conclave and Agristartup Meet of Thiruvananthapuram during 27-28 October 2017. This high profile meet was inaugurated by Hon'ble Minister for Agriculture Adv. Shri. V. S. Sunil Kumar, in the presence of Dr. Trilochan Mohapatra, Secretary DARE & Director General ICAR, Shri. Teeka Ram Meena IAS, Agricultural Production Commissioner, Govt of Kerala; Shri Bhaskarjyoti Sharma IAS, Special Secretary of Agriculture, Odisha Government; along with other dignitaries from Kerala and Odisha states. Dr. Christy Fernandez IAS (Retd), Chairman, KSIDC has flagged off the Agristartup meet on 27 October 2017.

Adv. Shri. V. S. Sunil Kumar, during his inaugural address has called for maximising the income of farmers by reducing the production cost as well as creating agricultural enterprises. Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR, New Delhi, during his presidential address, has

Inaugural address by Adv. Shri. V. S. Sunil Kumar, Hon'ble Minister for Agriculture, Govt. of Kerala

Presidential address by Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR New Delhi

called for promoting agristartup as a key instrument for stabilising market prices and securing farmers welfare. Shri. Teeka Ram Meena IAS, Agricultural Production Commissioner and Principal Secretary, Department of Agriculture, Govt of Kerala, explained about various schemes implemented in Kerala for creating agricultural enterprises. The Rashtriya Krishi Vikas Yojana (RKVY) project on tuber crops was launched by Shri. Bhaskarjyoti Sharma IAS, Special Secretary, Department of Agriculture and Farmers Empowerment, Govt. of Odisha. Dr. Sanjeev Saxena, Asst. Director General (IPTM), ICAR briefly explained about ICAR's role in Agristartup creation. Dr. Archana Mukherjee, Director, ICAR-CTCRI, welcomed the gathering and briefed about the significant achievements of ICAR-CTCRI in helping farmers to maximise their income. Dr. James George, Project Coordinator, AICRP on TC, ICAR-CTCRI, proposed vote of thanks.

The Tuber Crops Technology Conclave & Agri-Startup Meet (AGRI-STARTup1.0) is a unique stakeholder business meet intended to bridge the gap between the agri-innovators and industry, by bringing them under a platform to initiate dialogue and action to accelerate the technology commercialisation for creating sustainable agro-enterprises. This meet has integrated technology developers, financiers, entrepreneurship promotion agencies, policy makers along with successful agristartups from various states like Kerala, Assam and Telangana to promote agricultural entrepreneurship in Kerala. The successful start-ups have shared their experiences of creating a agri-business to motivate the young and aspiring entrepreneurs to venture into agribusiness. Various central and state industrial promotion agencies like KSIDC, MANAGE, and venture capitalists discussed on the critical aspect of debt and equity funding and narrated their schemes and criteria for choosing start-ups for financing. Besides, a session on Intellectual Property and Technology Licensing has elaborated on the ways to promote Public – Private Partnership. Dignitaries and experts from several International and national agencies like ICRISAT, Hyderabad; ICAR, New Delhi; AgriInnovate India; KSIDC; Sree Chitra Institute of Medical Sciences; NIIST among several others took part in this meet. Over 150 participants from eight states took part in this meet. AGRISTARTUP 1.0 was the first ever integrated technology conclave and agribusiness meet conducted in Kerala.

Vigilance Awareness Week 2017

The Institute observed Vigilance Awareness Week with the theme on "My Vision-Corruption Free India" during October 30 to November 4, 2017 as per the directive of the Central Vigilance Commission and in pursuance of the said directive issued by the Indian Council of Agricultural Research, New Delhi vides letter no. 51-9/2017-Vig. dated 13th October 2017. The week started with the vigilance pledge taken by all the employees of ICAR-CTCRI, Thiruvananthapuram which was administered by Dr. Archana Mukherjee, Director at 11.00 hrs on 30th October, 2017 in reception area of the Institute. A series of activities related to vigilance and anti-corruption at work place were organized namely, collage making competition (Theme: *India Against Corruption*), display of various posters etc. to create awareness

Vigilance awareness week 2017

amongst all categories of staff. A special invited talk was presented by Shri. P. Prakash, IPS, City Police Commnissioner, Thiruvananthapuram was arranged on 3rd November on vigilance aspects. The winners of various competitions were felicitated by the Chief Guest and the Director with prizes. The meeting was concluded by vote of thanks by Institute vigilance officer.

Entrepreneurship Development Programme for Agriculture Students

The ICAR–CTCRI in collaboration with College of Agriculture, Kerala Agricultural University (KAU), Vellayani has organised an "Entrepreneurship Development Programme" for BSc (Ag) final year students during November 16-17, 2017. During the programme, the students were equipped with critical skills in business planning. A pitching was also organised as a part of this programme. About 100 students and faculty took part in the programme.

EDP programme for B.Sc. Agri students of College of Agriculture, Vellayani

Open Day Programme celebrated at ICAR-CTCRI

As part of the "Science Promotion Week", a one day program titled "Sastrajalakom"was celebrated at ICAR-CTCRI on 17 November 2017, organized by the Science Forum Unit and Section of Extension and Social Sciences in view of the request from the Kerala State Council for Science Technology and Environment. The purpose of the program was to inspire the young generation and create scientific temper among all sections of the society. Around 120 students representing different schools of Thiruvananthapuram participated in the programme. It was marked with museum, field, laboratory and techno-incubation centre (TIC) visits as well as interaction with concerned officials for the latest research and development aspects of agriculture in general and tuber crops in particular. Dr. V. Ramesh, Principal Scientist coordinated the programme.

Open day programme celebrations

Horti-Technology Incubation for Agristartup and Entrepreneurship Development in Odisha

Dr. Trilochan Mohapatra, Secretary (DARE) & Director General of ICAR inaugurated the "Agristartup 2.0" at ICAR – Central Tuber Crops Research Institute, Bhubaneswar on November 18, 2017. Dr. Mohapatra stressed that the ICAR Institutes, Orissa University of Agriculture & Technology, Public sector entrepreneurship development agencies should work together to support budding entrepreneurs to harness the opportunities offered by recent technological advancement, market expansion and policy changes in the state. The Director General called for developing collaborative networks to catalyze agristartups in the state. Dignitaries like Dr. R.C. Agrawal, Registrar General, PPV&FRA, New Delhi; Dr. Sanjeev Saxena, Asst Director General, IP & TM, ICAR, New Delhi, Dr. Ajay Parida, Director, Institute of Life Sciences, Bhubaneswar, Dr. Subhrendu Sekhar Dey, Managing Director, APICOL (The Agricultural Promotion & Investment Corporation of Odisha Limited), Bhubaneswar along with Directors and Scientists of ICAR Institutes in Odisha were present during the inauguration and interactive session. Dr. Mohapatra also inaugurated the newly developed “RKVY Techno-Incubation Centre”-a food processing facility dedicated for promoting tuber crops based enterprises in Odisha. Dr. Mohapatra chaired the Interactive Sessions for Agristartup and Horti entrepreneurship. During interactive session, the Director General interacted with several budding entrepreneurs from Odisha and suggested to develop sound business models for mushroom production and processing and to lead it to rank No 1 in India. He also stressed in harnessing quality seed production in mango and rice for creating sustainable agri-horticulture in Odisha. Representatives from startup promotion agencies like Startup Mission Odisha, APICOL and Technology Business Incubator, KIIT University explained the various schemes available for promotion of startups in Odisha. In the Scientist-Startup Interface session, Dr. Archana Mukherjee, Director, ICAR-CTCRI; Dr. M. Nedunchezhiyan, Head (i/c), Regional Centre of ICAR-CTCRI and Dr. P. S. Sivakumar, Chairman – Intellectual Property & Technology Management unit of ICAR-CTCRI interacted with the participants on the modalities of using the Incubation Centre for creating sustainable tuber crops enterprises. About 100 aspiring entrepreneurs, representatives from Central and state agencies, farmers and students participated in the meet.

Agristartup 2.0 at ICAR-CTCRI RC, Bhubaneswar

Tuber crops day celebrations

Tuber crops day was celebrated on 4 December 2017 in the Millennium Hall of ICAR – CTCRI. The celebration was inaugurated by Shri Muralidharan Thazhakara, Programme

Mr. Muralidharan Thazhakara, Progamme Officer, All India Radio delivering inaugural address

Felicitation of award winning farmer

Officer, All India Radio. In his inaugural speech, he pointed out the importance of traditional knowledge and sustainable agriculture in the context of climate change. He also stressed about the importance of tuber crops as food-cum-livelihood security crop, especially to the poor tribal communities. The meeting was presided over by Dr. Archana Mukherjee, Director, ICAR-CTCRI. Dr. Sheela Immanuel, Head, Extension and Social Sciences welcomed the gathering. Five progressive tuber crops farmers were felicitated during the function. Dr. D. Jaganathan, Scientist proposed the vote of thanks. The inaugural function was followed by Scientist-Farmer interface. About 200 farmers attended the function.

Agricultural Education day

The Agricultural Education day was celebrated at ICAR – CTCRI in the Millennium Hall of the Institute on 4 December 2017. The program was inaugurated by Dr. Archana Mukherjee, Director, ICAR–CTCRI. The inauguration was followed by a variety of competitions. Quiz competition was conducted for the farmers of Kerala and winners were awarded with certificates and prizes. Welcome speech and importance of education day was delivered by Dr. G. Byju, Principal Scientist. Dr. B. G. Sangeetha, Scientist proposed vote of thanks. All the scientists, technical, administrative and supporting staff, research scholars, M.Sc. students, apprentice trainees and college and school students actively participated in the meeting.

Participants of Agricultural Education day 2017

Vishwa Mrida Diwas-2017 Celebrations at ICAR-CTCRI

World Soil Day-2017 was organized at the Institute on 05 December 2017. The focal theme for this year, as chosen by the Food and Agriculture Organization (FAO), Rome, Italy was “Caring for the planet starts from the ground”. About 130 participants representing scientists, technical staff, students and farmers attended the main function. A short video film was shown to the participants. In addition, pamphlets in English and Hindi on “Soil Health Card Scheme” were distributed. Banners and hoardings in English and Hindi were displayed as per the guidelines received from the council. The event was marked with guest lecture, soil day pledge, distribution of soil health card to farmers and soil laboratory visits by the school students. The program was co-ordinated by Dr. V. Ramesh.

Distribution of Soil Health Card to the farmer by Director, ICAR-CTCRI

Hoarding on Soil Health Card scheme

Seminar on Rural Entrepreneurship through Value Added Agriculture

The Division of Crop Utilization conducted a one day seminar on “Rural Entrepreneurship through Value Added Agriculture” sponsored by Kerala State Council for Science, Technology and Environment (KSCSTE)-Kerala Biotechnology Commission (KBC) – Biotechnology Innovations for Rural Development (BIRD) Project on 22 December 2017. Dr. S. Pradeep Kumar, Member Secretary, KSCSTE inaugurated the function. Topics covered included, entrepreneurship developments in horticulture, scope of under exploited agri-produce for micro enterprises, Organic farming for Safe Food and Sustainable Income, Central and state financial schemes for rural entrepreneurship and Food safety-rules and regulation. A total of 150 participants from various parts of Kerala attended the seminar.

Seminar on Rural Entrepreneurship

Entrepreneurship Development programme on Cassava-based Agro-Enterprises for Developing Sustainable Livelihoods

Shifting the focus from traditional starch and sago to new generation industries like biofuels – ethanol and bioplastics can bring significant changes in the livelihoods of Malayali tribals – was the message delivered during the Entrepreneurship Development programme “Cassava-based Agro-Enterprises for Developing Sustainable Livelihoods” organised by ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Thiruvananthapuram in collaboration with Veterinary College & Research Institute, Namakkal, National Institute for Agricultural Extension Management (MANAGE), Hyderabad and Hand in Hand India (NGO) at the Top–Sengottupatti Village, Pachamalai Hills on 02 February, 2018. This programme was organised to explore new ways of commercializing cassava by converting them into new generation products like ethanol, bioplastics, animal feed and functional foods. A team of scientists from ICAR-CTCRI led by Dr. P. Sethuraman Sivakumar, Principal Scientist along with Dr. V. Uma and Dr. S. Karthikeyan, Assistant Professors of Veterinary College have sensitised tribal farmers on various business options available using cassava based value added technologies. During the meeting, Dr. V. Ramesh, Principal Scientist, has explained techniques of profitable soil fertility management. The opportunities and methods of producing quality seeds were dealt by Dr. R. Muthuraj, Principal Scientist while Dr. M. Surulirajan, Assistant Professor, Krishi Vigyan Kendra (KVK), Sirugamani briefed about various pests and disease management in the industrial cassava production. Dr. D. Jaganathan of ICAR-CTCRI and Shri. Murugesan of Hand in Hand India demonstrated various value products developed from cassava.

In the Scientist-Farmer Interface the cassava farmers interacted with scientists on specific aspects related to cassava value addition and entrepreneurship development. A short-term strategy for introducing high starch cassava varieties like Sree Athulya and Sree Pavithra in Pachamalai through minisett propagation technique was decided through farmer participatory mode at the meeting. About 100 Malayali tribal farmers took part in the event.

EDP on Cassava based agro enterprises

National Science Day-2018

The National Science day was celebrated at ICAR-CTCRI during 23–24 February 2018. The programme was sponsored by Kerala State Council for Science, Technology and Environment (KSCSTE) and supported by Department of Science & Technology, Govt of India. Dr. V. Ramesh, Principal Scientist, ICAR-CTCRI was the Programme Co-ordinator and Dr. Mrs. Shirly Raichal Anil, Principal Scientist, ICAR-CTCRI was the General Convenor of the NSD-2018 celebrations. The programme was conducted on focussing this year theme *i.e.* “Science and Technology for sustainable future”. Dr. Archana Mukherjee, Director, ICAR-CTCRI presided over the inaugural function held on 23 February. Dr. Purnachandra Rao, Director, NCESS, Thiruvananthapuram was the chief guest of the inaugural function.

National Science day celebrations 2018

Open day program for school students; inter collegiate quiz competition for college students, in-house quiz and elocution competitions for the staff of ICAR-CTCRI were organised during the two day event. The valedictory function was held on 24 February and presided over by Dr. Archana Mukherjee, Director, ICAR-CTCRI. Dr. Asha Kishore**,** Director, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram was the Chief Guest. The Chief Guest gave away prizes and certificates to the winners of various competitions.

EDP on Utilising Village Incubation Centre for Creating Sustainable Tuber Crops Based Enterprises

As part of the North Eastern Hill Development project ‘Entrepreneurship Development Programme on “Utilising Village Incubation Centre for Creating Sustainable Tuber Crops Based Enterprises” was organized on 14 March 2018 at ICAR-CTCRI & ICAR RC NEH Village Incubation Centre, Riha Village, Ukhrul dist., Manipur. More than 100 progressive farmers and other stakeholders had participated in the programme. Dr. R. Muthuraj, Principal Scientist, Dr. D. Jaganathan and Dr. T. Krishnakumar Scientists handled lecture cum discussions on tuber crops based technologies. Dr M. R. Sahoo, Senior Scientist, ICAR Research complex for NE region, Manipur and Dr. Ramakrishna, Programme Coordinator, KVK, Ukrul emphasized on the prospects of the village incubation centres which were established under the ICAR-CTCRI-NEH programme as the sustainable livelihood of the tribal communities.

Village incubation centre at Riha, Manipur

The established village incubation centres were not only helpful for increasing rural livelihood but also for doubling the farmer's income through value addition of tuber crops through primary and secondary processing. Planting materials of tuber crops and value added products of tuber crops were distributed. Demonstration on preparation of value added products was conducted at Village Incubation centre, Riha village. Farm advisory visits were conducted to the tuber crops growing areas of Riha village. Video programme was covered in DD Kisan on the topic 'Tuber crops based technologies for enhancing profitability in Manipur'

Workshop on Tuber Crops Technology based Enterprise Development

Stakeholder Workshop on "Tuber Crops Technology based Enterprise Development in Manipur" was organized on 15 March 2018 at ICAR Research Complex for NEH, Manipur Centre, Imphal. Dr. N. Prakash, Director, ICAR Research Complex for NEH Region emphasized on doubling the farm income through tuber crops based enterprises. Chief Guest of the function, Shri P. K. Bal, Chairman of Manipur Rural Bank elaborated the role of bankers in entrepreneurship development. Dr. I. Meghachandra Singh, Joint Director, appealed to the concerned stakeholders for optimum utilization of the Tuber Crops Incubation Centres established by ICAR at Riha

Dr. N. Prakash, Director, ICAR-Research Complex for NEH Region delivering presidential address

Participants of the workshop

and Thoyee villages in Ukhrul. Scientific delegates from ICAR-CTCRI, Thiruvananthapuram, Dr. R. Muthuraj, Dr. D. Jaganathan and Dr. T. Krishnakumar provided technical back upto the stakeholders. Dr. M.R. Sahoo highlighted the success story of the tuber crop incubation centres as the life line of the tribal communities. More than 50 entrepreneurs, SHG members, scientists and technicians had participated and deliberated on scope and opportunities of tuber crops based enterprises in Manipur state.

Library corner

Library continued the information support services to the research and training activities of the Institute. In addition to the routine services, the major activities undertaken were:

1. **Circulation of books**: A total of 245 books were issued to the users on loan and it was recorded properly in the books issue register.
2. **CeRA:** About 30 Document Delivery Request (DDR) of outside users of CeRA were satisfied by sending hard copy of library materials.
3. **Ready-reference service**: Provided ready assistance and solutions to the user's on various queries. These include enquiries in person or over the phone regarding any matters related to information sources like URLS of websites related to our work, downloading of files, common plant names, phone numbers, geographical information etc. More than 1635 users availed the facility of reference services from the library.
4. **Reading and reference facilities to the research students within and outside the Institute**: Services were extended to the students from Colleges and University Departments, who undertook their BSc, MSc project works, Ph. D and Pdf works under the guidance of the Institute Scientists during 15 days, 1-3 months and 3-5 years respectively. They were given necessary guidance in the use of reference resources and also photocopying facility.
5. **Photocopying:** Library continued to provide photocopying service to the Institute staff and other library users on official/payment basis. During this period, 40456 copies were provided against their work indents, which included official copies and private copies.

6. **Training cum awareness programme:** A training cum awareness programme on J-Gate @ CeRA was arranged to the various categories of users of the Institute about the usage of jgateplus.com

Hindi Corner

Hindi Workshop and Fortnight Celebrations 2017

A one-day Hindi workshop cum valedictory function of the Hindi Fortnight celebrations 2017 was organized on 15 November 2017 where, Dr. James George, Project Co-ordinator and Director in charge presided. Shri. Mohan Choudhari, Assistant Director (OL) and Member Secretary (TOLIC), Office of the Chief PMG, Thiruvananthapuram was the Chief Guest. Prize distribution was done by the Chief guest. The topic of the workshop was “Noting and Drafting and Official Language Implementation”. In total, 34 participants attended the workshop.

Hindi Workshop

The OLIC meeting was conducted on 21 December 2017 to review the progress of work for the quarter October-December 2017 under the Chairmanship of Dr. Archana Mukherjee, Director and Chairperson, OLIC, ICAR-CTCRI. In connection with the Prabodh Correspondence Course under Central Hindi Training Institute, New Delhi, the first contact programme was conducted from 18-19 December 2017 at All India Radio, Vazhuthacaud and seven staff members attended.

State of art of MGMG

The scientists made 75 visits to the MGMG villages and met 1247 farmers. Twenty three meetings were conducted, which were attended by 657. Mobile based advisories numbering 1948 were given on improved varieties, tuber crop production and value addition, nutrient management, decision support tool for cassava nutrient management, pests and disease control in various crops, application of bio-pesticides for management of different pests and diseases, cassava marketing, vegetable cultivation and manuring in coconut. Tuber crop leaflets (702) were also supplied to farmers. Bio-pesticides were distributed to 45 farmers. Planting materials of cassava, sweetpotato, greater yam and elephant foot yam and arrowroot were given to 18 farmers. Soil health cards were distributed to the selected farmers in *MGMG* villages. Production technologies of cassava, sweet potato, yams and elephant foot yam and balanced application of fertilizers based on soil test data were given 114 farmers.

General awareness created among the farmers in the *MGMG* villages were, use of fungicides (combination of mancozeb and Carbendazim) for elephant foot yam disease, Use of *Menma*, *Nanma* and *Shreya* for the control pests in Banana and sucking insects in vegetables, improved agro-techniques of tropical tuber crops, improved varieties and advanced nutrient management techniques in tuber crops, correction of soil acidity and balanced application of fertilizers based on soil test data, production technologies for cassava, sweet potato, and yams, post-harvest disease management aroids, especially elephant foot yam, collar rot management in elephant foot yam, tuber crops processing and value addition, integrated pests & disease management in tropical tuber crops, SSNM of cassava, information regarding the methods and dosage of fertilizer and herbicide application, knowledge on new varieties of tuber crops and advances in nutrient management and selection of pest and disease free planting materials

The major problems identified in the *MGMG* villages were, labour shortage, price fluctuations, climate change, spiralling whitefly, virus, nematode and secondary fungal infection in elephant foot yam, soil acidity and nutritional disorders, luxuriant weed growth under climate change, cassava mosaic disease, sweet potato weevil, pest and diseases, unavailability of quality planting material, banana pseudostem weevil, sooty mould in all crops, anthracnose in greater yam, fungal infection in elephant foot yam and lack of short duration cassava varieties, lack of irrigation facilities, zinc and boron deficiency.

Linkages were created with ATMA, Thiruvananthapuram, Krishi Bhavan, Pothencode, Krishi Bhavan, Kazhakootam, VFPCK, KAU, Orissa University of Agriculture and Technology, Veterinary hospital, State horticulture department, KVK, Mitraniketan, Department of Veterinary and Animal Sciences, MATSYAFED, Thiruvananthapuram, Depas-rtment of Fisheries and Panchayat Vikasana Samithi.

Farm advisory visit

Demonstration on improved varieties

Scientist-farmer Interaction

Supply of planting materials

Farm advisory visit

Training Programme

Field visits

Swachh Bharat Abhiyan

ICAR-CTCRI is dedicatedly involved in various activities related to "Swachh Bharat Abhiyan", the nation-wide cleanliness programme conceptualised by the Hon'ble Prime Minister of India. Since its inception in 2014 at ICAR-CTCRI, various cleanliness initiatives have been implemented such as:

- Swachh Bharat Abhiyan was conducted weekly on every Saturday for half an hour and all the staff members were instructed to clean their respective laboratories and sitting areas.
- On the last working day of the month, Swacch Bharat Abhiyan was conducted for one hour, during which all the staff members were involved in cleaning the campus as a whole.
- Attendance register was maintained to keep record of presence of members.
- Dust bins, hand gloves and brooms for cleaning were purchased and Swachh Bharat Abhiyan logo and tag line were used in the Institute.
- All members participated to clean offices, cabins, laboratories, garden area, main road area, processing complex, canteen and field area.
- Plastics, bottles, papers etc. were collected and destroyed completely by using incinerator.
- Old and broken items, furniture, glassware and plastic were replaced.

Swachhata Pakhwada and Swachhata hi Seva campaign

ICAR-CTCRI organised the Swachhata Pakhwada from 16-31 May as well as the Swachhata Hi Seva from 15 September to 02 October 2017 to spread the message of cleanliness to the public. 'Swachhata Shapath' was administered by Dr. Archana Mukherjee, Director. All the staff were involved in the cleaning efforts. Plastics, weeds and waste materials were removed from field and public places like children's park in Aakulam tourist village.

Swachhata pakhwada & Swachhata Hi Seva campaign by staff members of ICAR-CTCRI

The Regional Centre, ICAR-CTCRI also celebrated the Swachhata pakhwada from 16-31 May 2017 and Swachhata Hi Seva from 15 September to 2 October 2017.

Swachhata pakhwada & Swachhata Hi Seva campaign by staff members of ICAR-CTCRI RC Bhubaneswar

Field Level Demonstrations/OFTs conducted

- Fifty demonstrations on improved varieties of cassava, sweet potato, elephant foot yam, yams and taro were established in Tamil Nadu, Kerala, Karnataka and Manipur. Farmers were trained to adopt scientific agro management practices. Pests and diseases *viz.*, mealy bug, spiraling white fly and cassava mosaic disease in cassava and sweet potato weevil and leaf eating insects in sweet potato were managed with integrated pest and disease management practices.
- Soil and plant analysis of samples and interpretation of results from on-farm experiments conducted to validate customized fertilizers for SSNM of cassava in 5 AEU zones (35 farmers across five districts) of Kerala.
- On-farm validation of FBMP and customized fertilizers for elephant foot yam and yams in Palakkad and Malappuram districts.

Farm advisory visits

- A multi-disciplinary team consists of Dr. E. R. Harish, Dr. R. Muthuraj and Dr. D. Jaganathan visited cassava fields in Thovalai taluk of Kanyakumari district of Tamil Nadu during second week of January 2018 to assess the incidence of mealybug in cassava. Farmers were recommended integrated pest management package for the management of mealy bug in cassava.

Assessment of mealy bug incidence in cassava in Kanyakumari dt, Tamil Nadu

- A multidisciplinary team of scientists visited Uttara Kannada and Belagavi districts of Karnataka for assessing the performance of tuber crops farming during July and November 2017. Visited Kanyakumari district of Tamil Nadu for assessing the performance of FLDs on improved varieties of cassava during December 2017. A team of scientists visited Namakkal and Trichy districts of Tamil Nadu during first week of February 2018 for assessing the performance of improved varieties of cassava.

Farm advisory visit in Namakkal dt, Tamil Nadu

Farm advisory visit in Pachamalai hills, Tamil Nadu

Recreation Club Corner

The Independence Day function was organized on 15 August 2017 by the recreation club of

ICAR – CTCRI. Onam celebrations – 2017 were organized on 30 August 2017 and club members participated in the pookolam competition and outdoor games. Winners were awarded with prizes. The event culminated with an enthusiastic Uriyadi ritual in connection with Onam. Republic day function on 26th January 2018 was also organized with great pomp and joy and after the message by the Director, the club members along with their family enjoyed breakfast arranged by the club.

Independence day celebrations 2017

Onam celebrations 2017

Participations in Exhibitions

ICAR-CTCRI participated in the following exhibitions for the benefit of stakeholders. Large number of farmers, college and school students, industrialists and other general public acquired knowledge on improved technologies of tuber crops.

1. State Agricultural Exhibition at Tagore theatre, Vazhuthacaud, Trivandrum on 16 August 2017.
2. Tuber Crops Technology Conclave and Agristartup Meet at ICAR-CTCRI, Sreekariyam, Thiruvananthapuram during 27-28 October 2017.
3. Young Entrepreneurship Summit 2017 at Le Meridian Convention Centre, Cochin on 12 September 2017.
4. EUREKA 2017 at Sarvodaya Central Vidyalaya on 10 November 2017.
5. CORVISION 2017 at Cordova Senior Secondary School, Ambalathara, Trivandrum during November 14-16 2017.
6. 11th Indian Fisheries and Aquaculture Forum at Le Meridian Convention Centre, Cochin during 21-24 November 2017.
7. Agricultural exhibition at VFPCK, Anchal, Kollam during 07-11 December 2017. (Bagged first prize)
8. Kerala Kaumudi December Fest 2017 at Kanakakunnu palace, Thiruvananthapuram during 18-31 December 2017.
9. Workshop on Agro processing and value addition 'VAIGA' at Kerala agricultural university campus, Vellanikkara, Thrissur, Kerala during 27-31 December 2017.
10. Info Student Fest 2018 at Saraswathi Vidhyalaya, Vatiyoorkavu, Trivandrum during 05-06 January 2018.
11. Kisan Conference and Agri Business Expo at ICAR-Central Plantation Crops Research Institute, Kasaragod during 05-10 January 2018.
12. Machinery Expo 2018 at Jawaharlal Nehru International Stadium ground, Kaloor, Kochi during 12-15 January 2018.
13. International Symposium on Remote Sensing for Ecosystem Analysis and Fisheries, ICAR-Central Marine Fisheries Institute, Kochi, Kerala during 15-17 January 2018.
14. 30th Kerala Science Congress Expo at Municipal Stadium, Thalassery, Kannur District during 26-30 January 2018.
15. 1st International Extension Congress 2018 at ICAR-Central Institute for Women in Agriculture, Bhubaneswar during 1-3 February 2018.

16. 3rd ARRW International Symposium on Frontiers of Rice Research for Improving Productivity, Profitability and Climate Resilient at ICAR-National Rice Research Institute, Cuttack during 06-09 February 2018.

17. National Banana Festival 2018 at Vellayani Devi Temple ground, Kalliyoor, Thiruvananthapuram during 17-21 February 2018. (Bagged second prize)

18. National Horticultural Fair 2018 at ICAR-Indian Institute of Horticultural Research, Bangalore, Karnataka during 15-17 March 2018.

19. State agricultural exhibition and KRUSHAK PATSHALA "Krushi Odisha 2018" at Bijupatnaik play ground, Baramunda, Bhubaneswar during 06-09 March 2018.

20. Krishi Unnati Mela 2018 at ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi during 16-18 March 2018.

21. Green Fest 2018 (AgriFest and Kappa Maholsav), Kanakakunnu palace, Thiruvananthapuram, Kerala during 28 March to 8 April 2018.


Tuber Crops Technology Conclave and Agristartup Meet at ICAR-CTCRI


Young Entrepreneurship Summit 2017 at Le Meridian Convention Centre, Cochin


'VAIGA' at KAU campus, Vellanikkara, Thrissur


National Banana Festival 2018 at Kalliyoor, Thiruvananthapuram

वर्ष 2017 – 2018 के दौरान इस संस्थान में की गयी राजभाषा कार्यान्वयन समिति संबंधित कार्यक्रम

राजभाषा कार्यान्वयन समिति की बैठक का आयोजन

- इस संसथान की निदेशक महोदया की अध्यक्षता में, दि. 29.06.2017, 25.09.2017, 21.12.2017 और 22.03.2018 को राजभाषा कार्यान्वयन समिति की बैठकों का आयोजन किया गया। इस अवसर पर राजभाषा कार्यान्वयन संबंधित विभिन्न मुद्दों पर विचार–विमर्श किया गया। उसके आधार पर उक्त मुद्दों का अनुपालन किया जा रहा है।

हिंदी कार्यशाला का आयोजन

- केंद्र सरकार की राजभाषा नीति के अनुपालन में इस संस्थान के सभी कर्मचारियों के लिए दि. 29.06.2017 को "राजभाषा एवं प्रबंधन" विषय पर एक दिवसीय हिंदी कार्यशाला का आयोजन किया गया। भा.कृ.अनु.प.–केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनंतपुरम की निदेशक महोदय डॉ. अर्चना मुखर्जी, निदेशक और अध्यक्षा (रा.भा) ने हिंदी के महत्व पर प्रकाश डालते हुए समारोह का उद्घाटन किया। डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (रा.भा) ने सभागृह में उपस्थित सभी महानुभावों के साथ साथ श्री. ए. सोमदत्तन, सहायक निदेशक (सेवानिवृत; तिरुवनंतपुरम) का विशेष रूप से स्वागत किया और कार्यशाला में अच्छी उपस्थिति पर संतोष प्रकट किया। श्री. ए. सोमदत्तन ने "राजभाषा एवं प्रबंधन" पर व्याख्यान दिया। कुल 43 प्रतिभागियों ने कार्यशाला में उत्साहपूर्व सहभाग लिया।

- दि. 15.11.2017 को "टिप्पणी, आलेखन और राजभाषा कार्यान्वयन" विषय पर एक दिवसीय हिंदी कार्यशाला आयोजित की गई। डॉ. जेम्स जॉर्ज, निदेशक–प्रभारी, भा.कृ. अनु.प. – केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनंतपुरम ने अध्यक्षीय भाषण दिया। उन्होंने हिंदी के महत्व पर प्रकाश डालते हुए कार्यशाला का उद्घाटन किया। डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (रा.भा.) ने सभा का स्वागत किया, विशेष रूप से श्री. मोहन चौधरी, सहायक निदेशक (रा.भा.) एवं सदस्य–सचिव (न.रा.का.स.), मुख्य पोस्ट मास्टर जनरल के कार्यालय, तिरुवनंतपुरम का स्वागत किया। कुल 34 प्रतिभागियों ने कार्यशाला में उत्साहपूर्व सहभाग लिया।

- दि. 23.03.2018 को "राजभाषा निति, कार्यान्वयन एवं प्रोत्साहन" पर एक दिवसीय हिंदी कार्यशाला आयोजित की गई। डॉ. अर्चना मुखर्जी, निदेशक और अध्यक्षा (रा.भा.), भा.कृ.अनु. प.–केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनंतपुरम ने अध्यक्षीय भाषण दिया। उन्होंने हिंदी के महत्व पर प्रकाश डालते हुए समारोह का उद्घाटन किया। डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (रा.भा.) ने सभागृह में उपस्थित सभी सहभागियों का स्वागत किया, विशेष रूप से श्री. आर. जयपाल, वरिष्ठ हिंदी अधिकारी, भारतीय अंतरिक्ष विज्ञान एवं प्रौद्योगिकी संस्थान, वलियमला, तिरुवनंतपुरम का स्वागत किया। श्री. जयपाल ने "राजभाषा नीति, कार्यान्वयन एवं प्रोत्साहन" पर व्याख्यान दिया। कुल 30 प्रतिभागियों ने कार्यशाला में उत्साहपूर्व भाग लिया।

हिंदी पखवाड़ा समारोह का आयोजन

- दि. 14–28 सितम्बर 2017 को हिंदी पखवाड़ा मनाया गया। इस संस्थान के अधिकारी गण और बच्चों के लिए विविध हिंदी प्रतियोगिताएं आयोजित की गई. जिनमे निबंध लेखन, अनुवाद, भाषण, कविता पाठ, सुलेख, खुला मंच, अन्ताक्षरी, सिर्फ एक मिनट जैसी प्रतियोगिताए शामिल हैं। सितंबर 2017 में हिंदी पखवाड़ा समारोह के संचालन के संबंध में, निम्नलिखित 5 श्रेणियों के लिए 8 हिंदी प्रतियोगिताओं का आयोजन किया गया।

1. वैज्ञानिक
2. तकनीकी / प्रशासनिक
3. कुशल सहायक कर्मचारी
4. अस्थायी कर्मचारी
5. बच्चे

- प्रतियोगिताओं में कुल 40 प्रतिभागियों ने सहभाग लिया। हिंदी पखवाड़ा समारोह का समापन समारोह 15 नवंबर 2017 को आयोजित किया गया। डॉ. जेम्स जोर्ज, इस संस्थान के निदेशक (प्रभारी) ने समारोह की अध्यक्षता की। समापन समारोह के अवसर पर आमंत्रित विशेष अतिथि श्री. मोहन चौधरी, सहायक निदेशक (न.रा.का.स.) एवं सदस्य सचिव, न.रा.का.स., मुख्य पोस्ट मास्टर जनरल कार्यालय, तिरुवनंतपुरम द्वारा सभी विजेताओं को पुरस्कार वितरण किया गया ।

- इसके अलावा तिरुवनंतपुरम नगर राज भाषा कार्यान्वयन समिति के तत्वावधान में आयोजित हिंदी प्रतियोगिताओं में इस संस्थान के प्रतिभागियों ने भाग ले करके पुरस्कार प्राप्त किये। इस संस्थान के वैज्ञानिक, डॉ॰ विसालाक्षी चंद्रा और डॉ॰ केसव कुमार, नगर राजभाषा कार्यान्वयन समिति, तिरुवनंतपुरम द्वारा संयुक्त हिंदी पखवाड़ा समारोह 2017–18 के सिलसिले में आयोजित प्रतियोगिताओं में भाग लिये और

वे क्रमशः कविता पाठ प्रतियोगिता में दूसरा पुरस्कार और भाषण प्रतियोगिता में प्रोत्साहन पुरस्कार प्राप्त किए।

- तिरुवनंतपुरम नगर राज भाषा कार्यान्वयन समिति की बैठकों में, इस संस्थान के निदेशक और अध्यक्ष (रा.भा.), डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (रा.भा.) और श्रीमती. टी. के सुधालता, सहायक मुख्य तकनीकी अधिकारी (हिंदी कक्ष) ने सहभाग लिया।

प्रोत्साहन योजना

- हिंदी में काम करनेवालें को प्रोत्साहन योजना में भाग लिए/ प्रोत्साहन के पात्र कर्मचारियों को नकद पुरस्कार दिया गया। इस वर्ष एक प्रतिभागी को पुरस्कार वितरण किया गया।
- इस संस्थान के वैयक्तिक सहायक, श्रीमती के. पद्मिनी नायर को नगर राजभाषा कार्यान्वयन समिति, तिरुवनंतपुरम द्वारा आयोजित प्रोत्साहन योजना के अंतर्गत हिंदी भाषा में मौलिक काम करने के लिए पुरस्कार दिया गया।
- इस संस्थान की सभी रबड़ की मोहरें, नामपटल, साइनबोर्ड, फॉर्म, पत्र शीर्ष आदि द्विभाषी रूप में बनाया था।
- प्रशासनिक कामकाज में उपयोग द्विभाषी प्रपत्र शामिल किया था।
- हिंदी में प्राप्त पत्रों के उत्तर हिंदी में दिए गए हैं।
- सभी परिपत्र एवम धारा 3(3) के सभी कागजात द्विभाषी रूप में बनाये गये हैं।
- वार्षिक कार्यक्रम के निर्धारित लक्ष्यानुसार अधिक से अधिक पत्राचार हिंदी में किये गये हैं।
- वर्ष 2016 – 2017 के दौरान राजभाषा हिंदी के प्रगामी प्रयोग संबंधी कार्य निष्पादन में पाँचवा स्थान प्राप्त करने के उपलक्ष्य में भा॰ कृ॰ अनु॰ प॰–केंद्रीय कंद फसल अनुसंधान संस्थान को न.रा.का.स. द्वारा प्रमाण पत्र प्रदान किया गया।

Important Events and Achievements

Events	Date
Annual Group Meeting of AICRP on Tuber Crops	28-30 April 2017
H.H. Sree Visakham Thirunal Endowment Lecture	18 May 2017
Swachhta Pakhwada	16-31 May 2017
Foundation Day Celebrations	29 July 2017
Brain storming on developing standards for quality planting materials of tuber crops	2 August 2017
Collaborative Workshop on Good Practices in Quantitative Social Science Research	7-12 August 2017
Indo-Swiss Cassava Network Project Meeting	28-31 August 2017
Swachhta Hi Sewa	15 September-02 October 2017
Women Farmers Day	17 October 2017
AGRISTART up 1.0: Tuber Crops Technology Conclave & Agri-Startup Meet 2017	27-28 October 2017
Vigilance Awareness Week	30 October – 4 November 2017
Entrepreneurship Development Programme for Agricultural Students	16-17 November 2017
"Sastrajalakom" under Science Promotion Week	17 November 2017
Horti-Technology incubation for Agristartup and Entrepreneurship Development in Odisha	18 November 2017
Tuber Crops Day Celebrations	4 December 2017
Agricultural Education Day	4 December 2017
Vishwa Mrida Diwas-2017	5 December 2017
Seminar on Rural Entrepreneurship through Value Added Agriculture	22 December 2017
Entrepreneurship Development Programme on cassava-based Agro-Enterprises for Developing Sustainable Livelihood	2 February 2018
National Science Day	23-24 February 2018
Workshop on Tuber Crops Technology based Enterprise Development	15 March 2018
Web Telecast and Stake holders interface programme	17 March 2018
Achievements	
Institute projects	8
Flagship projects	2
External aided projects	18
External fund mobilised ₹ (lakhs)	808.541
Resource generated ₹ (lakhs)	67.25
Tuber crops germplasm maintained in the field gene bank	5,570
Tuber crops varieties released	5

Events	Date
Dignitaries visited the Institute	38
Scientists visits abroad	3
Technologies commercialized	7
ICT Apps developed	2
Awards received	7
Publications in peer reviewed journals	63
Papers presented in conferences / seminars / symposia / workshops etc.	37
Books	4
Book chapters	12
Technical bulletins	6
Popular articles	25
Folders, leaflets	10
e-Publication	1
Trainings conducted	59
Exhibitions organized	21
FLDs conducted	50
Institute staff members trained	47
Radio talks	5
TV programme	4
Farmers visited the Institute	1,653
Students visited the Institute	1,933
Officers visited the Institute	239
B. Sc. students guided	105
M. Sc. students guided	59
Ph. D. scholars guided	19
Ph. D. awarded	5
PDF guided	3

List of varieties of ICAR-CTCRI registered with ICAR-NBPGR

Sl. No.	Crop Name	Botanical Name	National Identity	Donor Identity	Variety Name	Ingr. No.	Year	Pedigree	Developer	Developing Institute	Novel Unique Features
1	Cassava	*Manihot esculenta*	IC0586850	Triploid Cassava: 4-2	Sree Athulya	10144	2010	OP-4 (2x) X Sree Visakham (4x)	M.T.Sreekumari, K. Abraham, M. Unnikrishnan and S. Ramanathan	ICAR-CTCRI Thiruvananthapuram, Kerala	Higher yield and high extractable starch
2	Cassava	*Manihot esculenta*	IC0586851	Triploid Cassava: 5-3	Sree Apoorva	10145	2010	Ambakkadan (2x) X Sree Sahya (4x)	M.T.Sreekumari, K.Abraham, M. Unnikrishnan and S. Ramanathan	ICAR-CTCRI Thiruvananthapuram, Kerala	Higher yield and high extractable starch
3	Sweet potato	*Ipomoea batatas*	IC0593650	ST-14	Bhu Sona	13020	2013	JP-14	S.K. Naskar and Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar, Odisha	High β carotene (13-14.5 mg $100g^{-1}$) and salinity tolerance
4	Sweet potato	*Ipomoea batatas*	IC0593651	ST-13	Bhu Krishna	13021	2013	JP-13	S.K. Naskar and Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar, Odisha	High anthocyanin (85-90 mg $100g^{-1}$) and salinity tolerance
5	Sweet potato	*Ipomoea batatas*	IC0593652	ST-10	Bhu Swami	13022	2013	JP-10	S.K. Naskar and Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar, Odisha	High extractable starch (20-21%)

भाकृअनुप
ICAR

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किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch