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वार्षिक प्रतिवेदन
ANNUAL REPORT
2018–2019

भाकृअनुप-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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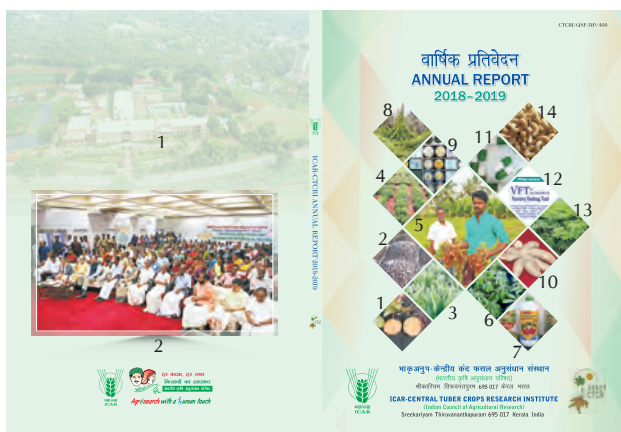

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PREFACE

The ICAR-Central Tuber Crops Research Institute (CTCRI), in its 56th year of service, is spearheading with 67 improved varieties, besides farmer-friendly production, protection and value addition technologies in tropical tuber crops, a group of climate-ready crops that can sustain food, nutritional and environmental security. Termed as 'cheap energy capsules' and rich in dietary fibres, minerals, vitamins and anti-oxidants, roots and tubers are no more 'orphaned' or 'poor-man's crop', but have been raised to the status of 'nutraceutical-rich health foods and future smart crops'. In this background, I take pride to present the research accomplishments, technological advancements and development activities for the year 2018-2019 documented in the form of 'Annual Report of ICAR-CTCRI'.

The genetic wealth constituting 5579 accessions, continued to be enriched and conserved with valued traits. Two cassava mosaic disease (CMD) resistant varieties, Sree Sakthi and Sree Suvarna, were recommended for Central release for cultivation in Tamil Nadu, Andhra Pradesh, Maharashtra and Kerala for industrial use. Four early maturing, high yielding and drought tolerant sweet potato genotypes; two greater yam lines resistant to anthracnose, Da-110 and JAS-2; high yielding white yam hybrids, DrH-1180 and DrH-1157 and two high yielding white yam bushy hybrids, Drd-1095 and Drd-1142 and protocol for short term storage of cassava synthetic seed were developed.

The sustainable resource management technologies like feasible cropping systems involving tuber crops and pulses, water saving techniques in elephant foot yam, water scheduling for taro, drip fertigation for greater yam + maize system, soil test based INM and nutrient use efficient cassava genotypes for saving NPK fertilizers will help to enable 'Doubling of Farmers Income by 2022', the most important mission-mode programme of the Govt. of India. *Sree Poshini,* a mobile app developed for SSNM of tropical tuber crops is made available in Google play store.

IDM package for postharvest rot in elephant foot yam and anthracnose in yam, CMD resistant lines through OFTs at Salem and LAMP based diagnosis of *Sri Lankan cassava mosaic virus* were the other major research highlights. A few notable value addition technologies/products comprise sweet potato anthocyanin capsules, cassava flour based pasta, rice analogue, noodles from cassava–millet based composite flour, particle boards from cassava stem, functional sago using sweet potato leaf powder and beetroot powder, thermoplastic starch sheets and wax coating of cassava tubers for prolonged shelf life. Technology commercialisation strategies assessment model, modified methodology for assessing the sustainable livelihood analysis of tuber crop farmers using DFID methodology, R-package for Soil Quality Index and two Mobile Apps, VFT-Cassava and VFT-Taro were developed.

Further, Corporate Social Responsibility initiatives were taken up by ICAR-CTCRI staff that included cleaning of flood affected areas and financial contribution.

'The Techno-Incubation Centre' is extending hand holding support to young entrepreneurs. Eight technologies on production and value addition were commercialized. The Institute is moving forward with the twin flagship programme of the Govt. of India, '*Mera Gaon Mera Gaurav*' and 'Swachh Bharath Mission'. The Institute bagged the 'Best Annual Report Award' for 2017-18. The quality research publications numbering to 260, including those in high impact national and international journals have improved the scientific credibility.

A Video entitled 'Produce tuber Reduce hunger' was prepared and released by Shri. Radha Mohan Singh, Hon'ble Union Minister for Agriculture & Farmers' Welfare at New Delhi. Another significant event was the interactions held with Smt. Krishna Raj, Hon'ble Minister of State for Agriculture & Farmers' Welfare.

The Institute hosted the Hon'ble Prime Minister Shri. Narendra Modi Ji's interactions with Kerala farmers through video conferencing on the occasion of *"Pradhan Mantri Kisan SAmman Nidhi" (PM-KISAN)* scheme. For strengthening the R & D activities of the institute, RAC and IMC meetings were also convened. Besides, ICAR-CTCRI participated in 29 exhibitions and organized 80 trainings with the mission to reach the unreached. The Institute also observed World Environment Day, International Yoga Day, 150th Birth Anniversary of Mahatma Gandhi, World Soil Day, National Science Day and Tuber Crops Day.

I express my deep sense of gratitude to Dr. Trilochan Mohapatra, Hon'ble Secretary, DARE and Director General, ICAR for his invaluable guidance and support. I sincerely acknowledge the timely guidance provided by Dr. Anand Kumar Singh, DDG (Horticulture Science). I also thank Dr. T. Janakiram, ADG (HS-I), Dr. V. Pandey, Dr. B.K. Pandey, Dr. M. Das, Dr. S. Kant and Shri. P.K. Srivastava for their cooperation.

The support extended by PPV & FRA, Indo-Swiss collaboration, RKVY-Govt. of Kerala & Govt. of Odisha, KSCSTE, Kerala State Planning Board, Coconut Development Board, MANAGE, KVKs and other R&D Institutes and consortia research platforms of ICAR are duly acknowledged. The unstinted support from ICAR and the concerted efforts and hard work of the entire ICAR-CTCRI family enabled the Institute to make this year commendable. My sincere thanks to all our staff. I also appreciate and congratulate the editorial team for bringing out this publication on time.

14 June 2019

Archana Mukherjee
Director

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EXECUTIVE SUMMARY

The genetic wealth conserved with newer collections, varieties released, processes, protocols, technologies, methods, high value compounds and post-harvest machineries developed under eight Institute projects, two flagship projects as well as 27 external funded projects are given below:

Crop Improvement

- A total of 5579 accessions, comprising 1211 cassava, 1124 sweet potato, 1110 yams, 683 edible aroids, 209 minor tuber crops and 1242 collections from Regional Centre were maintained and conserved in the field gene bank.
- Sixty eight new collections of tuber crops, cassava (5), sweet potato (5); yams (13); edible aroids (11) and minor tuber crops (35) were added to the germplasm.
- About 375 indigenous cassava accessions were characterized using a combination of IPGRI/NBPGR/IITA descriptors for 51 traits, which grouped them into 25 morphotypes. The characters such as stem perimeter, total fresh tuber yield plant^{-1} and total stem and foliage weight plant^{-1} recorded maximum variation.
- Two CMD resistant cassava varieties, Sree Sakthi and Sree Suvarna, were recommended for Central release for cultivation in Tamil Nadu, Andhra Pradesh, Maharashtra and Kerala under irrigated/rainfed upland for industrial use. Sree Sakthi had an average tuber yield of 43 t ha^{-1} and Sree Suvarna 38 t ha^{-1}. Both are non-branching varieties.
- Cassava lines having desirable traits were identified viz., 15S-436 with CMD resistance, good culinary properties and high yield (48.10 t ha^{-1}); 15S-406 with high dry matter content and tuber yield (55 t ha^{-1}); 15S-156 with maximum dry matter (51.79%) and CMD resistance as well as seven lines rich in β carotene (17S-135, 15S-139, 17S-154, 17S-191, 17S-259, 17S-255 and 17S-52). The cassava varieties, CO-1, Sree Reksha, Sree Sahya, Kalpaka and CR-43-2 were identified for tolerance to postharvest physiological deterioration.
- Four early maturing sweet potato accessions, No.15, S30/16, Baster-45 and No. 527 with high yield ranging from 18-21.40 t ha^{-1}; crop duration of 75 to 80 days and responding well to lower nutrient doses were identified. Four genotypes viz., 84 x 14, Dhenkanal local-2, Howrah and SB21/57 were identified as drought tolerant. Three lines viz., 84 x 14 (8.55 t ha^{-1}), S-783 (7.75 t ha^{-1}) and 84 x 1 (7.60 t ha^{-1}) were identified as high yielders under drought stress condition. Five sweet potato genotypes viz., S-1712, S-1652, S-27, Bhu Krishna and 526/7 were found best for processing.
- RNAplonc *(https://github.com/TatianneNegri/RNAplonc/)*, a plant lncRNA identification tool, was used to predict 9215 lncRNAs for the first time in sweet potato.
- Anthracnose resistant lines viz., Da-110 and JAS-2 (highly resistant) and Da-200, Da-340, Da-374, Da-489, TCR 308, TCR 319, TCR 264 and TCR 113 (resistant) were identified in greater yam. In the pre-breeding lines, three hybrids viz., DaH-9/196, DaH-22-2-3 and DaH-58FG were identified as having high field tolerance/ resistance to anthracnose disease. Greater yam lines having other desirable traits along with high yield were also identified viz., DaH-10-1-2 (65.42 t ha^{-1}) and DaH-23-2-1 (59.26 t ha^{-1});

DaH-8-39 (45.67 t ha^{-1}) with yellow flesh as well as DaH-9/196 (44.03 t ha^{-1}) having anthracnose resistance.

- In white yam, high yielding hybrids were developed viz., DrH-1180 (59.67 t ha^{-1}) and DrH-1157 (47.32 t ha^{-1}). Highest dry matter was recorded in DrH-1150 (46%) as well as DrH-187 and DrH-1157 (42%). DrH-1181 was identified with yellow flesh colour.
- Two white yam bushy hybrids with high yield (>30 t ha^{-1}), Drd-1095 and Drd-1142, were developed. Drd-1060 was identified as having the highest dry matter (40.68%). Among the non-trailing white yam, SD-15 was identified as the highest yielder (64.60 t ha^{-1}), out-performing Sree Dhanya (23.87 t ha^{-1}), the present popular dwarf variety.
- Few promising lesser yam accessions were identified, CTDE-64 (2.6 kg $plant^{-1}$) and CTDE-39 (2.5 kg $plant^{-1}$) having high yield.
- In taro, lines were identified viz., C-292, C-465, C-621, TCR 368, TCR 947 A, TCR 961, E-14, H-9, I-17 and HOB T_2-1, having moderate tolerance to TLB.
- A promising arrowroot accession, M-6, having high yield (57.12 t ha^{-1}), dry matter content (34.44%), total starch (22.50%), ash content (1.14%) and lowest sugars (0.76%) was identified.
- In yam bean, a promising hybrid, 3 x 10, with high yield (34.48 t ha^{-1}) as well as the highest ability of DPPH radical scavenging activity (42.22%) was developed.
- In attempts on bio-prospecting for novel traits in tuber crops, 500 µg dose of ethanolic extract of *Coleus aromaticus* leaf produced a clear zone of inhibition indicating its antibacterial effect against *Staphylococcus aureus.*
- *In ovo* screening of angiogenic effects of tuber crops showed that ethanol extracts of sweet potato variety Bhu Krishna and *D. alata* (Da-340) have anti-angiogenic effects as evidenced by reduced number of micro blood vessels around the disc as well as breakage of major blood vessels.

Crop Production

- Five technologies for the production of liquid foliar micronutrient formulations for SSNM of cassava (2 products), sweet potato, elephant foot yam and yams were commercialized. *Sree Poshini*, a mobile app developed for SSNM of tropical tuber crops is made available in google play store.
- The sustainability yield index (SYI) of package of practices (PoP: FYM @ 12.5 t ha^{-1} + NPK @ 100:50:100 kg ha^{-1}) (0.665) was established over absolute control (0.385) with mean values of 0.738 and 0.389 after 13 years of continuous experimentation in cassava.
- The cassava genotypes viz., CI-905, 7III E3-5, Sree Pavithra and CI-906 were identified as nutrient-use efficient as the application of NPK fertilizers could be reduced to 25%, saving 75% of the recommended dose.
- Sree Reksha responded well to organic farming. Of the 12 cassava varieties tested, Sree Reksha produced significantly higher yield (40.69 t ha^{-1}), higher profit (₹ 4,42,062 ha^{-1}) and B:C ratio (3.63), followed by Sree Pavithra (29.49 t ha^{-1}; ₹ 2,74,070 ha^{-1} profit and 2.63 B:C ratio).
- Developed organic techniques involving innovative practices of 3% *Panchagavya* and 10% vermi wash for cassava-vegetable cowpea and cassava-groundnut systems, which was profitable.
- The maximum net photosynthetic rate *(Pn)* of 15 cassava genotypes increased due to short-term (ten minutes) exposure at eCO_2 concentrations between 400 and 1000 ppm. Maximum increment in *Pn* was recorded at CO_2 between 400-600 ppm relative to 400 ppm in varieties Sree Jaya (23%) and H-226 (21%). Among the tested varieties, Sree Reksha was observed to be the top performing variety under irrigated as well as water deficit stress conditions.
- The total carbon emissions from major inputs of cassava cultivation in climate smart agriculture (CSA) was estimated to be 116850.13 ton carbon equivalent (CE) as compared to conventional practice (CP), which was 144561.27 ton CE, thereby showing the higher carbon efficiency of CSA (0.31) over CP (0.19) by reducing GHG emission.

- In sweet potato, 64 and 84 days after planting (DAP) and in elephant foot yam, 4 and 5.5 months after planting (MAP) were identified as the critical growth stages for foliar nutrition.
- Treatment of elephant foot yam corms with carbon disulphide @ 80 ml 100 kg^{-1} resulted in maximum uniform sprouting, better growth and significantly higher corm yield.
- Productive-profitable-energy efficient-nutrient saving cropping systems involving tuber crops and pulses were evolved. These include, elephant foot yam + soybean, taro + green gram/black gram, dwarf white yam + green gram systems.
- Water saving techniques were developed in elephant foot yam. Highest corm yield and B:C ratio (2.91) was obtained by providing 50% CPE irrigation along with plastic ground cover mulching (37.46 t ha^{-1}), followed by application of Pusa hydrogel (35.72 t ha^{-1}; 2.77) and with 100% irrigation (32.03 t ha^{-1}; 2.67).
- On-farm validation experiments of customized fertilizers developed for elephant foot yam in seven farmers' fields of Kerala have shown that site specific nutrient management (SSNM) resulted in significantly higher corm yield (44 t ha^{-1}) than farmer fertilizer practice (FFP) (34.50 t ha^{-1}), which was 27.50% higher over FFP.
- In greater yam + maize intercropping system, fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} in 60 splits at 3 days interval resulted in higher greater yam equivalent yield (39.70 t ha^{-1}), gross (₹ 5,96,000 ha^{-1}) and net returns (₹ 3,84,200 ha^{-1}) as well as B: C ratio (2.81).
- Irrigation of taro crop up to 24 weeks @ IW/CPE ratio of 1.0 resulted in maximum cormel yield (19.91 t ha^{-1}), which was on par with irrigation for 24 weeks under different irrigation levels of 0.75, 1.25 and 1.50 and also furrow irrigation. The water requirement of upland taro was worked out to be approximately 3 mm per day for producing optimum cormel yield. Water productivity was estimated at 3.4 kg m^{-3}.
- A total number of 150 micro plants of different cassava varieties against cassava mosaic virus and 120 numbers of elephant foot yam variety Gajendra were indexed. Quality planting materials of tuber crops viz., 80,000 cassava stems, 13 tonnes of elephant foot yam, 18 tonnes of greater yam, 1 ton of taro, 4.12 lakhs vine cuttings of sweet potato and 50 kg of yam bean seeds were produced at ICAR-CTCRI and distributed to the farmers' of different states.
- A total quantity of 7875 cassava stems, 1325 kg of yams, 7700 kg of elephant foot yam and 1225 kg of taro were supplied to 63 contact ST farmers in Tribal settlements of Thiruvananthapuram, Kottayam and Idukki districts of Kerala identified with the assistance from the State Department of Agriculture.
- Tuber crops planting material like, sweet potato 2,00,000 vine cuttings, cassava 5000 stems, greater yam tubers 3000 kg, maize 10 kg, red gram 10 kg and yam bean seeds 100 kg were distributed to 200 tribal farmers of Mohana and R. Udayagiri blocks of Gajapati district, Odisha, for demonstrating tuber crops based farming system in an area of 0.2 ha model. Vegetable kits, 300 numbers and 2000 poultry birds (Vanaraja) were also distributed to tribal farmers to supplement the farm income.

Crop Protection

- The whiteflies attacking tuber crops were identified as *Bemisia tabaci* (cassava, sweet potato), *Aleurodicus rugioperculatus* (arrowroot) and *Aleurodicus disperses* (cassava) through molecular characterization. Cassava whitefly (*Bemisia tabaci*) from different tuber crops growing areas belongs to Asia II5 biotype (having upto 2% sequence variation). Bioinformatics analysis (QIIME and MG-RAST) of endosymbionts in whitefly populations showed variation in *Enterobacteriaceae*, based on agro ecological zones (85.01% in plains and 8.34% in hilly zones).
- Imidacloprid (0.001%) and biopesticide *Nanma* (5.0%) reduced the sweet potato weevil population significantly. Out of the 25 sweet potato genotypes, five, viz., S-1661, Howrah, Bhu Sona, Bhu Krishna

and Kanhangad showed the expression of proteinase inhibitor and cysteine proteinase inhibitor genes.

- A new strain of entomopathogenic nematode (EPN) was isolated from soil samples collected from Kattakada, Thiruvananthapuram, Kerala and identified as *Steinernema siamkayai*.
- LAMP technique for the detection of *Sclerotium rolfsii* causing collar rot of elephant foot yam was standardised by designing specific primers. Association of seven more pathogens, *Rhizopus oryzae*, *Cunninghamella elegans*, *Ceratobasidium* sp., *Fusarium brachygibbosum*, *Fusarium oxysporum*, *Colletotrichum gloeosporioides* and *Penicillium citrinum* with tuber rot in elephant foot yam was confirmed. Treating elephant foot yam tubers with *Trichoderma*/ fungicide viz., Mancozeb 0.15% or Carbendazim 0.05% or combination of Mancozeb and Carbendazim (0.2%) before storage could effectively mitigate the postharvest loss in elephant foot yam.
- Developed an IDM package for greater yam anthracnose. Spraying 0.025% Carbendazim and *Nanma* (0.7%) seven times, first three at fortnightly intervals and further monthly after symptom initiation showed highest reduction in the intensity of greater yam anthracnose (75%), which could reduce 50% of the fungicide use. Two bacterial endophytes, *Bacillus cereus* (SrS1) and *Bacillus subtilis* (MaL1) from arrowroot leaf and Chinese potato stem, reduced 87.07% and 64% of anthracnose intensity in greater yam respectively, which showed their potential in managing the disease as well as promoting the growth.
- Partial genome of *Taro bacilliform virus* showed 100% similarity with *Taro bacilliform* China isolates. Whole genome sequence of *Sweet potato leaf curl virus* using Rolling Circle Amplification showed 90% similarity with *Sweet potato leaf curl virus* Greece isolate (KF697069.1).
- The sequence of pSLCMV A (Genbank accession No. MK404225) showed maximum similarity of 99% with SLCMV-[TVM1] and SLCMV B (Genbank accession No. MK404226) showed maximum similarity of 99% with SLCMV-[Ker20] sequence. The sequence of ICMV A showed maximum similarity of 95% with ICMV-[Mah] sequence. Infectious clones of SLCMV and ICMV were developed and validated in tobacco (*Nicotiana benthamiana*).
- Association of SSRY28 and SSRY44 with CMD resistance in 39 resistant and 21 susceptible cassava genotypes was demonstrated. In transcriptome dataset analysis of cassava infected with *Cassava mosaic virus*, out of 19 SNAC genes, eight genes (*MeNAC22*, *MeNAC28*, *MeNAC61*, *MeNAC62*, *MeNAC63*, *MeNAC75*, *MeNAC79* and *MeNAC121)* displayed more than two fold inductions during virus infection.
- The dry matter content of the resistant lines, obtained from second clonal progeny through pyramiding of different sources of CMD resistance genes ranged from 8.06% (17S-97) to 47.70% (17S-2). The promising CMD resistant clones viz., 17S-146 (41.30%), 17S-20 (44%), 17S-39 (44.10%), 17S-241 (45.40%) and 17S-2 (47.70%) had higher dry matter content. Excellent culinary quality was recorded by 17S-2, 17S-48, 17S-36, 17S-43, 17S-106, 17S-180, 17S-365 and 17S-209. The promising clones, 17S-143, 17S-347, 17S-322 and 17S-248 were selected for conducting advanced yield trial.
- Cassava synthetic seeds produced from healthy cassava shoot tips could be stored up to 42 days at room temperature.

Crop Utilization

- Functional pasta was developed from the composite flour containing cassava flour, maida, soy flour and resistant cassava starch.
- Process was optimized for producing sweet potato pasta enriched with protein from low cost sources such as green peas, Bengal gram flour and casein and the protein content in the pasta varied from 7.50 to 15.10%.
- Process conditions were optimized for preparing functional pasta from elephant foot yam flour and sweet potato flour by incorporating millet flour and pseudo-cereals

such as buckwheat and quinoa flour. The developed pasta was rich in dietary fibre and minerals.

- Noodles enriched with soy flour and beetroot powder were prepared from the composite flour containing cassava and maida. There was a significant increase in fibre content (1.07 - 2.31%) when compared to control (0.76%).
- Functional sago with enhanced dietary fibre content and antioxidant property was developed from dry and wet cassava starches by incorporation of beetroot powder and sweet potato leaf powder.
- Resistant starches of cassava and sweet potato, RS4 type, was synthesised by chemical modification with citric acid and their structural and functional properties were compared with those of modified lentil, potato and banana starches. The modified starches contained high levels of resistant starch and slowly digestible starch with medium glycemic index.
- The recipe for ready-to-use paratha mix from sweet potato flour, millet flour and multigrain flour was also standardized.
- Methodology for preparation of rice analogue was developed.
- Sweet potato and greater yam anthocyanin capsules were developed as nutritional supplement.
- The sweet potato tuber residue left after anthocyanin extraction has been used to prepare flour and it was successfully utilized in bakery products to replace up to three fourth of maida.
- High quality cassava flour (HQCF) was produced by static pressing method and the process conditions such as pressure, pressing time and loading weight were optimized. The starch loss due to pressing was very less i.e., in the range of 0.98 to 2.58%.
- Thermoplastic starch sheets with improved physical properties were developed from oxidized cassava starch as well as from cassava starch-wax composites by adding glycerol as plasticizer and the process conditions were optimized.
- Cassava stem based particle boards were made with cassava starch and wax as well as with cross-linked cassava starch as binder. The process conditions were optimized in each case.
- Wax coating of cassava tubers have been standardized for extending the shelf life. Paraffin and microcrystalline waxes were suitable for the coating of tubers. The tubers could be stored without any PPD symptoms up to 2 weeks by this treatment and no significant effect of genotypes/varieties was observed.
- The effect of biochar application on tuber yield and soil quality parameters in sweet potato studied under well irrigated and water deficit conditions has shown an increase in soil microbial activity, organic carbon content and mineral content.
- The techno-incubation centres at headquarters and regional centre were actively involved in imparting hands-on-trainings and also providing incubation facilities for preparing various tuber crops based food products. Three MoUs also were signed for the technology for the production of snack foods.

Extension & Social Sciences

- Fifteen frontline demonstrations on improved varieties of cassava viz., Sree Jaya, Sree Vijaya, Sree Swarna, Sree Pavithra, Sree Athulya and Sree Apoorva were established in Kanyakumari, Salem and Namakkal districts of Tamil Nadu.
- The yield of improved varieties of cassava was higher by 15.45% over that of the local varieties. The net income realized from improved varieties of cassava in the above districts was ₹ 1.28 lakhs, which was 28% higher over that obtained from local varieties (₹ 1.0 lakh).
- Demonstrations on improved variety of Chinese potato viz., Sree Dhara conducted in Tirunelveli district, Tamil Nadu, indicated that yield of Sree Dhara (26.70 t ha^{-1}) was higher by 16.60% over that of the local varieties (22.90 t ha^{-1}). Net income realized from Sree Dhara was ₹ 1.79 lakhs ha^{-1} (B:C ratio: 2.77) in comparison to local varieties,

which was ₹ 1.43 lakhs ha^{-1} (B:C ratio: 2.46).

- Analysis of consumption pattern of tuber crops among farmers in Kanyakumari district revealed that tuber crop viz., potato was frequently (5-6 per week) consumed by the respondents, followed by cassava, sweet potato, greater yam, elephant foot yam and taro. Per capita consumption (kg/month) of potato was 0.56 followed by, cassava (0.54), sweet potato (0.26), elephant foot yam (0.22), taro (0.16) and greater yam (0.10).
- Sustainable livelihood analysis of tuber crop farmers was conducted among 60 elephant foot yam growers and 60 banana growers from two districts viz., East Godavari and West Godavari. The Rural livelihood sustainability index for banana growers was slightly higher (69) than that of the elephant foot yam growers (66). Physical and natural capital indices were more in both the cases. In the order of merit, human capital index was less among all the capitals. Major sources of livelihood as reported by both the farmers were agriculture, employment in government/private sector and small business. The vulnerability factors were price fluctuation, crop failure due to weather aberrations and increased labour cost. The trends observed were price rise (input cost), climate change and labour shortage.
- Self learning sweet potato crop growth model was developed using neural networks algorithm of artificial intelligence. Developed two mobile apps VFT:cassava and VFT:taro for identifying varieties of cassava and taro respectively from the images of leaves. Convolutional Neural Network (CNN) image classification model was developed for cassava using the pictures of emerging leaves (top view) of four cassava varieties, Vellayani Hraswa, Sree Vijaya, Sree Pavithra and Sree Sakthi. CNN image classification model was developed using leaf images of Muktakeshi and Sree Pallavi varieties of taro.
- Developed R-package for Soil Quality Index (SQI) by integrating ANOVA, Principal Component Analysis and computation of SQI. Deep learning methods were compared for classification based on soil types and prediction of SQI.
- A survey of Agricultural start-ups in India indicated the presence of five categories of agristartups in India viz., Upstream (input) marketplace startups, Downstream (output) farm-to-fork supply chain startups, IoT and Big data led innovation startups, engineering-led innovation startups and Farming as a Service (FaaS) startups. Among the entrepreneurial ecosystem domains, about half of the papers (51.43%) focused on cultural domain, followed by support (25.71%).
- There was significant growth in production and productivity of cassava during the 1961-2017, while declining trend in area during the same period was observed. In case of sweet potato, both area and production showed declining trend, while productivity showed significant growth trend during the same period. Cassava starch showed significant decline in quantity of exports while in value terms, there was non-significant growth during 1994-2018. Significant growth in cassava starch imports both in terms of the quantity (32.5%) and value (43.9%) was observed during 2003-2018. Revealed Symmetric Comparative Advantage (RSCA) indicated that India has comparative advantage in SAARC region for exporting cassava starch; sweet potato; roots and tubers nes and flour roots and tubers nes; in case of ASEAN region for sweet potato exports, roots and tubers nes; in case of BRICS region for cassava dried exports and in case of IOR-ARC, for sweet potato, flour roots and tubers nes and roots and tubers nes exports during 1995 to 2016.

Technology Commercialization, Revenue generation, Education, Training, Exhibitions, Publications

- Eight technologies including five micronutrient foliar formulations for site-specific nutrient management in tropical tuber crops and three for the production of cassava fried snacks were transferred to four entrepreneurs in Tamil Nadu and

Kerala. Value added fried products and fried chips from cassava and sweet potato on a technology licensing and consultancy mode were given to three firms/individuals.

- A total of ₹ 130.69 lakhs was generated as revenue through technology commercialization, farm sales, students fee, analytical charges and other professional service functions.
- ICAR-CTCRI is an approved Research Centre for undertaking Ph. D. programme on tuber crops. During the period, the Institute has offered exposure training to B.Sc./B. Tech students, project work of M.Sc. students, imparted technical guidance for Ph.D. and PDF programme totalling to 285. Five students were awarded Ph.D. and 22 students received M.Sc. degrees.
- A total of 874 farmers, 426 students and 114 officials from different parts of the country were imparted training by ICAR-CTCRI.
- ICAR-CTCRI participated in 29 exhibitions and bagged first/second prizes in the category of 'Best Exhibition Stall Award' in VAIGA & Krishi Unnati Mela, National Horticultural Fair and Krishidham Expo.
- ICAR-CTCRI bagged the 'Best Annual Report Award' for 2017-18 under Small Institutes category.
- The Institute had a total of 260 publications: Research papers: 70; Symposia: 84; Books: 4; Book chapters: 13; Technical bulletins: 3; Popular articles: 56; Folders/leaflets/ pamphlets: 14; Course/training manuals: 8; Institute publications: 7; e-publication: 1.
- Radio talks: 8; TV talks: 5; Video: 1.

INTRODUCTION

ICAR-CTCRI, Headquarters, Thiruvananthapuram (48.19 ha)

ICAR-CTCRI, Regional Centre, Bhubaneswar (20 ha)

ICAR-CTCRI (1963-2019)

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. It has one Regional Centre (RC) at Bhubaneswar. 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 21 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, strategic 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 56 years of concerted research have led to the development of several sustainable production, protection and processing technologies for tuber crops, besides release of 67 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 technologies were also developed in the recent past enabling resource generation through consultancies and commercialization. ICAR-CTCRI has a wealth of germplasm of tuber crops, totalling 5579. 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, works on molecular based improvement are also being continued. The ICAR-CTCRI has released 67 varieties with various quality 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. The two latest cassava varieties, Sree Reksha and PDP CMR 1 are resistant to CMD and are high yielding. The β carotene rich sweet potato varieties, Bhu Sona, Bhu Kanti and Bhu Ja, anthocyanin rich Bhu Krishna and mid-season drought tolerant Bhu Swami have gained wide popularity among the rural and tribal people. Three varieties in yams viz., Sree Nidhi, Sree Haritha and Sree Swetha were also recently 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 the development of facilities and formulation of programme using this advanced technology for the improvement of tuber crops. The Institute has strong programme 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 were developed 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 and farm income. Integrated crop protection technologies developed for cassava mosaic disease, cassava tuber rot, taro leaf blight, collar rot of elephant foot yam, anthracnose of greater yam and sweet potato weevil would help the farming community in eventualities. Management of banana pseudostem weevil through cassava based biopesticides, viz., *Nanma* and *Menma* was a success in the farmers' fields.

Efforts in crop utilization have paid rich dividends in terms of value addition and diversified technologies. Technologies for the industrial sector include the products like superabsorbent polymers, graft copolymerized starches, cold water miscible starch, solid adhesives, pasta products etc. Cassava starch composite based biodegradable films and adhesive formulations for corrugation and paper industries are also developed. 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. Improved tuber crop varieties are gaining popularity in Kerala, Tamil Nadu, Odisha, Bihar, Uttar Pradesh and Gujarat through RKVY and other schemes.

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), 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), Shri. L.C. Sikka Endowment Award (2014), IZA (International Zinc Association)-FAI

Award (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 several prizes in National and International Agricultural Exhibitions. The Best Annual Report Award (1997-98) and (2017-18) among the category of small Institutes was conferred to ICAR-Central Tuber Crops Research Institute for succinctly presenting the research results.

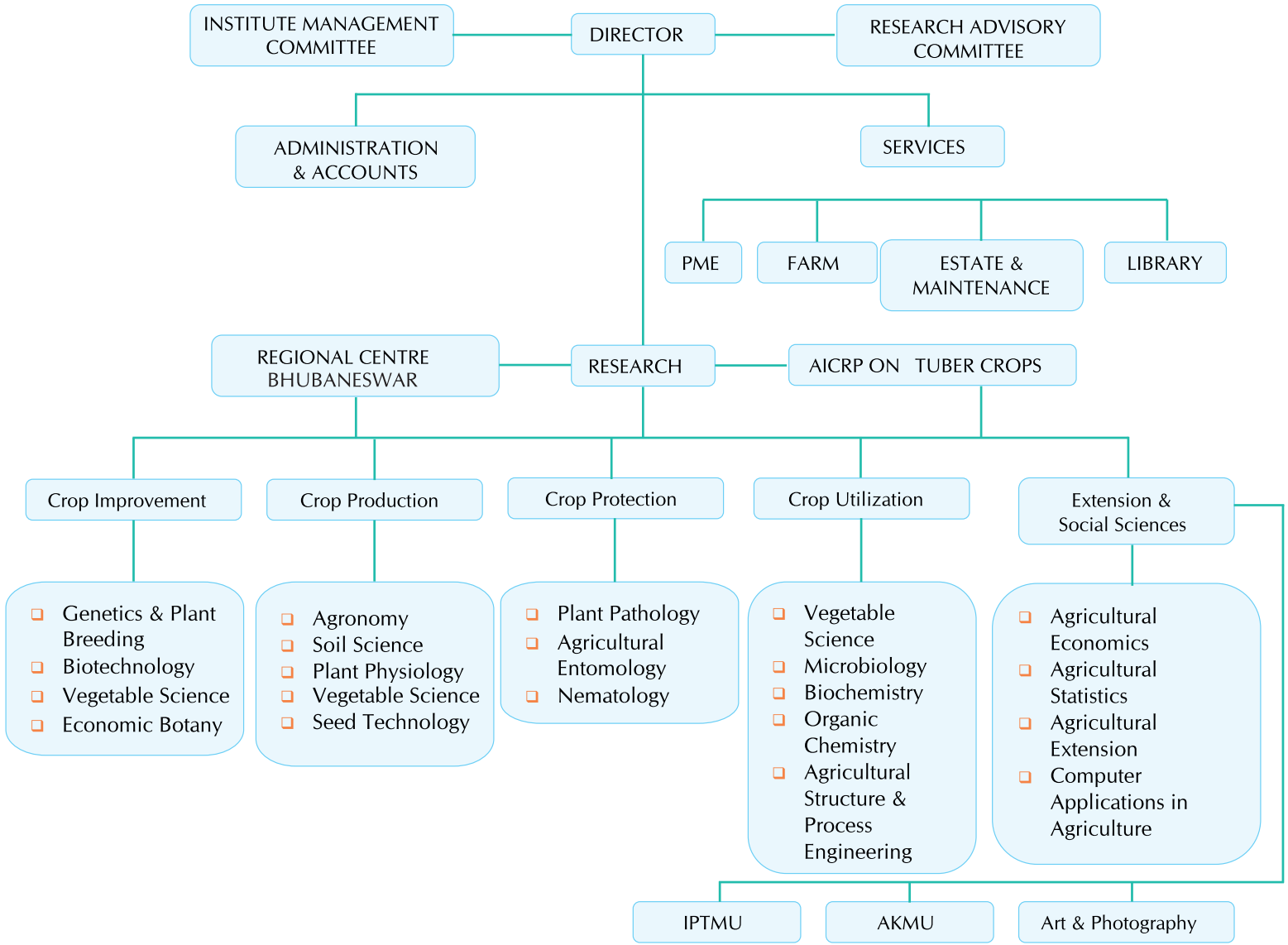
The Institute has conducted more than 20 national and international symposia/seminars/workshops. The Institute is well equipped to conduct basic, strategic and applied research with its state-of-art laboratories. The infrastructural facilities of the Institute have increased during the X and XII Plan periods.

Extra mural 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, Network and Consortia projects of ICAR, are enriching the research activities. Institute Technology Management Unit (ITMU) of the Institute has been active in carrying out IP activities. Various technologies related to value addition have been commercialised through ITMU under consultancy, licensing and contract research mode. The 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 campus is now wi-fi enabled through access controlled wi-fi devices and controllers. VPN connectivity is established for global access to the servers. The home page can be accessed as ICAR-CTCRI 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 macrorrhizos* (L.) G. Don, 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.) Spreng., Lamiaceae
5.	Lesser yam: *Dioscorea esculenta* (Lour.) Burk., Dioscoreaceae	12.	Yam bean: *Pachyrhizus erosus* (L.) Urban, Fabaceae
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* Ker-Gawler, Cannaceae

ORGANISATIONAL SETUP



Staff Position (2018-2019)

Category	Sanctioned	Filled	Vacant
RMP	1	1	0
Scientists	51	48	3
Technical	47	38	9
Administration	31	24	7
Skilled support staff	55	35	20
Total	**185**	**146**	**39**

Progressive Expenditure (2018-2019)

Sl. No.	Head	Unified Budget RE (₹ in lakhs)	Expenditure (₹ in lakhs)
Grant-in-aid-Capital			
1.	**Works**		
	Office Building		
	i. Institute	95.75	95.75
	ii. SCSP	30.00	29.94
2.	Equipments, Information Technology, Library Books and Journals	5.39	5.50
A.	**TOTAL CAPITAL EXPENDITURE**	**131.14**	**131.19**
Revenue			
1.	Establishment Expenses and Salaries		
	i. Establishment Charges	**2009.82**	**1990.53**
	ii. Overtime Allowance	-	-
	Pension and Other Retirement Benefits	**245.00**	**239.19**
2.	Travelling Expenses		
	A. Domestic TA/Transfer TA	37.67	37.67
	B. Foreign TA	-	-
	Total TA	**37.67**	**37.67**
3.	Research and Operational Expenses		
	A. Research Expenses		
	i. Institute	31.29	31.29
	ii. SCSP	9.74	9.74
	B. Operational Expenses		
	i. Institute	59.03	59.03
	ii. TSP	10.00	10.00
	iii. NEH	4.00	4.00
	iv. SCSP	38.49	38.49
	Total Research and Operational Expenses	**152.55**	**152.55**
4.	Administrative Expenses		
	A. Infrastructure		
	i. Institute	85.65	85.65
	ii. SCSP	24.35	24.36
	B. Communication		
	i. Institute	2.44	2.44
	ii. SCSP	1.95	1.95
	C. Repairs and Maintenance		
	i. Equipments, Vehicles and Tyres		
	a. Institute	14.57	14.57
	b. SCSP	0.73	0.73
	ii. Office Building	17.15	17.15
	iii. Residential Building	1.91	1.91
	iv. Minor works	7.34	7.34
	D. Others (excluding TA)		
	i. Institute	40.95	40.95
	ii. SCSP	4.74	4.74
	Total Administrative Expenses	**201.78**	**201.79**
	Miscellaneous		
	A. HRD (Domestic)	0.67	0.67
	B. Other items (Fellowships, Scholarships etc.)	0.00	0.00
	C. Publicity and Exhibitions	0.65	0.65
	D. Guest House-Maintenance	4.65	4.65
	E. Other Miscellaneous	1.26	1.26
	Total Miscellaneous	**7.23**	**7.23**
B.	**TOTAL (Grant in Aid - General)**	**644.23**	**638.41**
	GRAND TOTAL (CAPITAL + ESTABLISHMENT + GENERAL)	**2785.19**	**2760.13**
	P. Loans	**10.00**	**4.50**

RESEARCH ACHIEVEMENTS

INSTITUTE PROJECTS

CROP IMPROVEMENT

Conservation and Utilization of Germplasm of Tuber Crops for Sustaining Production

Field gene bank

Cassava

In cassava, five new accessions, one from Wayanad and the rest from the East Ghasi Hills of Shillong, were added to the existing germplasm. The existing 1211 accessions of cassava comprising indigenous, exotic, landraces and breeding lines were planted in the field during June-July 2018 for maintenance, characterization and preliminary evaluation.

Of these, 375 indigenous accessions maintained in the field genebank were characterized using a combination of IPGRI/NBPGR/IITA descriptors for 51 traits (31 above ground and 20 below ground tuber traits) and the data on stem, leaf and flower characters, tuber yield and yield attributing characters was subjected to cluster and principal component analysis. Cluster analysis divided these 375 accessions into 25 distinct clusters (Fig. 1 and 2). The genotypes CI-4 of cluster-6 and CI-69B of cluster 7 having a similarity percentage of 0.01% were found to be highly diverse among all the genotypes. The cluster 11 had the highest number of 42 genotypes with a similarity of 84.42%. The 14 genotypes in cluster 10 were 94.56% similar to each other followed by cluster 16 (89.08%) and cluster 4 (88.45%). The first principal component contributing more (9.60%) to the total variation, was associated with stem perimeter, total fresh tuber yield plant^{-1} and total stem and foliage weight plant^{-1} indicating that these characters were responsible for maximum variation. The traits that caused less variation (2%) were mature leaf colour, central leaf lobe tip length, roots on tuber, tuber surface colour and tuber taste.

Tuber flour samples of 100 accessions of cassava were analysed biochemically for total starch, sugar, crude fibre and ash content on dry weight basis. Total starch content was highest for the accession CI-187 (69.20%) and lowest in CI-205 (54.20%), while, total sugars was highest for the accession CI-260 (4%) and lowest in CI-186 (1.10%). Ash content ranged from 0.88% in CI-186 to 2.0% in CI-241 and crude fibre content ranged from 0.68% in CI-273 to 1.36% in CI-190.

Twenty indigenous accessions of cassava, 10 each from two different morphotypes viz., fully green

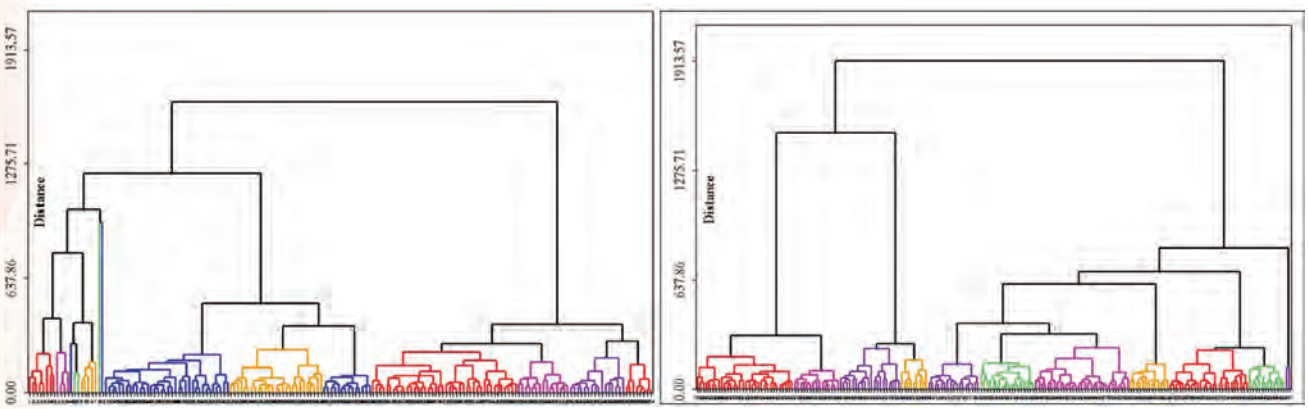


Fig. 1. Dendrogram showing 375 accessions grouped in 25 clusters

Fig. 2. Morphotypes in the cassava germplasm based on morphological clustering

and the greenish purple plant types were screened using 25 morphological traits and ISSR markers to find out the genetic variability existing within this set and also to identify the duplicates, if any, among these accessions. The cluster dendrogram on morphological data divided these 20 accessions into three main clusters. Cluster I consisted of six accessions, cluster II and III, of seven accessions each, with two sub-clusters. The molecular study grouped the 20 accessions into three major clusters. Cluster I with 11 accessions, cluster II with eight and cluster III with a single accession. Among these 20 accessions, CI-10 and CI-20 formed a ball cluster with 92% similarity while, accession CI-665 was identified as a separate entity. This study revealed that variability existed at the genetic level among accessions that were found similar morphologically. DNA samples of these accessions were deposited in the DNA bank.

Sweet potato

A total of 1124 sweet potato accessions are being maintained in the field gene bank. Five accessions were collected this year from Idukki and Thrissur districts, Kerala. Morphological characterization of 85 accessions of sweet potato from the eastern states of India including three wild species, *I. triloba*, *I. pes-tigridis* and *I. aquatica* was done based on IPGRI descriptors, DUS guidelines as well as molecular markers. No duplicates were identified in this set. There was a lot of intra-clusteral variability, indicating good amount of variability within this set. *I. triloba* showed similarity between *I. batatas* ranging from 0.43 to 0.63, whereas, *I. pes-tigridis* showed similarity between *I. batatas* ranging from 0.46 to 0.63. *I. aquatica* showed similarity of 0.40-0.57 between *I. batatas.* S-1408 and S-1572 showed the least similarity (37%) and were collections from Chhattisgarh and West Bengal, respectively.

Preliminary evaluation of yield and tuber traits were performed for 56 accessions in augmented design with two controls (Sree Arun and Kanhangad local) and 12 blocks. The storage root yield ranged between 0.01 to 0.46 kg per plant (0.8 t ha^{-1} to 38 t ha^{-1}) with some accessions showing no tuberisation. Among these, tuber skin colour ranged between purplish pink (10) pink (12) and light pink (10) to white colour (13). The flesh colour varied from white to orange with some accessions showing purple or purplish tinge.

Cooking quality was assessed for tuberising accessions based on IPGRI descriptors. Among the white or cream flesh type, S-1751, S-809, S-625, S-823, S-643, S-620 and S-691 were rated as having very good taste. Among the purple flesh type, S-1638 and S-1648 were tasty. Among the orange flesh type, S-618 was having good taste. Based on organoleptic evaluation, 13 were having high starch, 17 medium starch and the rest were low starch lines. Apart from that, one accession (S-1710) had high fibre, eight had medium fibre and the remaining ones were with very low fibre as assessed by mouth-feel. Sweetness of storage root was highest in accessions, S-1751, S-632, S-809, S-613, S-823, S-643, S-620 and lowest in S-1641 and S-1646. The catalogue is updated based on the above data along with photographs (Fig. 3).

Fig. 3. Promising sweet potato accessions, S-1638, S-1751, S-1801 and S-681

In another evaluation trial laid out in RBD with 12 promising accessions, including Sree Arun as control, S-1609 and S-1401 showed significantly higher yield with 0.260 kg $plant^{-1}$ and 0.235 kg $plant^{-1}$ with starch content of 17.46% and 16.34% (fw basis), respectively. The content of total starch was significantly higher in S-1628 (22.64%) and S-1656 (22.27%).

Yams

A total of 1110 accessions of yams comprising greater yam (591), white yam (158), lesser yam (220), potato yam (6) and wild yams (135) are being maintained in the field gene bank. Five accessions of greater yam, one accession each of potato yam and lesser yam (*D. esculenta* var. *spinosa*) and six wild yams were added to the field gene bank (Fig. 4). The greater yam germplasm was characterized based on 38 descriptors and database was updated.

Fig. 4. New collection of lesser yam, Mukkizhangu (*Dioscorea esculenta* var. *spinosa*)

Molecular characterization of 35 accessions of greater yam was carried out using 15 ISSR and 10 SSR primers. Thirty five accessions of greater yam were screened in the field and also under lab conditions for anthracnose resistance. Da-110 and JAS-2 were highly resistant (Fig. 5), while Da-200, Da-340, Da-374, Da-489, TCR 308, TCR 319, TCR 264 and TCR113 were resistant to anthracnose disease.

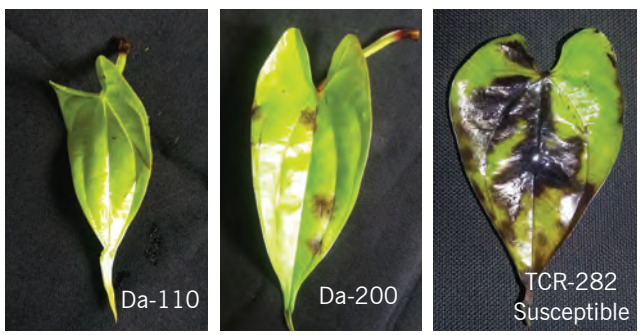


Fig. 5. Screening of greater yam germplasm for anthracnose resistance

In white yam germplasm, the tuber yield ranged from 0.40 kg $plant^{-1}$ (DR-353) to 6.45 kg $plant^{-1}$ (DR-44). Seven accessions viz., DR-2, DR-43, DR-44, DR-46, DR-170, DR-313 and DR-128 were high yielding (>5 kg $plant^{-1}$). DR-59 produced high yield coupled with compact tuber shape. DR-80, DR-57 and DR-113 had excellent cooking quality.

In lesser yam, the highest tuber yield was recorded by CTDE-64 (2.6 kg $plant^{-1}$), followed by CTDE-39 (2.5

kg plant^{-1}). The highest number of marketable tubers (51) was also recorded by CTDE-39.

Edible aroids

A total of six edible aroids, comprising three taro genotypes from Moidangpok, Manipur and three elephant foot yam accessions from Kerala (2) and Tamil Nadu (1) were added to the germplasm collection. Six hundred and eighty three edible aroid germplasm comprising 429 taro, 203 elephant foot yam, 48 tannia and 3 *Alocasia* are being maintained in the field gene bank. During 2018, IC numbers were obtained from ICAR-NBPGR for 59 taro accessions received from NEH region. DNA isolated from 19 elephant foot yam accessions was stored in the DNA bank. Field screening was done for 71 accessions of taro for resistance against taro leaf blight (TLB). Out of these, 10 (viz., C-292, C-465, C-621, TCR 368, TCR 947 A, TCR 961, E-14, H-9, I-17 and HOB T_2-1) were moderately resistant, 16 were susceptible, six highly susceptible and the rest 39 did not show any symptoms of TLB. Flowering was seen in seven taro accessions (viz., C-66, C-292, C-485, C-621, H-45-75, HOB T_2-1 and TTr17-7). Preliminary yield data of 28 accessions of taro showed that cormel yield ranged from 1.36 (H-12) to 16.11 t ha^{-1} (MNMS/14-2) and total yield from 1.98 (H-12) to 19.63 t ha^{-1} (Line 4).

Two distinct taro accessions namely, the dasheen taro from Joida (VHAK/2017-4) and the non-acrid *Colocasia* spp. (AD/2018-CC-1) were analyzed for biochemical characters viz., total starch, total sugar, total ash, crude fibre and calcium oxalate. The results are shown in Table 1.

Table 1. Biochemical characters of two distinct taro accessions

Sample name	Total starch	Total sugar	Crude fibre	Total ash	Total oxalate
			(% FW basis)		
VHAK/2017-4 (Tuber)	18.43	1.19	0.30	0.67	0.11
VHAK/2017-4 (Petiole)	1.43	0.07	0.11	0.09	0.02
AD/2018-CC-1 (Tuber)	15.96	0.89	0.25	0.50	0.11
AD/2018-CC-1 (Leaf)	0.84	0.003	0.25	0.13	0.12

Molecular characterization of 36 taro accessions based on its reaction to TLB was done using three sets of markers (RAPD, ISSR and SSR). All 32 primers gave high polymorphism as explained by average number of alleles per locus, which ranged from 4 to 8.20 (RAPD); 2.38 to 6.13 (ISSR) and 1.10 to 6.20 (SSR); and Polymorphism Information Content (PIC), which ranged from 0.62 to 0.89 (RAPD); 0.71 to 0.86 (ISSR) and 0.30 to 0.69 (SSR). All the 36 accessions showed diversity as explained by heterozygosity values, which ranged from 0.66 to 0.89 (RAPD); 0.75 to 0.87 (ISSR) and 0.33 to 0.74 (SSR). Dendrogram generated through ISSR and RAPD had some common groupings, whereas those obtained from SSR was different. Mantel's test established that no correlation existed between the three marker systems studied and no duplicates could be identified in this set. Many divergent lines could be identified using these marker systems viz., C-276 and C-679 (RAPD); IC012294 (SSR) and Muktakeshi (ISSR) which could be made use of in breeding programs to exploit heterosis.

Minor tuber crops

A total of 35 new minor tuber crops germplasm, comprising Chinese potato (1), edible Canna (8), tikhur (2), starchy *Costus* spp. (16) and other starchy *Curcuma* spp. (8) were collected and conserved in the field gene bank, in addition to the existing 209 accessions. Preliminary evaluation and characterization was made through conventional methods for newly collected germplasm of edible *Canna*, starchy *Curcuma* and *Costus* spp. Preliminary evaluation resulted in the identification of potential genetic stocks of these species. The variation exhibited for qualitative characters were recorded for potential stocks (Fig. 6-8)

Fig. 6. Variation shown by the tubers of new collections of edible *Canna*

Fig. 7. New collections of tikhur- *Curcuma angustifolia*

Fig. 8. New collections of starchy *Curcuma* spp. collected from Athirapalli and Kulathupuzha, Kerala

Fifteen accessions belonging to eight species of *Curcuma* maintained in the field gene bank (Fig. 9) were characterized for 13 qualitative and 15 quantitative morphological traits as well as using molecular markers (ISSR and SSR) to study the genetic variation existing in them. Wide variability was observed among the accessions. The dendrogram based on morphological traits grouped the genotypes into four major clusters (Fig. 10). The highest intra-specific similarity was observed between the two *C. raktakanta* accessions (94%) while, maximum inter-specific similarity was observed between *C. amada*-2 and *C.aromatica*-1. PCA showed that the characters such as leaf midrib colour, rhizome flesh colour, leaf texture and aroma of rhizome contributed mostly to the variability among the accessions of *Curcuma*.

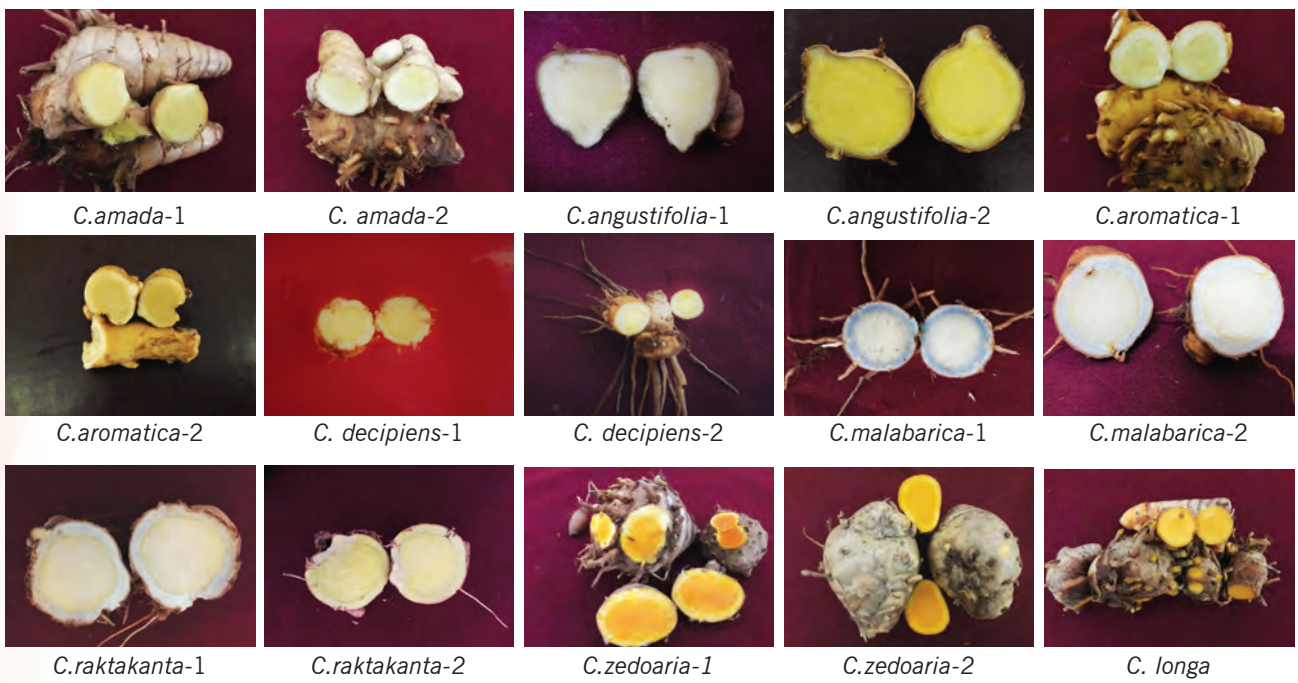


Fig. 9. Rhizome cross sections of 15 selected accessions of *Curcuma* species

The ISSR/SSR markers studied, showed high polymorphism. Clustering based on ISSR markers produced five clusters (Fig. 11). The SSRs produced six clusters (Fig. 12). *C. angustifolia*-1 was found to be highly variable from *C. angustifolia*-2 suggesting the occurrence of intra-specific variability. In both the dendrograms (ISSR and SSR) clustering results were same in all the species, except in *C. aromatica*. The intra-specific similarity was highest among *C. raktakanta* accessions and lowest between *C. angustifolia* collections in both ISSR and SSR profiling. The total percentage polymorphism obtained by ISSR characterization was 94.31, while, it was 91.11% in the SSRs. In the cluster I of the dendrograms constructed using the key morphological characters and combined molecular markers (ISSR and SSR), the sub-cluster of *C. decipiens*-1 and 2 got distantly separated from others. In the cluster-IV of both the dendrograms (morphological and molecular), *C. malabarica* and *C. raktakanta* were clustered together showing the highest inter-specific similarity among the eight species. The results indicated that both intra and inter-specific variability was observed within the selected 15 accessions belonging to eight species. Inter specific variability was more compared to intra specific.

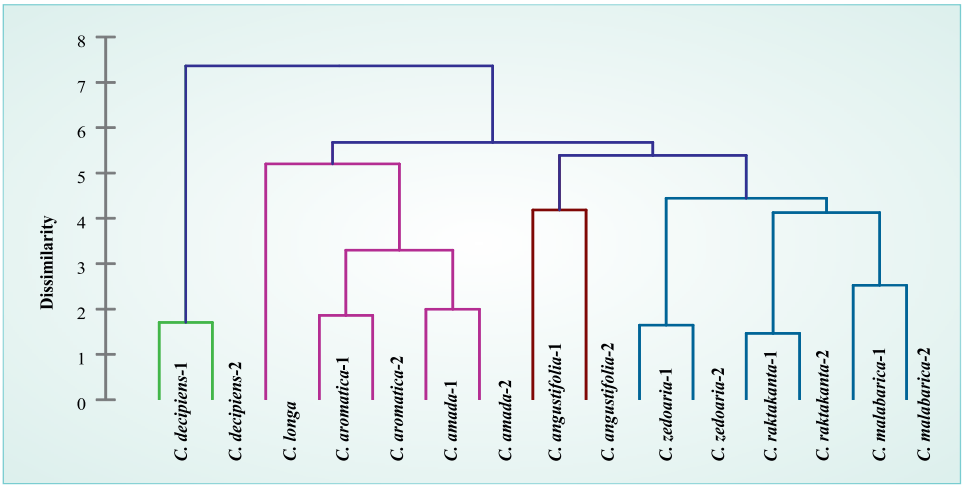


Fig. 10. Dendrogram based on morphological characters

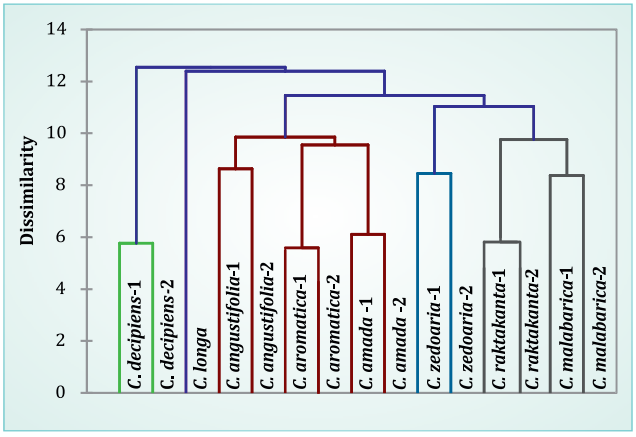


Fig. 11. Dendrogram based on 10 ISSR markers

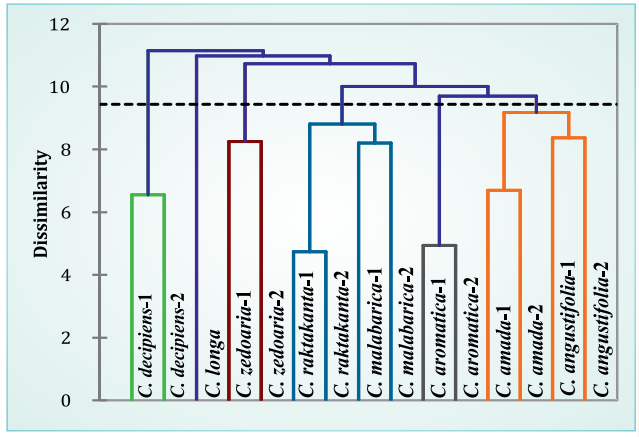


Fig. 12. Dendrogram based on 7 SSR markers

Germplasm at Regional Centre

At the Regional Centre, ICAR-CTCRI, Bhubaneswar, a total of 1242 germplasm of tropical tuber crops, comprising cassava (113), sweet potato ((373), taro (507), elephant foot yam (41), yam (51), yam bean (146) and other minor tuber crops viz, chinese potato (5), arrowroot (2) tannia (1) and Alocasia (3) are being maintained in the field gene bank. Two taro lines were collected from Boudh district, Odisha, one line from Jagatsinghpur, Odisha and two lines were received under DUS testing, which are being established. Hundred accessions of sweet potato germplasm were characterized for yield and flesh colour. Among them, accession 87 (1.20 kg plant^{-1}) was the highest yielder, followed by accession 78 (0.90 kg plant^{-1}) (Fig. 13), accession 72 (0.8 kg plant^{-1}) and accession

100 (0.8 kg plant^{-1}). Of these, 27 were light yellow-fleshed accessions, 13 light orange-fleshed ones, 26 were cream-fleshed accessions and 34 were white-fleshed accessions. Fifty accessions of sweet potato were evaluated for P, K, Ca, Mg, Cu, Fe, Zn and Mn content in leaves and tuber**.** Hundred accessions of sweet potato germplasm were characterized for drought tolerance**.** Hundred accessions of yam bean were evaluated for yield and ten lines were selected (Fig. 14). Accession 71 (1.90 kg plant^{-1}) was the highest yielder, followed by accession 77 (1.74 kg plant^{-1}), accession 39 (1.62 kg plant^{-1}), accession 54 (1.55 kg plant^{-1}), accession 70 (1.43 kg plant^{-1}), accession 10 (1.35 kg plant^{-1}), accession 35 (1.34 kg plant^{-1}), accession 57 (1.33 kg plant^{-1}), accession 10 (1.33 kg plant^{-1}) and accession 56 (1.31 kg plant^{-1})**.** Thirty accessions of yam bean tuber were evaluated for micronutrient analysis through particle induced x-ray emission (PIXE) technique. Out of 50 taro accessions evaluated for acridity in the leaf and petiole, 36 accessions had very high acridity level, eight were medium acrid and six low acrid.

Fig. 13. High yielding sweet potato lines (Accessions 78 and 87)

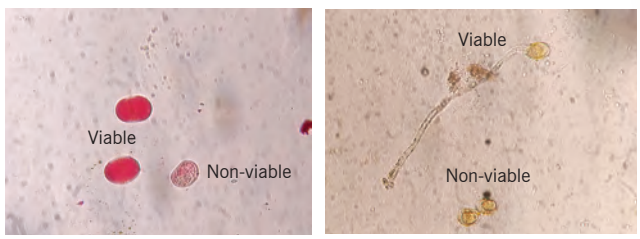
Fig.14. High yielding yam bean lines

In vitro conservation of tuber crops germplasm

Accessions of sweet potato and yams received from ICAR-NBPGR and other accessions of cassava, sweet potato and yams were sub-cultured and maintained in the *in vitro* gene bank at ICAR-CTCRI, HQ. Cultures of 116 sweet potato, 62 yams and 15 cassava accessions were sub-cultured and maintained. At the Regional Centre, 400 cultures of released, pre-release and exotic lines that included 10 varieties of cassava, 11 varieties of sweet potato, 5 varieties of taro, 4 varieties of yam, 2 varieties of elephant foot yam and 4 varieties of Chinese potato are being maintained under *in vitro* condition.

Cryopreservation and *in vitro* conservation of yam pollen

For the standardization of protocol for cryopreservation and *in vitro* conservation of yam pollen, male flowers were collected during anthesis (between 11.30 am to 12.30 pm) from white yam (20-4D) and greater yam (DaH-1157) and immediately stored in liquid nitrogen (-196^{o}C). Viability of the fresh pollen as well as stored pollen were tested by acetocarmine staining and *in vitro* pollen germination tests. Freshly collected white yam pollen recorded 77.99% staining and 61.85% germination (Fig. 15), while in greater yam, 76.63% staining and 63.99 % germination was recorded under laboratory conditions. Similarly, cryo-stored pollen of white yam recorded 30.29% staining and 20.01% *in vitro* germination, while 37.08% staining and 27.51% *in vitro* germination was observed in cryo-preserved pollens of greater yam. Hand pollination in the field was done on selected female parents of white yam and greater yam using fresh pollen (Fig. 16 a) as well as stored pollen. About 45.48% fruit set was observed in white yam (Fig. 16 b), whereas 37.46% was recorded in greater yam, with fresh pollen. A total of 2.26% fruit set in white yam and 11.42% in greater yam was observed when cryo-stored pollens were used for pollination. Pollen of *Dioscorea* spp. under study failed to store well as very less *in vitro* germination and fruit set was observed when pollinated.



(a) (b)

Fig. 15. Viability of white yam pollen assessed by acetocarmine test (a) *in vitro* germination test (b) using fresh pollen

(a) (b)

Fig. 16. Pollination of female parent in greater yam (a) Fruit set in white yam (b) using fresh pollen

Gene bio-prospecting for novel traits in tuber crops

The ethanolic extracts of sweet potato tubers Bhu Ja, Bhu Krishna, S-1467 as well as purple leaf of sweet potato and hexane extract of S-1467 leaf didn't produce a zone of inhibition as compared to antibiotic Ampicillin, which was used as a control. Ethanolic extract of *C. aromaticus* leaf (500 µg dose) produced a clear zone of inhibition indicating its antibacterial effect against *S. aureus* (Fig. 17). *In ovo* screening of angiogenic effects of tuber crops were done. The ethanol extracts of *D. alata* (Da-340) and sweet potato variety, Bhu Krishna, showed anti-angiogenic effects as evidenced by reduced number of micro blood vessels around the disc as well as breakage of major blood vessels.

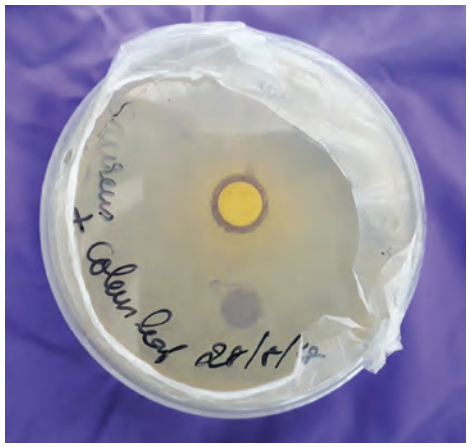


Fig. 17. Anti-bacterial effect of ethanolic extract of *Coleus* leaf on *S. aureus*

Genetic Improvement of Tuber Crops through Conventional Breeding and Molecular Approaches

Cassava

Development of cassava mosaic disease (CMD) resistant varieties

In the activity on varietal improvement of cassava for CMD resistance, earliness, high starch and keeping quality, two cassava mosaic disease resistant varieties were recommended for Central release during the 26th meeting of the Central Sub Committee on Crop Standards, Notification and Release of Horticultural Crops held on 05 November 2018 at New Delhi.

Sree Sakthi has been recommended for cultivation in Tamil Nadu, Andhra Pradesh, Maharashtra and Kerala under irrigated/rainfed upland for industrial use. It is a non branching variety with a duration of 9-10 months and is completely resistant to cassava mosaic disease caused by both *Indian cassava mosaic virus* and *Sri Lankan cassava mosaic virus* (Fig. 18). It has cylindrical tubers with brown skin, cream rind and white flesh colour. It has high starch content of 29% (range: 26-32%). It has an average tuber yield of 43 t ha^{-1} with a potential yield of 80 t ha^{-1}.

Fig. 18. Plant and tubers of newly released CMD resistant variety, Sree Sakthi

Sree Suvarna has been recommended for Central release for cultivation in Tamil Nadu, Andhra Pradesh, Maharashtra and Kerala under irrigated/ rainfed upland conditions for industrial use. It is a non branching/top branching variety with brown stem, dark purple petiole, light brown emerging leaves, conical to cylindrical tubers with brown skin, cream rind and white flesh colour (Fig. 19). It has medium starch, 25-27% (range: 24-29.8%) and low cyanogens (45.01 ppm). It has an average tuber yield of 38 t ha^{-1} with a potential yield of 48 t ha^{-1}.

Fig. 19. Plant and tubers of newly released CMD resistant variety, Sree Suvarna

Development of CMD resistant lines with traits of interest

Ten early bulking lines were tested in replicated yield trial with Vellayani Hraswa as control. The highest tuber yield was recorded by 15S-255 (53.08 t ha^{-1}) followed by 16S-143 (43.21 t ha^{-1}) as compared to control, Vellayani Hraswa (34.56 t ha^{-1}) at six months after planting. The line, 15S-139 had the maximum tuber girth (24 cm), while 15S-404, the greatest tuber length (49 cm).

In the replicated yield trial for development of CMD resistant varieties for culinary purpose, 15S-

436 yielded the highest (48.10 t ha^{-1}), followed by 15S-409 (46.90 t ha^{-1}). In the second replicated yield trial of CMD resistant varieties with good culinary quality, 15S-406 yielded the highest (55 t ha^{-1}), with a dry matter content of 48.40% followed by 15S-43.

Sixty CMD resistant breeding lines were evaluated for dry matter content. The line, 15S-156 had the maximum dry matter (DM) content (51.79%), followed by 15S-433 (46.60%) and 15S-135 (45.27%). Twenty lines had high dry matter content (>40%). 15S-139 with dark orange flesh colour had the lowest dry matter content (25.44%).

Seven β carotene rich cassava lines (17S-135, 15S-139, 17S-154, 17S-191, 17S-259, 17S-255 and 17S-52) with yellow flesh colour were selected and planted for further evaluation. Two highly bitter lines (17S-133 and 17S-248) were selected and planted for raising mapping population for identifying molecular markers linked to cyanogen content in cassava. The induced polyploids of CMD resistant clone 9S-127 are being hardened for ploidy analysis.

Development of PPD resistant lines

In the activity on identification of molecular markers associated with postharvest physiological deterioration (PPD) in cassava, 15 cassava genotypes, categorized based on their reaction to PPD, were evaluated using different methods of PPD assessment. The study showed that the genotypes, CO-1, Sree Reksha, Sree Sahya, Kalpaka and CR-43-2 were tolerant to PPD symptoms with an average PPD score of < 1, whereas, Sree Pavithra, CR-43-11, Sree Padmanabha, 9S-127, 9S-132 and Vellayani Hraswa were highly susceptible in both the methods of evaluation with an average score > 8. The identified genotypes were characterized at molecular level using PPD specific microsatellite markers to determine the genetic diversity between these genotypes. The results showed that among the 16 genotypes of cassava, the lowest similarity index value (0.27) was observed between H-165, Sree Jaya, Sree Padmanabha and Sree Reksha. The dendrogram obtained using UPGMA analysis using NTSYS software package revealed two major principal cluster groups, where, the Cluster I consisted of two accessions viz., Kalpaka and CO-1, which were highly tolerant to PPD. The Cluster II comprised 13 accessions, which was subdivided into two sub-clusters, which comprised a mixture of susceptible and tolerant ones. The size range of amplified product obtained from PPD specific SSR markers was 400-987 bp. The number of alleles per primer ranged from 8 to 16. The percentage of polymorphism was 80%. Biochemical characterisation of the identified lines showed that there was a substantial decrease in starch content and increase in sugar content over the storage period for evaluation. This pattern of change was consistent in both tolerant and susceptible genotypes, respectively. Parental polymorphism survey with the identified PPD tolerant and susceptible parents was conducted with 47 SSR markers, including PPD specific and other cassava primers. Hybridisation was attempted between the genotypes contrasting for PPD tolerance and 250 hybrid seeds were collected.

Screening for drought tolerance

In the experiment on identification of drought tolerant lines in cassava, 25 genotypes were screened for drought stress tolerance in the field conditions. Sprouting of stem cuttings was measured at three weeks after planting and it was found that H-226 had the highest per cent of sprouting (94.44%), followed by Vellayani Hraswa (83.33%), 8S-501 (66.67%), 9S-127 (58.89%) and CI-126B (51.1%) under water deficit stress conditions. The maximum shoot length was observed in H-226 at one month after planting (11.30 cm).

For molecular profiling of drought tolerant cassava genotypes, EST-Microsatellite markers derived from the drought transcriptome of cassava were employed to screen 24 genotypes including the released varieties of cassava. Six out of eight loci amplified namely, MeESSR 38 (heat-shock protein), MeESSR 39 (E3 ubiquitin ligase PUB14), MeESSR 47 (Thylakoid membrane phosphoprotein 14 kDa, chloroplast precursor), MeESSR 82 (acyl-ACP thioesterase), MeESSR 83 (cytochrome P450) and MeESSR 100 (lipoic acid synthetase), which were polymorphic, whereas, MeESSR 22 (H(\+)-transporting ATPase plant/fungi plasma membrane type) and MeESSR 44 (copper-transporting atpase paa1) were found to be monomorphic. Number of different alleles with a frequency greater than or equal to five was 2.00±0.327 and the mean expected heterozygosity (He) was 0.212±0.052. MeESSR 47 was the highly heterozygous locus with a Polymorphism Information Content of 0.416 and Shannon's Information Index of 0.607. The lower mean Shannon's Information Index (0.353±0.082) indicated less diversity among the genotypes for these alleles.

Sweet potato

Development of early maturing, weevil resistant, high starch, carotene rich orange flesh and anthocyanin rich purple flesh sweet potato for food-nutrition and processing

Sweet potato breeding and evaluation under different categories are being continued to achieve the targeted traits like early maturity (75-90 days), weevil resistance, high starch (>16%), high β-carotene (>12 mg $100g^{-1}$) and high anthocyanin (70 mg $100g^{-1}$) for food-nutrition and processing.

Germplasm evaluation

Progressive evaluation of germplasm lines identified four accessions that showed early maturity namely, No.15, S30/16, Baster-45 and No.527. Observations were in coherence with earlier studies. Yield ranged from 18 t ha^{-1} to 21.40 t ha^{-1} within 75 to 80 days and these accessions responded well to half doses of N and K.

Evaluation of OP generated breeding lines

Of the selected 29 OP lines, maturity of 75 days was observed in 12 sweet potato lines, of which 2 were orange-fleshed, 5 white-fleshed and 5 purple-fleshed, respectively. The remaining 5 purple-fleshed, 3 white-fleshed and 9 orange-fleshed sweet potato were observed to have 90-100 days maturity. The yield ranged between 20.40 to 22.80 t ha^{-1} and 24.20 to 30.60 t ha^{-1} for lines showing 75 days and 90 days maturity, respectively.

Evaluation of clonal generation of F_1s

The evaluation of clonal generation of hybrids raised during 2014-15 resulted in the identification of 15 lines (white-5, orange-4 and purple-6), of which, 75 days maturity was recorded in 3 white, 3 orange and 6 purple-fleshed lines (Fig. 20). The remaining were of 90 days maturity (Fig. 21). Weevil infestation of less than 5% was recorded beyond 75 days.

The clonal lines of 2015-16 cross revealed higher yield in 11 lines (white-5, orange-5 and purple-1). Maturity was recorded as 75 days in orange (4) and white (5) lines. No weevil infestation was observed till 90 days.

The clonal generation of hybrids raised during 2016-17 revealed 7 lines (white-4, orange-2 and purple-1) with the targeted traits. Among these, 75 days maturity was recorded in 3 white-fleshed, 2 orange-fleshed and 1 purple-fleshed line with yields ranging from 18.60 to 21.50 t ha^{-1} and the remaining white line matured in 90 days with yield of 23.90 to 27.30 t ha^{-1}.

All the early maturing (75 days duration) lines showed no weevil infestation. Starch content ranged from 14.80 to 23.30%; β-carotene, 8.60 to 16 mg $100g^{-1}$ and anthocyanin, 58.60 to 99.20 mg $100g^{-1}$. Inheritance of valued traits indicated both dominance as well as interactions.

Fig. 20. Clonal lines of F_1s having 75 days maturity: purple flesh (A), orange flesh (B) and white flesh (C) sweet potato

Fig. 21. Clonal lines of F_1s having 90 days maturity: white flesh (A) and orange flesh (B & C) sweet potato

Breeding for drought tolerance in sweet potato

Among the selected 27 genotypes subjected to field screening at Regional Centre, Bhubaneswar, high yield under drought stress condition was recorded in the genotype 84 x 14 (8.55 t ha^{-1}), followed by S-783 (7.75 t ha^{-1}) and 84 x 1 (7.60 t ha^{-1}). Under control (irrigated) condition, high yield was obtained in the genotype 84 x 1 (15.78 t ha^{-1}), followed by Howrah (15.34 t ha^{-1}) and 84 x 14 (14.25 t ha^{-1}). High drought resistance index was recorded in Dhenkanal local-2 (1.87), followed by SB21/57 (1.80) and S-783 (1.58) and high mean productivity was recorded in 84 x 1 (11.69), followed by Howrah (11.53) and 84 x 14 (11.40). High drought resistance index coupled with high yield under drought stress condition was recorded in Dhenkanal local-2 (1.87 and 7.45), followed by S-783 (1.58 and 7.75) and SB21/57 (1.81 and 7.03). High stress tolerance index was recorded in 84 x 14 (10.69), followed by 84 x 1 (10.26) and S-783 (9.31).

During *in vitro* screening, at 10 g l^{-1} of PEG treatment, the genotype Dhenkanal local-2 resulted in maximum shoot length, root length, shoot weight and root weight, followed by 84 x 1 for number of leaves, shoot weight and shoot length. Whereas, at 15 g l^{-1} of PEG treatment, the genotype 683 produced high root length, shoot weight and root weight, followed by SB21/57 for root length, shoot weight and number of leaves and Dhenkanal local-2 for number of leaves, shoot length and root length. The results showed that the genotypes 84 x 14, Dhenkanal local-2, Howrah and SB21/57 were drought tolerant.

Developing sweet potato hybrid clones for processing

In the activity on developing sweet potato hybrid clones suitable for processing, 25 sweet potato genotypes were evaluated for 43 traits, including leaf, tuber, yield and processing traits. The evaluation for processing traits showed that dry matter content ranged between 20.70 and 34.77%, total starch content ranged between 10.96 and 15.65%, total sugar content between 1.75 and 5.44%, flour content between 16.74 and 44.79% and peel loss between 2.16 and 15.74%. The tubers were processed into chips and sensory evaluation was carried out using 9 point hedonic scale. All the genotypes were accepted in general for the six sensory traits; only one genotype was 'disliked' for taste, crispiness, texture and mouth feel. Sensory evaluation of fried chips of sweet potato genotypes showed that S-1652, Bhu Krishna, S-27 and JAS-12-pink ranked best for appearance; SP-1712, S-1652 and 526/7 for taste; SP-1712, S-1652 and 526/7 for texture; S-1652, Bhu Krishna and S-27 for colour; SP-1712, S-1652, Sree Rethna and Sree Arun for crispiness; S-1652, SP-1712 and 526/7 for mouth feel, respectively. Based on overall acceptability, S-1652 ranked first with a mean value of 7.73, followed by SP-1712 (7.41), 526/7(7.06), S-27 (7.06), Sree Varsha (7.04) and Bhu Krishna (6.59). The fried chips of SP-1712 and S-1652 were very much preferred by consumers with an average score of 2.83 and 2.56, respectively (Fig. 22). Gauri with an average value of 1.33 was the least preferred. Five sweet potato genotypes (S-1712, S-1652, S-27, Bhu Krishna and 526/7) selected from this current study will be used for further evaluation.

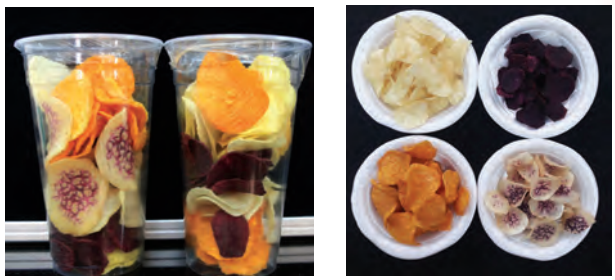


Fig. 22. Fried chips of sweet potato

Yams

In the advanced yield trial of greater yam hybrids, DaH-10-1-2 (65.42 t ha^{-1}) yielded the highest (Fig. 23), followed by DaH-23-2-1 (59.26 t ha^{-1}).

Fig. 23. Flesh colour of DaH-10-1-2

Among the yellow-fleshed greater yam hybrids, DaH-8-39 produced the highest tuber yield (45.67 t ha^{-1}). The pre-breeding lines of greater yam were screened for resistance to anthracnose and three hybrids viz., DaH-9/196, DaH-22-2-3 and DaH-58FG showed high field tolerance/resistance to anthracnose disease. In the evaluation of anthracnose resistant lines for yield, DaH-9/196 yielded the highest (44.03 t ha^{-1}).

Sixteen SSR, 15 ISSR and 11 RAPD primers were screened using a population of 40 greater yam

genotypes comprising 16 resistant and 14 susceptible lines to identify molecular markers linked to anthracnose resistance. The results indicated the association of three ISSR markers (UBC 807, UBC 836 and $(GA)_9AT$) with anthracnose resistance in greater yam.

In AYT of white yam, DrH-1180 produced the highest yield (59.67 t ha^{-1}) followed by DrH-1157 (47.32 t ha^{-1}). The white yam hybrid clones were evaluated for dry matter content and DrH-1150 had the highest dry matter (46%), followed by DrH-187 and DrH-1157 (42%), while, DrH-37 had the lowest dry matter content (26%). One white yam genotype (DrH-1181) was identified with yellow flesh colour.

Fig. 24. Tubers of white yam pre-release variety, SD-15

Among the new bushy white yam genotypes, two hybrids (Drd-1095, Drd-1142) produced high yield (>30 t ha^{-1}). Drd-1060 had the highest dry matter (40.68%), followed by Sree Dhanya (38.37%). In the evaluation trial of non-trailing white yam, SD-15 (Fig. 24) produced significantly higher yield (64.60 t ha^{-1}) than Sree Dhanya (23.87 t ha^{-1}). SD-15 had broader leaves and thicker vines as compared to the other bushy white yam varieties. It recorded high yield on par with the trailing white yam variety, Sree Priya (63.78 t ha^{-1}).

Taro

For the identification of resistance against TLB in various taro genotypes, screening over the years have resulted in the identification of 12 genotypes (C-84, C-370, C-388, C-565, C-679, C-690(v), C-717, TCR 267, TCR 326, IC310104, IC087153 and Colocasia Nicobar Chukchukia village), which showed resistance. For introgression of TLB resistance in taro, OP seedlings and hybrids produced during the previous years were transplanted to pots. Here, only the OP seedlings survived. OP seedlings of susceptible line C-157 showed that of the five seedlings, two showed stoloniferous nature of tubers, while in the resistant line 690(v), out of the seven seedlings, one was found highly susceptible to TLB. Variation was observed in petiole colour. Maximum number of cormels was observed in the line 690(v)-24 (8 nos). OP seeds from a high yielding line TTr17-7, which showed tolerance to TLB was collected.

For identification of molecular markers associated with TLB, three marker systems (RAPD, ISSR and SSR) were tried on 36 taro genotypes (18 susceptible and 18 resistant ones). Of the 32 primers tested, ISSR primer UBC 811, produced a unique band in seven out of the 18 resistant genotypes, which was completely absent in the susceptible ones. Sequencing was done in four of the seven samples viz., IC012601, C-370, C-679 and C-84. Similarity searches revealed the presence of five genes associated with resistance - *Arabidopsis* gene (ID-AT5G57830) having zein-binding protein function; *Arabidopsis* gene (ID-AT5G53900) with serine/threonine-protein kinase function; *Arabidopsis* gene (ID-AT5G12290) having DGS1 (galactoglycerolipid biosynthesis) function and *Arabidopsis* genes (ID-AT3G10880)-coding for an unknown protein and (ID-AT4G33330) having functions in Glucuronyltransferase protein.

In the trial on taro conducted with six accessions and Sree Rashmi as the check, the average cormel yield ranged from 1.12 (IC416980) to 6.17 t ha^{-1} (U-29) and the total yield from 1.87 (IC416980) to 8.27 t ha^{-1} (U-29). The check, Sree Rashmi yielded 6.35 and 8.99 t ha^{-1} cormel and total yield, respectively.

Breeding for quality improvement in taro

Under the activity on breeding for quality improvement in taro at Regional Centre, seven single crosses of taro, 18 x TCR-369, Nycle x 224, 12 x TCR-369, 12 x TCR-429, 12 x 022067, TCR-369 x TCR-429 and TCR-813 x 419746 were sown in nursery. The seedlings of F_1 crosses were transplanted in pots and further in the field for evaluation. All F_1 crosses were evaluated for various nutritional traits of leaves including antioxidant activities like DPPH and CUPRAC assay and the values showed a wide range. Evaluation was done for free radical scavenging ability against DPPH assay (62.17% to 98.13% dry weight in leaf); CUPRAC assay (58.34 to 99.53 µ mol trolox/g dry weight in leaf); total phenolics (28.45 to 67.52 mg gallic acid/g dry weight in leaf);

sugar (1.35% to 2.18% in dry leaf); starch (10.22% to 43.16% in dry leaf); crude protein (7.39 to 23.51 g/100g dry weight in leaf); phosphorous (106.07 to 305.11 mg/100g dry weight in leaf), potassium (872.22 to 1225.30 mg/100g dry weight in leaf); iron (7.50 to 21.15 mg/100g dry weight in leaf); copper (0.62 to 1.87 mg/100g dry weight in leaf); zinc (4.65 to 7.95 mg/100g dry weight in leaf) and manganese (2.87 to 7.05 mg/100g dry weight in leaf).

Elephant foot yam

In elephant foot yam, the hybrids developed by crossing promising cultivars are being evaluated for vegetative and tuber characters. The corms obtained from the hybrid seedlings from previous years' crosses were harvested and tuber characters were recorded. The corm weight ranged from 10 - 200 g in the hybrid seedlings.

Tannia

In AYT 1, Xa AD/2014-15 was the best yielder, both in terms of cormel (2.69 t ha^{-1}) and total yield (5.61 t ha^{-1}) and it was significantly higher in terms of total yield as compared to the local check yielding 0.25 (cormel yield) and 1.13 t ha^{-1} (total yield).

Arrowroot

Advanced yield trial of seven arrowroot genotypes done for the second year in RBD showed that the rhizome yield ranged from 42.36 t ha^{-1} in M-4 to the highest value of 57.12 t ha^{-1} in M-6, with an average rhizome weight/plant of 260 g.

The number of rhizomes per plant was 9 in M-2 and M-3, 10 in M-6, 11 in M-1, M-4, M-5 and M-7. Random rhizome length was highest in M-7 (25.77 cm) and lowest in M-1 (22.88 cm), while, rhizome girth was 9 cm invariably in all the genotypes. Plant height was highest in the genotype, M-7 (114.34 cm) and lowest in M-4 (92.22 cm). Number of tillers/ plant were 5 (M-4, M-7), 6 (M-1, M-2, M-3) and 7 in (M-5, M-6). Number of leaves per plant ranged from 42 in M-4 to 49 in M-5.

Biochemical evaluation of tubers was done for moisture, total starch, sugar, crude fibre, ash and dry matter on fresh weight basis. M-6 had the highest values for dry matter content (34.44%), total starch content (22.50%), ash content (1.14%) and lowest for sugars (0.76%). Dry matter content of tubers of the seven genotypes of arrowroot showed that the percentage ranged from 33.16 in M-5 to 34.44 in M-6 and 34.40 in M-1. In the other genotypes, the values ranged from 33.74 (M-4), 33.54 (M-3), 33.46 (M-2) and 33.17 (M-7).

Yam bean

Yam bean breeding experiments were conducted at Regional Centre. The F_4 generation of five best F_1 hybrids along with check variety (RM-1) were planted in 2018 for evaluation of yield and other yield contributing traits. Another set of 10 F_4 generations, that were good in F_1 generation was also maintained for successive generations. Yet another set of five F_4 generation seeds were raised for production of F_5 generation, for evaluation. Tuber yield in F_4 generation of best F_1 hybrids ranged from 30.22 t ha^{-1} (3x9) (Fig. 25) to 34.48 t ha^{-1} (3x10) as compared to 25.44 t ha^{-1} in RM-1 as a check variety. In the second set of 10 lines of F4 generation evaluated, it was found that three lines produced more than 30 t ha^{-1}. The F_5 generation seeds were harvested and stored for evaluation. Starch content (8.52-15.66%) and sugar content (3.48-8.24%) were recorded. The DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity determination showed that 3 x 10 had the highest ability (42.22%), while, 3 x 9 had the lowest scavenging ability (26.15%). One hundred and twenty F_2 lines were evaluated for flower colour inheritance. In the F_2 generation, the observed distribution fitted with the expected Mendelian ratio of 3 (purple flower):1 (white flower). The segregation of plant flower colour suggested monogenic dominant control of purple colour flower in yam bean.

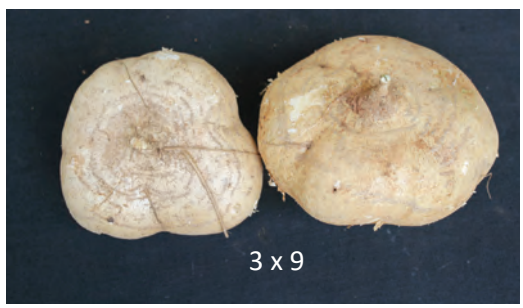


Fig. 25. F_4 generation of promising F_1 hybrids in yam bean

Developing breeder seed standards for yam bean and sweet potato

For developing breeder seed standards in yam bean, harvested fresh seeds of 53 accessions of yam bean maintained in the field gene bank were subjected to evaluation for varietal purity and germination potential. Under varietal purity, the qualitative

characters namely, flower color, seed colour and seed shape were evaluated. Out of 53 genotypes, only one genotype showed white petal with dull blue pattern, while the others showed dark blue pattern in white petals. The given genotypes showed considerable variability for pod length, number of seeds/pod and seed weight. There were two prominent seed shapes namely, kidney shape and square shape seeds in the 53 genotypes. Similarly, light brown and dark brown seeds were observed in the seed lot in addition to olive green colour. The above qualitative characters of flower color, seed colour and seed shapes are given in Fig. 26.

Fig. 26. The qualitative characters of flower color, seed colour and seed shape in yam bean

For the evaluation of different seed quality attributes viz., 100 seed weight and other germination attributes, fresh seeds of ten genotypes namely, Rajendra Local, Nepal, EC100550, IC25112, IC25117, DL-14, DL-16, DL-17, DL-20 and DPH-5 were studied. Among them, DPH-5 showed significantly higher seed quality attributes. The range of values recorded for 100 seed weight and germination percentage were 11.80 to 17.20 and 77 to 100, respectively. The range of values observed for root length, shoot length and vigour index were 11.30 to 21, 10.20 to 14.20 and 1976 to 3520, respectively. The stable qualitative characters will be studied further with large numbers of varieties and genotypes including released varieties for developing seed standards for breeders seed.

Marker assisted breeding

Pyramiding of genes for CMD resistance

The selected 50 CMD resistant clonal hybrid with high yield, high starch and good plant types were evaluated and will be used in cassava breeding program for further evaluation and breeding purpose.

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. This population was used for phenotyping the progenies at the time of harvest. At harvest, long tuber was observed in most of the progenies, like the parent 9S-127 and up to 5 kg tuber yield was recorded in the seedling progenies. The harvested tubers were used for dry matter (DM) and starch estimation. The parents namely, 9S-127 and MNga-1 had 43.82 and 37.96% starch, respectively. In the progenies, starch content ranged from 27.32 (MS-79) - 49.88% (MS-120) per cent. Out of 145 F_1 progenies, 37 progenies had < 38% DM, while, 53 progenies had DM ranging between 38-44% and 55 progenies had > 44% DM content. Wide variation for DM content was recorded from both parents. The harvested progenies were planted as clonal generation for evaluating yield, DM and starch content. The DNA samples of parents and progenies will be screened with more number of SSR markers for continued genotypic scoring. For phenotyping the population, parents along with clonal F_1 tuber were used for DM and starch estimation.

Genetic modifications for quality improvement in cassava

The CMD resistant cassava accession, 9S-127 was multiplied and maintained. FECs of 9S-127 were also maintained. To develop *gbss* silencing construct through gene editing tools, guide RNAs were synthesized *in silico*.

Characterization of abiotic stress responsive genes in cassava

Spatio-temporal and abiotic stress-specific expression patterns in normalized RNA seq datasets revealed constitutive as well as inductive responses of *MeHSP20* and *MeSnRK* family members in different tissues and developmental stages of cassava; 37 out of 67 *MeHSP20* and 22 out of 41 *MeSnRK* gene expression were induced either under drought/ cold stress conditions. The abiotic stress specific expression of *MeHSP20* genes is given in Fig. 27.

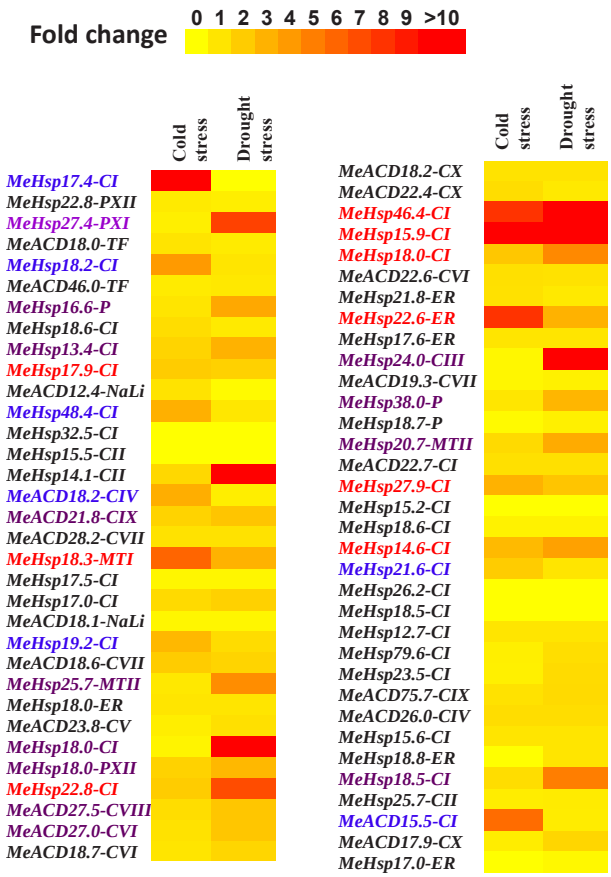


Fig. 27. Abiotic stress-specific expression of *MeHSP20* family genes in cassava

Statistical tools and technologies for tuber crops research and development

Gene network reconstruction in cassava using genomic data

Developing regulatory networks are gaining much significance in present times. The former approaches for Gene Regulatory Network (GRN) construction mainly rely on using gene expression data as input, but the time consumption and high cost of expression analysis paved way for developing new methodologies that make GRN prediction easier. The integration of genomic information along with gene expression data, could make the process of GRN construction more reliable than using expression data alone as input source. Using this approach, we have tried to develop the regulatory network of genes controlling immunity in cassava. Initially, the immunity related genes in cassava were identified by protein domain search and analysis using HMMER. Cassava specific genes were further filtered for high competency, mapped and annotated to determine its biological role and function. A set of 1919 immunity related genes in cassava were identified, out of which 22 were specifically conferring virus resistance, 727 of them were screened for bacterial blight resistance by microarray data integration and a network was created using the predicted interactions identified from 324 genes using STRING. The network obtained was visualized using Cytoscape and cross validated with simulated dataset generated from SynTReN. The generated network of immunity related genes in cassava could give more insight into the defence mechanism in cassava that can help in adapting to better crop improvement and management strategies.

Development of molecular markers for blight resistance in taro using bioinformatics tools

The preliminary data set from the SRA section of NCBI was used for the molecular marker development for blight disease resistance in taro. A total of 6,479,882 sequences obtained initially were reduced to 6,319,834 after pre-processing. The processed sequences were reduced to 79,608 sequences after *de novo* assembly and were finally assembled to 8547 contigs and 59,242 singlets. The contigs were then processed with various prediction pipelines to predict SSRs and SNPs. The tools, QualitySNP and AutoSNP were employed to detect the SNPs present within the contig sequences. MISA and SSRIT were used to predict the SSRs within the sequences. QualitySNP identified 518 synonymous and 44 non-synonymous SNPs from the 8547 contigs. MISA identified 967 mono, 1484 di, 558 tri, 14 tetra, 2 penta, 9 hexa and 393 compound SSRs. Five hundred and sixty two SNPs and 3034 SSRs were predicted *in silico* for blight resistance in taro.

Prediction of SSR and SNP markers for anthracnose resistance in yam using bioinformatics tools

The primary dataset obtained from NCBI-EST section (http://www.ncbi.nlm.nih.gov/nucest) were pre-processed using Seqclean and the rest valid 43,114 EST sequences were used for BLASTX against the anthracnose resistant gene database. Since the sequences were blasted against anthracnose resistant genes, significant reduction in time taken for prediction could be obtained. The resulting sequences were then assembled using CAP3 assembly programme and 5940 contigs were obtained. SSRs were predicted using MISA and SSRIT, while QualitySNP and AutoSNP were used for SNP prediction. One thousand seven hundred eighty nine non synonymous SNPs and 73

synonymous SNPs were obtained. One thousand and two SSRs were predicted *in silico* for anthracnose resistance in yams, where, 359 were mono, 268 were di, 342 were tri, 17 were tetra, 7 were penta and 9 were hexa nucleotide repeats.

Evaluation of miRNA prediction tools and *in silico* analysis of micro and long non coding RNAs in sweet potato (*Ipomoea batatas* L.)

The plant miRNA identification tools like NovoMIR and miRPlant, miRNA target prediction tools like psRNATarget and miRanda were compared for their prediction performance in miRNA-target identification. NovoMIR and psRNATarget had better performance in miRNA prediction and target identification, respectively.

Thirteen potential miRNAs were predicted in sweet potato using 37698 EST sequences through homology based approach. 343 pre-miRNAs from contigs and 698 pre-miRNA from singletons sequences were identified by NOVOMIR as the first step. Out of the 13 potential miRNAs, five were from contigs and eight were from singletons. The identified miRNAs were 20 to 22 nt in length and had a high MFE and MFEI values. Potential 81 target genes in sweet potato were identified by psRNATarget. Functional annotations of the targeted genes were also carried out and predicted miRNAs were reported to be involved in plant growth and development. In order to find out the expression of miRNAs, specific primers were designed and qRT-PCR analysis was performed, which showed different expression patterns within the selected genotypes. RNAplonc *(https://github.com/TatianneNegri/RNAplonc/)*, which is a plant lncRNA identification tool, was used to predict 9215 lncRNAs for the first time in sweet potato. The tool relies on almost 16 features that are robustly selected from about 5468 features to discriminate potential lncRNAs from protein coding genes in a user friendly manner with few computational resources.

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

Virus free planting materials were mass multiplied through procedures involving indexing, micro propagation, hardening and minisett multiplication under protected environment. Large scale multiplication of disease free planting materials was carried out in selected areas of Kerala, Tamil Nadu, Odisha and north-east India in a farmer's participatory mode.

A total number of 150 micro plants of different cassava varieties were indexed against cassava mosaic virus through micro propagation technique in the tissue culture laboratory. A total of 120 numbers of elephant foot yam (var. 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 and distribution to farmers are given in Table 2 and field view of planting material production of tuber crops are shown in Fig. 28, 29, 30 and 31. Mass multiplication of disease free planting material of cassava, elephant foot yam, greater yam, taro and Chinese potato was done in 4.70, 1.80, 1.25, 0.20 and 0.20 acres respectively, totalling to 8.15 acres in the different blocks of ICAR-CTCRI farm.

Table 2. Quality planting material production of tuber crops during the crop season 2018-19

Sl. No.	Name of the crops	Varieties	Quantity of planting material produced
1.	Cassava (No. of stems)	Sree Vijaya	30,000
		Sree Jaya	23,000
		Sree Pavithra	14,000
		Sree Swarna	13,000
		Total	**80,000**
2.	Elephant foot yam (ton)	Gajendra	12.00
		Sree Padma	1.00
		Total	**13.00**
3.	Greater yam (ton)	Sree Keerthi	5.5
		Sree Karthika	3.5
		Sree Shilpa	4.5
		Sree Roopa	2.5
		Orissa Elite	2.0
		Total	**18.00**
4.	Taro (ton)	Sree Rashmi	0.5
		Muktakeshi	0.5
		Total	**1.0**
5.	Sweet potato (No of vine cuttings)	Bhu Sona	2,25,000
		Bhu Krishna	1,87,000
		Total	**4,12,000**
6.	Chinese potato (No. of cuttings)	Sree Dhara	4,000
7.	Yam bean (kg)	RM-1	50

Sree Jaya

Sree Vijaya

Fig. 28. Field view of quality planting material production of cassava

Fig. 29. Field view of quality planting material production of elephant foot yam

Sree Shilpa

Sree Roopa

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

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

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

Planting material of cassava varieties, Sree Vijaya, Sree Jaya, Sree Swarna and Sree Pavithra were soaked in hot water, which resulted in zero cassava mosaic virus infection up to two months. The infection was 4, 6, 8 and 10% at 3rd month and 47, 43, 34 and 36% at 8th month after planting. In the Kalvarayan hills of Salem district, Tamil Nadu, cassava varieties, Sree Vijaya, Sree Jaya, Sree Swarna and Sree Pavithra showed no mosaic virus infection up to three months and the virus incidence was 8, 12, 14 and 17% at 4th month and 24, 33, 39 and 43% at 8th month after planting. Cassava varieties, Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Swarna planted in Kolli hills, Namakkal district, Tamil Nadu, showed no cassava mosaic virus infection up to two months and the virus incidence was 7, 9, 11 and 13% at 3rd month and 21, 23, 26 and 28% at 5th month after planting.

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. Steps involved in fumigation method are given in Fig. 32. Elephant foot yam corms treated with carbon disulphide @ 80 ml 100 kg^{-1} resulted in maximum uniform sprouting of 79.90, 99% at 15, 40 days after planting (DAP), followed by GA_3 200 ppm treated corm (73.50%, 95% at 15, 40 DAP). Greater plant height (68 cm), stem girth (24 cm) and canopy spread (82 cm) were recorded with carbon disulphide treated corm followed by GA_3 200 ppm at 90 DAP. Fumigation with carbon disulphide @ 80 ml 100 kg^{-1} of corm produced significantly higher corm yield (34.50 t ha^{-1}), followed by GA_3 200 ppm corm treatment (29.07 t ha^{-1}) (Fig. 33).

a. Fumigation of corm

b. Before fumigation

c. After fumigation of corm with uniform sprout

d. Single corm with sprout

Fig. 32. Fumigation treatment for uniform sprouting of elephant foot yam

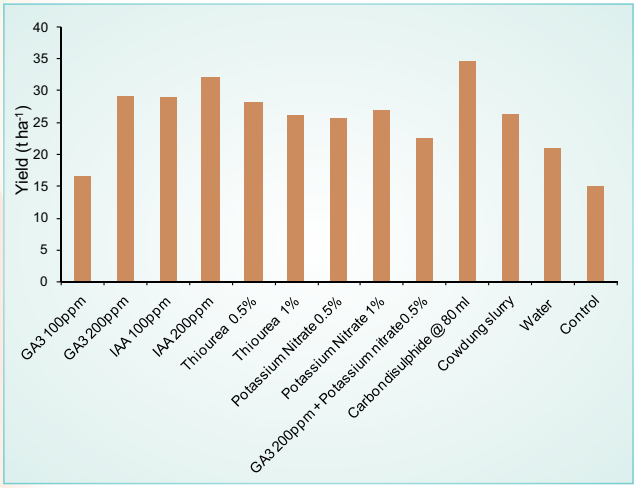


Fig. 33. Effect of growth regulators on corm yield in elephant foot yam

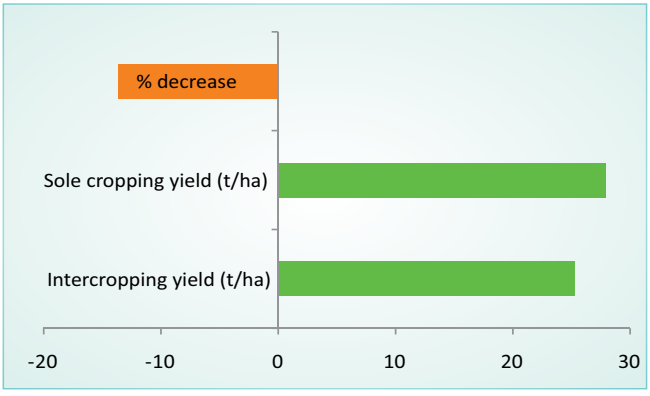
Cropping systems involving tuber crops and legumes

Intercropping system involving dwarf white yam and pulse crops

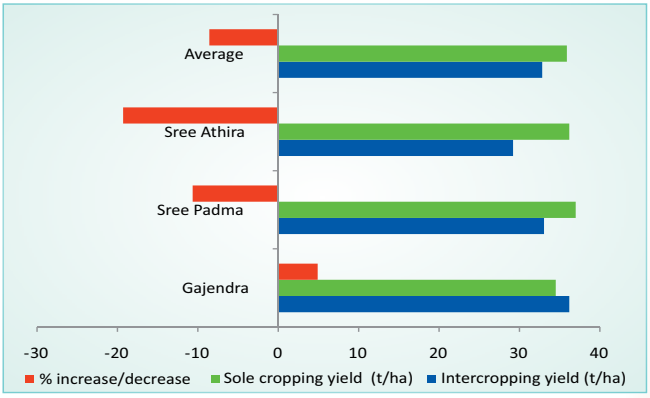
The field experiment to evaluate the feasibility of intercropping dwarf white yam with pulse crops was carried out for the first season. Dwarf white yam var. Sree Dhanya was intercropped with pulse crops, green gram (var. Co-Gg-7), black gram (var. Co-6) and soybean (var. JS-95-60) at two fertility levels of white yam (full FYM, N and K; half FYM and N, full K). Pulses and fertility levels did not impart significant effect on the productivity of dwarf white yam. Yield reduction due to intercropping was comparatively less (-9.55%) (Fig. 34). Dwarf white yam intercropped with green gram under full fertility level was the most productive (tuber yield 28.96 t ha^{-1}, tuber equivalent yield 31.17 t ha^{-1}, production efficiency 115.45 kg ha^{-1} day^{-1}), energy efficient (119.14 x 10^3 MJ ha^{-1}), profitable (net returns of ₹ 8,02,399 ha^{-1}; B:C ratio of 3.68) and better than sole dwarf white yam (added profit of ₹ 91,811 ha^{-1} over sole crop). This was closely followed by dwarf white yam intercropped with green gram under half fertility level. Nutrient saving to dwarf white yam to the extent of half FYM and N and full P was possible. The major, secondary and micronutrient status of soil was unaffected.

Intercropping system involving elephant foot yam and pulse crops

The feasibility of intercropping elephant foot yam and pulse crops was evaluated for two years. The



Dwarf white yam yield: Intercropping vs sole cropping



Elephant foot yam yield: Intercropping vs sole cropping (Average of two years)

Field view of dwarf white yam after harvest of pulses

Tuber yield of dwarf white yam in the cropping system

Fig. 34. Intercropping tuber crops with pulses

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). Averaging over two years, the yield of elephant foot yam under intercropping with pulses (32.82 t ha^{-1}) was similar (-8.58%) to sole cropping (35.90 t ha^{-1}) (Fig. 34). Among the treatment combinations, elephant foot yam var. Gajendra + soybean under full fertility level resulted in higher net income (₹ 10, 07, 356 ha^{-1}), B:C ratio (3.18) and added profit of ₹ 2,33,164 ha^{-1} over sole crop .

Intercropping system involving taro and pulse crops

In the field experiment to evaluate the feasibility of intercropping taro and pulse crops, 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 varieties of taro under full FYM, N, P and K were also maintained for comparison. Sree Kiran intercropped with green gram or black gram at the reduced fertility level produced higher tuber equivalent yield (12.34 and 11.89 t ha^{-1}), production efficiency (68.55 and 66.03 kg ha^{-1} day^{-1}) and equivalent energy (45.66 and 44.69 x 10^3 MJ ha^{-1}respectively) over sole taro.

Studies on intercropping in taro

A field experiment was conducted at the Regional Centre of ICAR-CTCRI, Bhubaneswar to study the effect of taro intercropping on yield potential, biological efficiency and economics. The experiment was laid out in randomized block design with three replications. The experiment consisted of seven treatments 1. Sole taro, 2. Sole maize, 3. Sole pigeonpea, 4. Taro + maize (TM5:1), 5. Taro + maize (TM5:2), 6. Taro + pigeonpea (TP5:1) and 7. Taro + pigeonpea (TP5:2). All the crops in intercropping systems were planted at 45 x 30 cm spacing. Sole taro was planted at 45 x 30 cm spacing, whereas sole maize and pigeonpea 60 x 30 cm spacing. The variety Muktakeshi (taro), H-4226 (maize) and CORG 9701 (pigeonpea) were used in this study. The recommended dose of fertilizers of respective crops as per net sown area basis was applied. Maize was harvested at 90 days after sowing, taro 165 days after planting and pigeonpea 200 days after sowing.

Sole taro produced significantly greater cormel equivalent yield (16.61 t ha^{-1}). This was due to higher yield potential of taro and lack of competition. The next best treatment was taro + pigeonpea (5:1) (15.56 t ha^{-1}). Sole pigeonpea and maize produced lower cormel equivalent yield (7.52 and 4.93 t ha^{-1} respectively). This was due to lower yield potential of pigeonpea and maize. The land equivalent ratio (LER) of taro + maize (5:1), taro + maize (5:2), taro + pigeonpea (5:1) and taro + pigeonpea (5:2) were >1. This indicated that all the above intercropping systems were biologically efficient. The LER is the most popular method of assessing intercropping systems. In this experiment, the duration of intercrops varied widely. Hence, area time equivalent ratio (ATER) was used for assessing the intercropping efficiency. The advantages of taro + pigeonpea (5:2) intercropping system disappeared when evaluated via ATER concept (Fig. 35). Economic analysis indicated that the sole taro resulted in greater gross and net returns (₹ 2.491 lakhs and ₹ 1.381 lakhs respectively) due to higher yield potential. The gross and net returns of taro + maize (5:1) and taro + pigeonpea (5:1) were statistically on par and were next best to sole taro. Sole pigeonpea and maize resulted in lower gross and net returns due to lower yield potential. The treatment, taro + pigeonpea (5:1) fetched greater B:C ratio (2.35), followed by sole taro and taro + maize (5:1) (2.24 and 2.23 respectively).

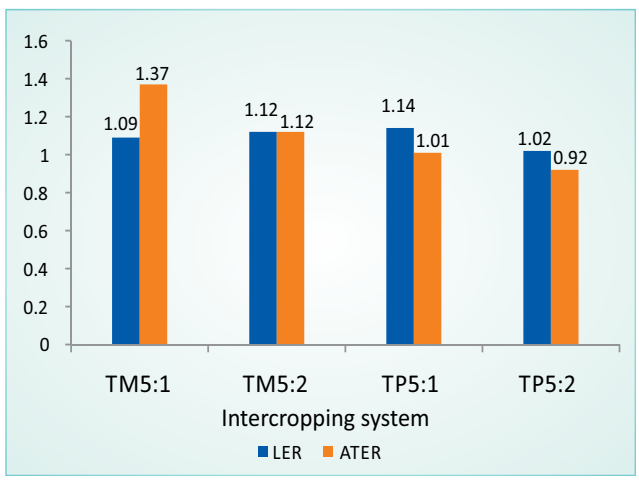


Fig. 35. Effect of taro intercropping systems on LER and ATER

Studies on fertigation interval and number of splits in greater yam + maize intercropping system

A field experiment was conducted 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 for the second season. The results revealed that the treatment I_1 (2 days interval) resulted in significantly higher maize yield compared to the other treatments (3 t ha^{-1}). The greater yam tuber yield and tuber equivalent yield (TEY) increased with increasing fertigation intervals. However, maximum greater yam and tuber equivalent yield of 35.10 and 37.60 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 (2.20, 35.10 and 37.30 t ha^{-1} respectively). The treatment I_1S_1 (40 splits in 2 days interval) resulted in greater maize yield compared to the other treatments (3.20 t ha^{-1}). 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 higher greater yam yield (37.30 t ha^{-1}) and tuber equivalent yield (39.70 t ha^{-1}). Fertigation beyond 180 days after planting decreased the tuber equivalent yield (Fig. 36). The treatment I_2S_3 resulted in 31.30 and 28.90% higher greater yam yield and tuber equivalent yield respectively over check (NPK soil application). The lowest maize, greater yam and tuber equivalent yields of 1.10, 16.10 and 17.20 t ha^{-1} respectively, were recorded in control (no fertilizers). The nutrient use efficiency in the treatment I_2S_3 was greater (107.3 kg kg^{-1}) as compared to the other treatments and it was 24.10% higher than the check (NPK soil application).

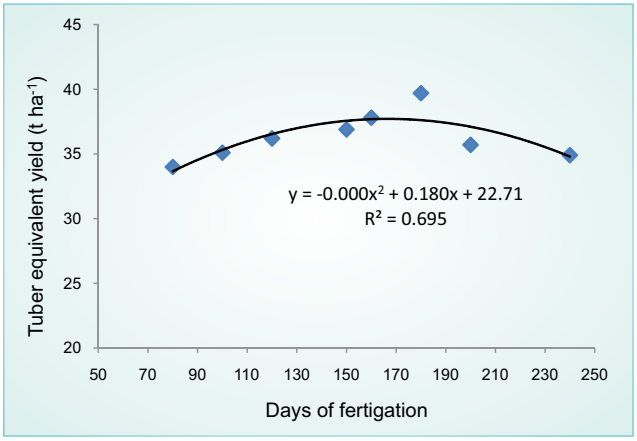


Fig. 36. Relationship of fertigation duration and tuber equivalent yield

The economic analysis indicated 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 (₹ 5,96,000 ha^{-1}) and net returns (₹ 3,84,200 ha^{-1}) as well as B:C ratio (2.81). Significantly lowest gross and net returns of ₹ 2,57,500 ha^{-1} and ₹ 1,21,100 ha^{-1} respectively as well as B:C ratio of 1.88 was noticed in control (no fertilizer).

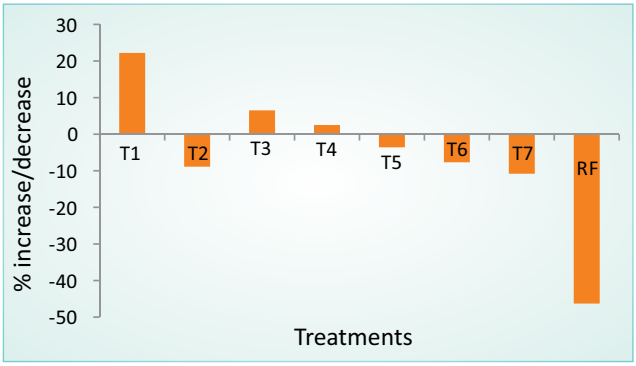
Water management studies in tropical tuber crops

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. Irrigation was given at the rate of 50% CPE along with different water saving techniques such as using plastic ground cover, foliar application of antitranspirant, soil application of pusa hydrogel, application of super absorbent polymers (SAP 1 and SAP 2), use of coir pith and crop residue mulching. Drip irrigation at 100% CPE and a rainfed crop were kept as controls for comparison.

The crop took 37-45 days for initiating sprouting, 50-55 days for achieving 50% sprouting and 55-75 days for full sprouting under the different treatments. Rainfed crop took 50 days for first sprouting, 65 days for 50% and 90 days for 100% sprouting. Morphological characters at 3 and 5 MAP indicated positive effects of the plastic ground cover mulching for soil moisture conservation. Available soil moisture varied from 6.60 to 17.30% (v/v) at different sampling intervals. Under rainfed conditions, moisture varied from 6.50 to 14.80% during different months.

Treatments varied significantly for corm yield. Maximum corm yield was recorded by providing 50% irrigation along with plastic ground cover mulching (37.46 t ha^{-1}) followed by application of Pusa hydrogel (35.72 t ha^{-1}) and it was on par with 100% irrigation (32.03 t ha^{-1}). The rainfed crop yielded the lowest corm yield (17.90 t ha^{-1}). Ground cover mulching resulted in 22.20% yield increase, followed by the application of Pusa hydrogel (6.50%) as compared to 100% irrigation. The rainfed crop resulted in 46.30% yield decrement as compared to 100% irrigated crop (Fig. 37).



T1: Irrigation at 50% CPE+ Ground cover; T2: Irrigation at 50% CPE + Anti transpirant ; T3: Irrigation at 50% CPE + Pusa hydrogel; T4: Irrigation at 50% CPE + Super absorbent polymer 1 (Magic Gel); T5: Irrigation at 50% CPE + Super absorbent polymer 2 (SAP) ; T6: Irrigation at 50% CPE + Coir pith; T7: Irrigation at 50% CPE + Bio mulching; RF: Rainfed control

Fig. 37. Variations in corm yield under water saving treatments compared to 100% irrigation

Economics was calculated under different water saving treatments, based on the pooled data. The B:C ratio was maximum (2.91) with ground cover mulching, closely followed by the application of Pusa hydrogel (2.77) for water saving and irrigation @ 100% CPE (2.67).

Water management studies in taro

The field experiment to standardise irrigation scheduling on upland taro was carried out for the second season. The experiment was laid out in 3 x 4 factorial design along with two controls, furrow irrigation and a rainfed crop. The treatment factors included three periods of irrigation (irrigation up to 8 weeks after planting (WAP), up to 16 WAP, up to 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)). The crop took 31-39 days for initiating sprouting and 48-51 days for achieving 50% sprouting. Furrow irrigation and rainfed crop took 31 and 55 days for first sprouting and 55 and 62 days for 50% sprouting, respectively. 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 moisture content varied from 7 to 15.60 % (v/v) under micro irrigation treatments, 7.20 to 17.05 % (v/v) under furrow irrigation and 5.30 to 7.70% (v/v) under rainfed control.

The crop was harvested during June 2018. There was significant difference in both cormel and total yield (corm + cormels) among the periods of irrigation. But different levels of irrigation did not result in significant variation in yield. Irrigation up to 24 weeks resulted in maximum yield and the yield decreased when irrigation was confined to 16 weeks and 8 weeks. Irrigation up to 24 weeks @ IW/CPE ratio 1.0 resulted in maximum cormel yield (19.91 t ha^{-1}), which was on par with irrigation for 24 weeks under different irrigation levels of 0.75, 1.25 and 1.50 and also furrow irrigation. Furrow irrigation and rainfed crop produced cormel yield of 15.25 and 3.47 t ha^{-1}, respectively. Total yield was maximum when irrigation was given for 24 weeks @ IW/CPE ratio 1.50 and was on par with the other three levels of drip irrigation and the furrow method. Based on the data collected, water requirement of upland taro was worked out to be approximately 3 mm per day for producing optimum cormel yield. Water productivity was estimated as 3.4 kg m^{-3} (Fig. 38).

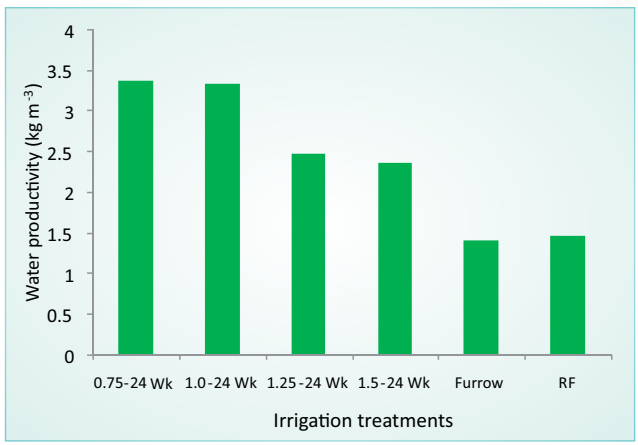


Fig. 38. Water productivity of taro under different irrigation treatments

Long term fertilizer cum manurial experiment in cassava

The long-term effect of treatments, comprising different levels of fertilizers (NPK @ 125:50:125, 100:50:100, 50:25:100, 50:25:50 kg ha^{-1}), soil test based fertilizer (STBF) cum manurial recommendation, (71:0:60 kg ha^{-1} + FYM @ 5 t ha^{-1}) and absolute control), different sources of organic manures viz., farmyard manure (FYM), vermicompost (VC), coir pith compost (CPC), green manuring *in situ* with cowpea (GM), crop residue (CR) and different combinations of secondary nutrient (Mg) and micronutrients (Zn and B) in single, two and three nutrient combinations, were assessed for the 13th season on growth, yield, tuber quality, soil chemical properties and nutrient uptake.

Sustainability of cassava was established even after 13 years of continuous cultivation in the same field with a tuber yield of 19 t ha^{-1} under absolute control. The sustainability yield index (SYI) of package of practices (PoP: FYM @ 12.5 t ha^{-1} + NPK @ 100:50:100 kg ha^{-1}) and absolute control were 0.665 and 0.385 with mean values of 0.738 and 0.389 (13 years). Soil test based application with complete omission of P for the last 13 years and N and K at 71 and 60% recorded yield (24.62 t ha^{-1}) on par with PoP (25.44 t ha^{-1}). The tuber yield under NPK @ 125:50:125 kg ha^{-1} (31.654 t ha^{-1}) was on par with PoP and STBF. In the case of different organic manures tried as alternatives to FYM @ 12.5 t ha^{-1}, green manuring *in situ* with cowpea (@ 16.83 t ha^{-1} green biomass) resulted in the highest tuber yield of 33.88 t ha^{-1} on par with that of vermicompost @ 3.91 t ha^{-1} (29.87 t ha^{-1}) and coir pith compost @ 4.60 t ha^{-1} (29.48 t ha^{-1}). Combination of different organic manures without chemical fertilizers resulted in significantly the lowest yield among the different treatments (15.15 t ha^{-1}). Moreover, the green manuring practice in all treatments produced higher yield over the same treatment in the FYM applied plots and there was no weed growth in those plots (Fig. 39 and 40). Among the different combinations of secondary and micronutrients, soil test based application of Mg (32.85 t ha^{-1}) had significant effect on tuber yield over PoP, which in turn can be justified for its soil Mg status (0. 767 meq 100 g^{-1}) below the critical level.

Fig. 39. Practice of green manuring with cowpea

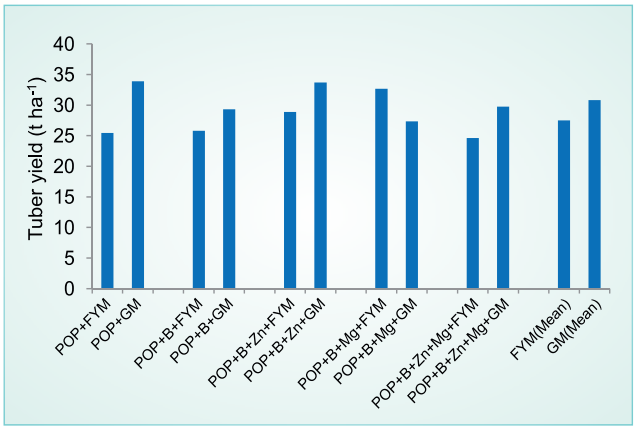


Fig. 40. A comparison of POP and green manuring on cassava tuber yield

Treatments imparted significant effect on stem and total dry matter production, Ca and Mg uptake of stem and Zn and Fe uptake of tuber. Treatments exerted significant effect on all soil parameters, except S. Though the quality attributes were not significantly influenced by treatments, soil test based application of Zn resulted in a sharp decline in the HCN content of tubers.

Significant reduction in available P status of soil was noticed under STBF and in treatments (levels of fertilizers) where P @ 25 kg ha^{-1} was applied. Similarly, continuous application of B and Zn resulted in their build up in soil compared to PoP, but the soil Mg build up over PoP was not significant. The content of Mg and Zn in the leaf, stem and tuber under treatments with these nutrients indicated no significant increase of these nutrients in the plant parts. However, Mg alone applied plots had comparatively higher Mg content over PoP in the case of tuber Mg including leaf and stem Mg over the other treatments. In the case of Zn, the leaf, stem and tuber Zn content was higher in all Zn applied treatments, compared to PoP. However, Zn + B resulted in comparatively better Zn content in all the plant parts.

Significant differences in soil bulk density (1.36 Mg m^{-3}), porosity (48.70%) and maximum water holding capacity (46.80%) 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 soil bulk density was the maximum (1.52 Mg m^{-3}) in absolute control among the six treatments studied.

Screening nutrient use efficient cassava genotypes for low input management

The nutrient use efficient genotypes viz., Sree Pavithra, 7 III E3-5, CI-905 and CI-906 were tested at four levels of NPK viz., 25, 50, 75, 100% NPK in split plot design (genotypes as the main plot treatment and levels of NPK as the sub plot treatments) with three replications for the third season. Genotypes varied significantly for tuber yield, soil N and K, total plant dry matter production (TPDMP), NUE parameters like physiological efficiency (PE), utilization efficiency (UE), nutrient efficiency ratio (NER), NPK utilization for biomass (NPKUtB), NPK utilization ratio (NPKUtR) and physiological parameters like relative growth rate (RGR), crop growth rate (CGR) and tuber bulking rate (TBR). Total plant dry matter, pH, NUE parameters viz., agronomic efficiency (AE), agro-physiological efficiency (APE), apparent recovery efficiency (ARE), UE, NPK utilization for tuber (NPKUtT), NPK uptake ratio (NPKUpR) and physiological parameters viz., CGR and TBR were significantly influenced by levels of fertilizers.

Among the genotypes, 7III E3-5 yielded the highest (43.89 t ha^{-1}), on par with CI-905 (41.07 t ha^{-1}). Averaging the yield over three seasons, highest yield was obtained from 7III E3-5 (38.48 t ha^{-1}), on par with CI-905 (36.46 t ha^{-1}) and Sree Pavithra (32.89 t ha^{-1}). During all the three seasons, there was no significant effect of levels of fertilizers. The tuber yield during the season under 25, 50, 75 and 100% NPK were 36.48, 36.35, 40.70 and 41.03 t ha^{-1} respectively. The mean yield (3 seasons) of these genotypes under 25, 50, 75 and 100% NPK were 32.03, 33.02, 34.29 and 36.17 t ha^{-1} respectively.

Sree Pavithra had significantly the lowest cyanogenic glucoside content (36.43 ppm) and the other three genotypes viz., 7III E3-5 (60.17 ppm), CI-905 (63.20 ppm) and CI-906 (75.93 ppm) were on par. Starch content was significantly the highest with CI-906 (21.90%), followed by 7III E3-5 (20.20%) and Sree Pavithra (19.69%), which were on par. Significantly the lowest starch content (17.99%) was recorded in CI-905. The genotype CI-906 had significantly the highest total plant dry matter production (40.60 t ha^{-1}), CGR (13.61 g m^{-2} d^{-1}) and NPKUpR (0.770). Parameters viz., RGR (6.55 mg g^{-1} d^{-1}), TBR (8.54 g d^{-1}) and NER (0.751) were highest with CI-906, which was on par with 7III E3-5 (Fig. 41).

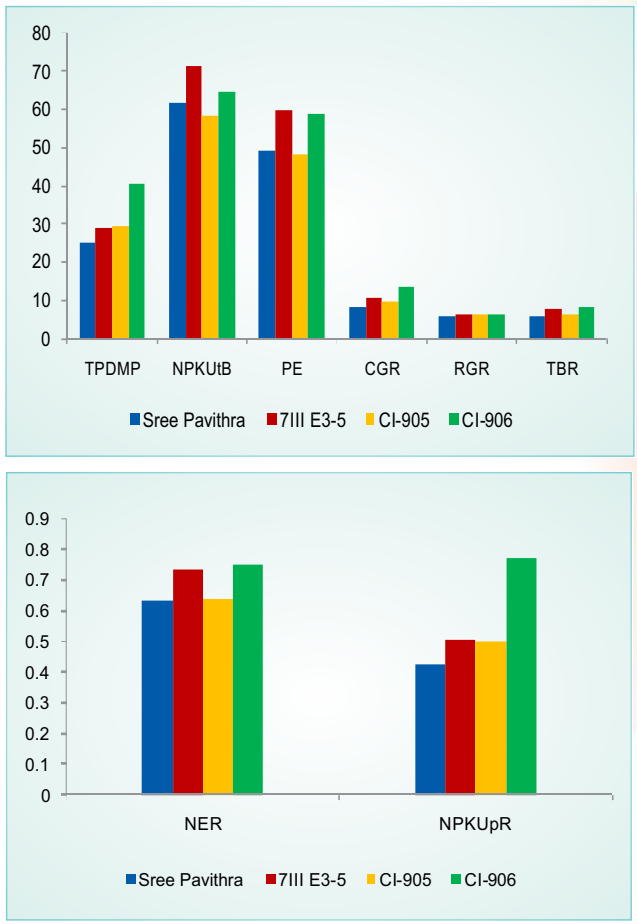


Fig. 41. NUE parameters of cassava genotypes

In the case of parameters influenced by NPK levels, AE (312.50), ARE (11.30) and utilization efficiency (596) were significantly the highest at 25% NPK; APE (40.30) and NPKUpR (0.403) at 50% NPK. Soil pH (4.79), CGR (12.34 g m^{-2} d^{-1}), TBR (8.03 g d^{-1}) and TPDMP (36.70 t ha^{-1}) were highest at 100% NPK, which was on par with 25 and 50% NPK in the case of pH, 50% and 75% NPK in the case of CGR and TPDMP, 50% NPK in the case of TBR (Fig. 42).

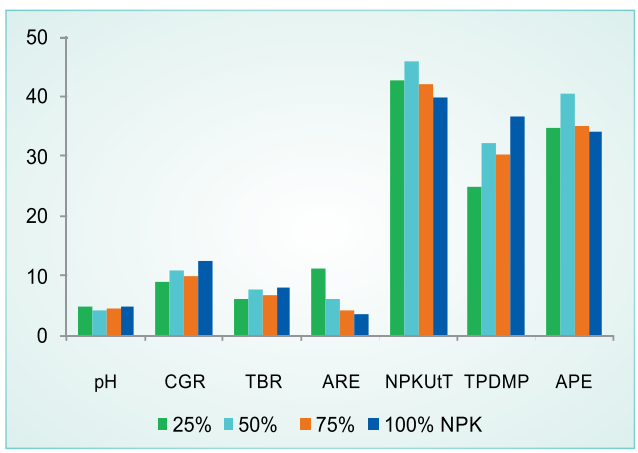


Fig. 42. NUE parameters influenced by different NPK levels

The interaction effect of genotypes and NPK levels were significant in the case of parameters viz., AE, TBR and NPKUtT. The genotype, CI-905 had the highest AE (351.30) on par with 7III E3-5 (306.40) and Sree Pavithra (302.40) at 25% NPK. The TBR was significantly the highest for CI-906 (11.06 g d^{-1}) at 100% NPK followed by CI-906 (8.64 g d^{-1}), 7III E3-5 (8.16 g d^{-1}) and CI-905 (7.93 g d^{-1}) and 7III E3-5 at 25% NPK (7.55 g d^{-1}). NPKUtT was highest for 7III E3-5 at 50% NPK (54.90) and was on par with 7III E3-5 at 25 (49.29), 75 (49.47) and 100% (49.11) NPK and CI-906 at 50% NPK (52.16). Hence, the different parameters computed to justify the NUE of the above genotypes clearly indicate that when these genotypes are used, the application of NPK fertilizers can be reduced to 25% saving 75% of the recommended dose. The tuber bulking efficiency of CI-906 at various stages is depicted in Fig. 43.

Fig. 43. Tuber bulking of CI-906 at different stages under 25, 50, 75, 100% NPK levels

Demonstration-cum-field validation trials were conducted through different KVKs in Kerala State in 24 farmers' fields (Fig. 44). The average yield of CI-906, CI-905, 7III E3-5 and Sree Pavithra without NPK fertilizers/25% NPK were 45.80, 43.20, 42.90 and 38.60 t ha^{-1} respectively. Genotypes viz., 7III E3-5 and CI-905 were preferred and accepted by the farmers due to dark yellow tubers rich in carotene and pink rind in the case of 7 III E3-5.

CI-905 CI-906

7III E3-5 Sree Pavithra

Fig. 44. On-farm trials on NUE genotypes of cassava

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

The major objective was to find out the critical growth stage of elephant foot yam (EFY) and sweet potato (SP) for foliar nutrition. Usually, foliar nutrition is given at the maximum vegetative growth stage of the crop. For this purpose, these crops were grown in lysimeter tanks of 1 m^3 under good management conditions by providing all the nutrients required as standardized earlier. Destructive sampling was done in the case of EFY five times viz., 2.5, 4,5, 7, 8.5 MAP and the fresh weight of plant parts viz., leaves, psuedostem, roots and tuber were taken. In addition, the N, P, K uptake per plant also was computed to confirm the critical growth stage. Similarly for sweet potato, destructive sampling was carried out six times at 22, 42, 64, 84, 103 and 124 DAP and fresh weight of leaves, vines, root and tuber along with NPK uptake per plant was determined. In EFY, the fresh weight, dry weight, N, P, K uptake of vegetative part (leaf + pseudostem) was maximum between 4 and 5.5 MAP and was 3343-6350, 389-509, 10.80-12.10, 1.90-2.40 and 5.30-8.20 g per plant respectively (Fig. 45). In sweet potato, the maximum vegetative growth was seen between 64 and 84 DAP and the respective values were 4264-4750, 597-744, 14.30-16.20, 1.10-1.70, 6.70-8.30 g per plant (Fig. 46). Hence, the critical growth stage for foliar nutrition of EFY and sweet potato were determined as 4-5.5 MAP and 64-84 DAP respectively.

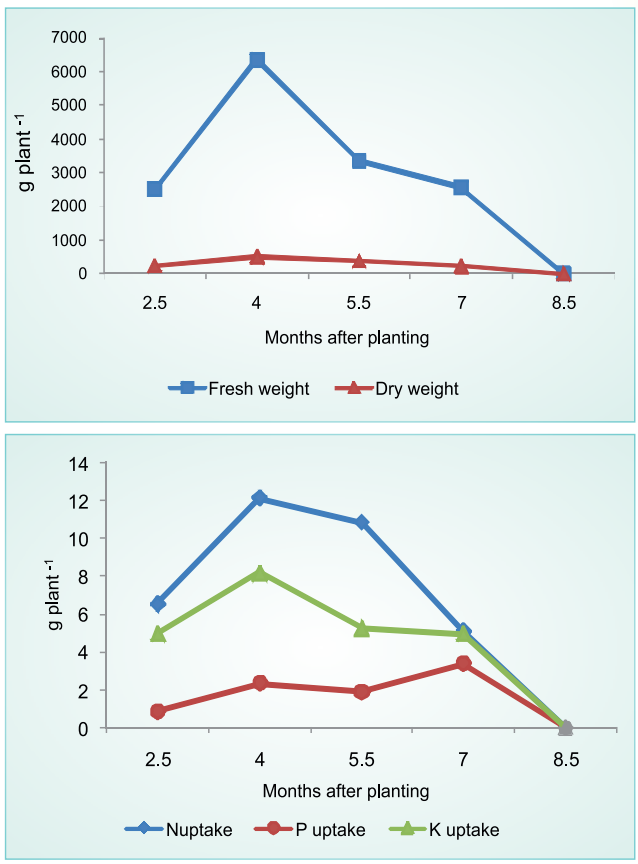
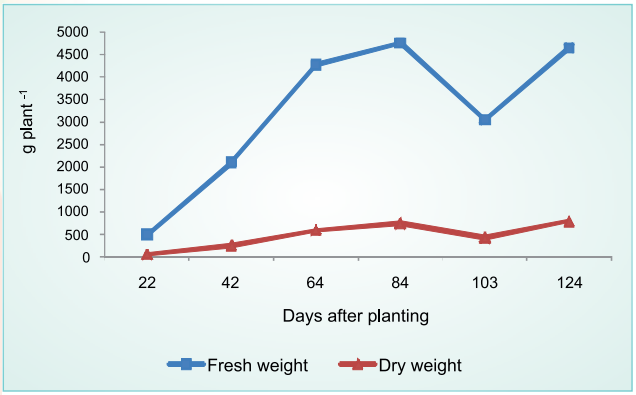


Fig. 45. Fresh weight, dry weight, NPK uptake (g per plant) of the vegetative part of elephant foot yam at different growth stages



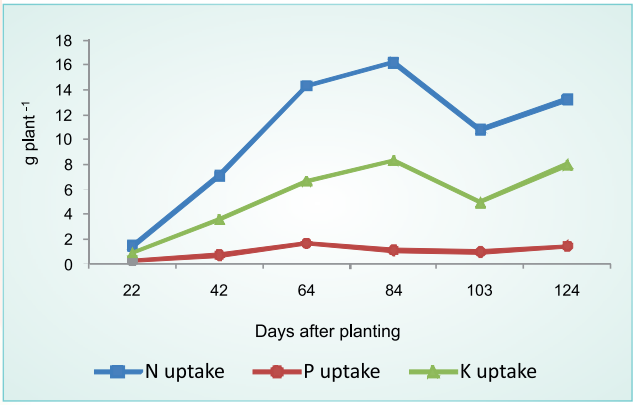


Fig. 46. Fresh weight, dry weight, NPK uptake (g per plant) of the vegetative part (leaf + vine) of sweet potato at different growth stages

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, white yam and taro. The fertilizer best management practices (FBMP) by SSNM treatment proved to be more profitable and environmentally sustainable than present recommendation (PR) (Cassava : SSNM – 31.68 t ha^{-1} and PR – 30.34 t ha^{-1}, 4.42% increase; Elephant foot yam : SSNM – 29.47 t ha^{-1} and PR – 28.46 t ha^{-1}, 3.55% increase; Greater yam : SSNM – 12.54 t ha^{-1} and PR – 11.63 t ha^{-1}, 7.82% increase; White yam : SSNM – 21.18 t ha^{-1} and PR – 22.51 t ha^{-1}, 5.91% decrease; Taro : SSNM – 12.61 t ha^{-1} and PR – 10.47 t ha^{-1}, 20.44% increase). The B:C ratio was also slightly higher under SSNM over PR (Fig. 47).

On-farm validation experiments of customised fertilizers developed for elephant foot yam were completed in seven farmers' fields in one of the major commercially grown regions in Kerala state, Aliparamba in Malappuram district. The SSNM resulted in significantly higher corm yield of 44 t ha^{-1} than farmer fertilizer practice (FFP), which produced 34.50 t ha^{-1}. On an average, the customized fertilizer treatment resulted in 27.50% higher corm yield over FFP (Fig. 48). A new set of on-farm validation experiments are being initiated at 5 farmers' fields in another important commercially grown region, Manjali, Karumalloor Panchayat in Ernakulam district. Sree Poshini, a mobile app developed for SSNM of tropical tuber crops is made available in Google Playstore. Decision support systems for SSNM of elephant foot yam, sweet potato, yams and taro are being developed.

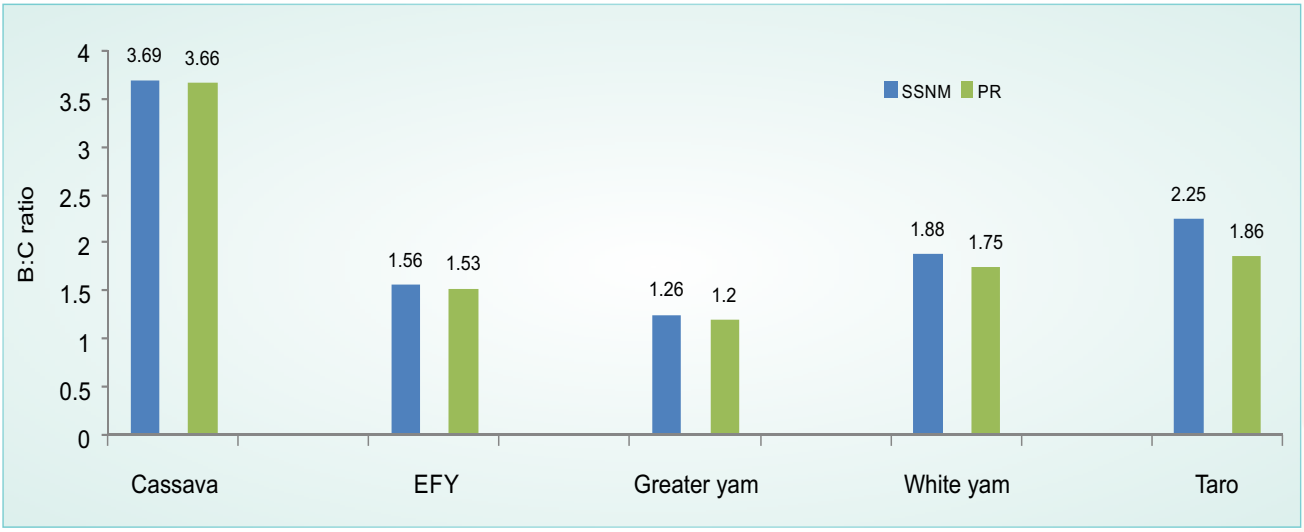


Fig. 47. B:C ratios of five SSNM on-station experiments

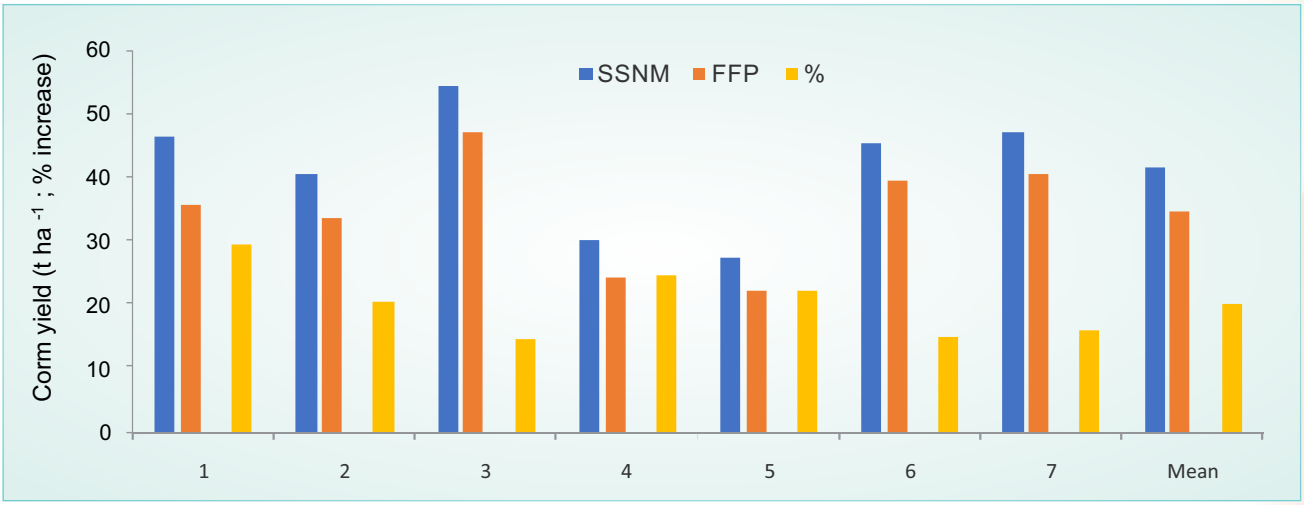


Fig. 48. On-farm validation of customized fertilizer for elephant foot yam based on SSNM technology

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

Results pertaining to the third consecutive *Kharif* season experiment carried out at Regional Centre, ICAR-CTCRI, Bhubaneswar with elephant foot yam-black gram cropping system showed that application of lime + FYM + NPK + $MgSO_4$ resulted in higher dehydrogenase activity (DHA) (0.521 µg TPF h^{-1} g^{-1}), followed by lime + FYM + NPK + $ZnSO_4$ (0.509 µg TPF h^{-1} g^{-1}). Among the organics, highest DHA was observed due to incorporation of FYM (0.411 µg TPF h^{-1} g^{-1}), over that of neem cake and vermicompost. Highest fluorescein diacetate hydrolysis assay (FDA) was observed due to integrated use of lime + FYM + NPK + borax (0.527 µg g^{-1} h^{-1}), followed by lime + FYM + NPK + $MgSO_4$ (0.509 µg g^{-1} h^{-1}). Highest urease activity was observed due to integrated application of lime + FYM + NPK + $MgSO_4$ (122.2 µg NH_4-N g^{-1} h^{-1}), followed by 150% NPK (119.4 µg NH_4-N g^{-1} h^{-1}). Lime addition had positive impact on urease activity in the soils. Integrated use of lime + FYM + NPK + $MgSO_4$ resulted in highest acid and alkaline phosphatase activities (32.18 and 30.87 µg PNP g^{-1} h^{-1}, respectively). The results indicated that soil bacteria and actinomycetes had significant impact on soil enzyme activities (DHA, FDA, urease, and phosphatase), which involved in the nutrient transformations and contributed to higher crop yields.

Impact of nutrients on soil microbes, enzyme activities and yield of elephant foot yam – black gram cropping system

A field experiment was laid out during *Kharif* 2018 with 14 treatment combinations (Control, N_{40}, N_{80}, N_{120}, P_{30}, K_{40}, K_{80}, K_{120}, $N_{80}P_{30}$, $N_{80}K_{80}$, $P_{30}K_{80}$, $N_{80}P_{30}K_{80}$, FYM @ 10 t ha^{-1}, FYM @ 10 t ha^{-1} + $N_{40}P_{15}K_{40}$) to study the impact of nutrients on soil microbes, enzyme activities and yield of elephant foot yam – black gram cropping system in an Alfisol. Black gram (local cultivar) seeds were dibbled as an intercrop in between elephant foot yam (var. Gajendra), which was spaced at 75 cm x 75 cm, and grown up to 70 days.

Combined application of NK resulted in higher yield response (41.30%) rather than PK (29.40%) and NP (28.50%), whereas, application of NPK resulted in higher yield response (56.60%) over that of other nutrient combinations. Incorporation of FYM @ 10 t ha^{-1} alone showed a yield response of 22.50% over control and higher yield response in comparison to single application of N, P and K @ 40, 30 and 40 kg ha^{-1}, respectively.

Combined application of NPK @ 40, 15 and 40 kg ha^{-1} along with incorporation of FYM @ 10 t ha^{-1} resulted in significantly highest corm yield (24.32 t ha^{-1}) with an increase of 4% yield over that of $N_{80}P_{30}K_{80}$. Significantly highest grain and haulm yields (615 and 2150 kg ha^{-1}, respectively) of black gram (as an intercrop with elephant foot yam) were obtained due to application of FYM + $N_{40}P_{15}K_{40}$. Significantly highest dry matter (25.02%) and starch (11.43%) contents were obtained due to application of FYM +

$N_{40}P_{15}K_{40}$. Combined application of NPK resulted in highest starch (11.36%) over that of NK (11.13%), PK (10.62%) and NP (10.40%). Total sugars ranged from 1.32 to 1.55%, with highest being due to integrated application of FYM + $N_{40}P_{15}K_{40}$. The dehydrogenase and urease activities were maximum (1.216 µg TPF h^{-1} g^{-1} and 172.28 µg NH_4-N g^{-1} h^{-1}, respectively) with the application of 80-30-80 kg ha^{-1} of N, P and K, respectively. However, the FDA and acid phosphatase activities were maximum (1.352 µg g^{-1} h^{-1} and 82.17 µg PNP g^{-1} h^{-1}, respectively) with the integrated use of FYM @ 10 t ha^{-1} along with 40-15-40 kg ha^{-1} of N, P and K, respectively. Application of lower doses of NPK along with FYM produced sustainable crop yields with good quality elephant foot yam and black gram, as an intercrop, over that of higher doses of chemical fertilizers alone.

Impact of tillage and mulching on soil water-nutrient use and productivity of cassava

The impact of three tillage (conventional (CT), deep (DT) and minimum (MT)) and mulch types on variations in soil bulk density (BD), water holding capacity (WHC) and porosity of laterite soil was studied for the fourth consecutive year. Results showed that the BD ranged from 1.47 to 1.72 Mg m^{-3} and the maximum value was observed in soils under minimum tillage, whereas CT and DT were on par (1.47-1.50 Mg m^{-3}). Increased soil porosity (44.50 %) was observed under CT and maximum WHC (42.1%) under soils of DT.

Surface soil moisture storage (volumetric), soil temperature variations and soil water transmission properties viz., saturated hydraulic conductivity (HC), sorptivity (SS) and matric potential (MP) were also estimated under different tillage and mulch treatments. Average soil water storage values were 8.10, 9.20 and 7.30% (v/v) and the soil temperature were 36.80, 35.70 and 36.50°C under CT, DT and MT practices, respectively. Among the mulch practices, GC showed high moisture content (9.80%, v/v) as compared to no mulch (7.20%, v/v). The cassava tuber yield of 29.90, 29 and 23.60 t ha^{-1} was obtained 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 estimated under different treatments showed that HC and SS of CT was 13 and 28% higher as compared to minimum tillage, whereas 12% increase in matric potential was observed under GC as compared to NM.

The results support the earlier studies; however variations in soil bulk density could considerably affect the physical characteristics in different tillage, thereby affecting sorptivity. This property needs to be improved upon to get the desired effects in minimum- tilled soils with time. A direct correlation was observed with the matric potential and soil sorptivity. The interactions among conventional tillage and GC mulch showed improved values (0.046 cm $min^{-1/2}$) as compared to first year (0.023 cm $min^{-1/2}$), but significantly less than soil sorptivity of deep tillage treatment. The interactions among minimum tillage and GC mulch showed improved values (0.046 cm $min^{-1/2}$) as compared to first year (0.023 cm $min^{-1/2}$), but significantly lesser than soil sorptivity of deep tillage treatment. Soil surface infiltration rate was 2.24 cm h^{-1} under CT, whereas it was 1.16 cm h^{-1} for MT plots (Fig. 49). Similarly, the two treatments differed considerably for steady state infiltration rate (cm min^{-1}) and cumulative infiltration (cm). Correlation studies showed that bulk density had a significant negative relationship with soil sorptivity in conventional-tilled and GC sheet applied plots (- 0.742* and -0.623*; P=0.05 respectively).

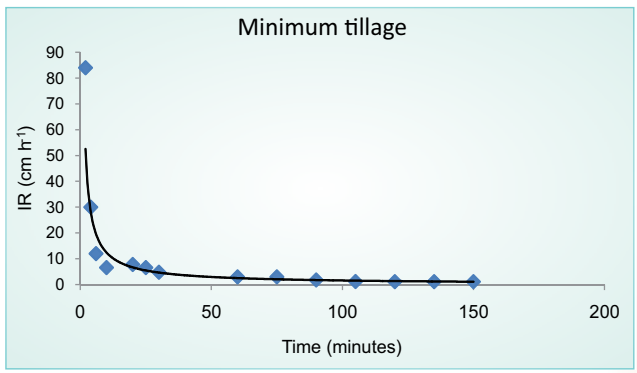


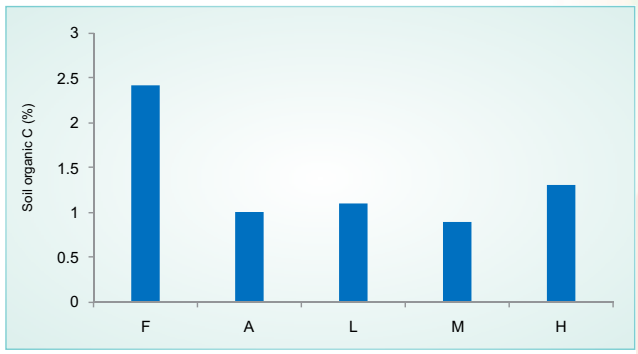
Fig. 49. Infiltration pattern in Ultisols under minimum tillage

Development of best soil carbon sequestration packages for hill cassava production systems

The Pachamalai hills, a major cassava area situated in Salem district, Eastern Ghats, Tamil Nadu was surveyed during August 2018 by visiting major cassava growing areas located at different elevations. Ten different villages consisting of agriculture and forest land use (for reference) were selected (Fig. 50). Geo-spatial, depth wise soil samples having varied soil organic carbon stocks were subjected

to detailed estimations of physical (texture, bulk density, porosity, maximum water holding capacity), chemical (pH, organic carbon, available N, P, K, Ca, Mg, S, micronutrients), biological properties (soil dehydrogenase, total glomalin and easily extractable glomalin, spore counts) and compared among three different elevations viz., low (700-800 m above msl), medium (800-900 m) and high (>900 m). Soils were predominantly with a texture of sandy loam to sandy clay loam with few areas under loamy soils. The organic carbon content was varying with elevations and ranged from 0.42 to 1.42% and similar trend was observed in the case of easily extractable glomalin (EEG) under both land uses (Fig. 51). Majority of cultivated soils were low in available N, P and medium to high in available K. The soil dehydrogenase was found to vary from 0.86 to 32.67 µg TPF g^{-1} h^{-1} and was maximum under forest soils. The number of spores per gram of dry soil was higher in sub surface soil in majority of samples. It varied from 3 to 50 among the soil. The forest lands were found to have 23 and 29 in surface and subsurface samples, respectively. Correlation studies showed that significant correlations existed among the soil properties viz., pH and Ca (0.73*, p=0.05), SOC and Ca (0.81*, p=0.05), among others.

Fig. 50. Geospatial core soil sample collections from agriculture (top) and forest (bottom) land use



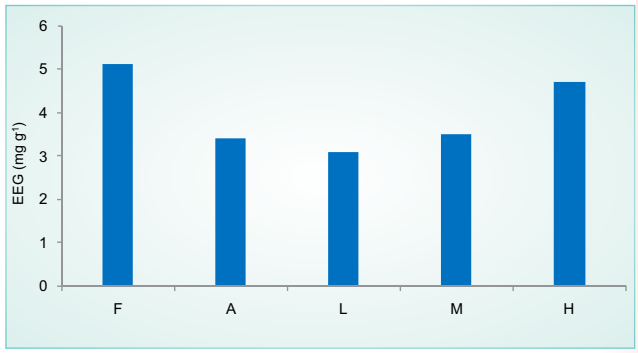


Fig. 51. Effect of land use (Forest, F and Agriculture, A) and elevations (Low, L; Medium, M; High, H) on soil organic carbon and easily extractable glomalin (EEG) contents

Studies on the 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

In the experiment on induction of tolerance to high temperature stress (HTS) through chemical treatments in sweet potato, vine cuttings of the variety Sree Arun was planted in RBD with five replications under open field and polychamber conditions with and without humidification. Five foliar spraying treatments viz., water spray (control), 0.2% $CaCl_2$, 4-12 weeks after planting at fortnight intervals, 0.2% Salicylic acid, 4-12 weeks after planting at fortnight intervals and 1000 ppm Benzyl adenine (BA), 4-12 weeks after planting were applied. On bright sunny day, plants under open field conditions experienced 32-34°C temperature with 65-75% RH and 2189-2420 µmol m^{-2} s^{-1} photosynthetic photon flux density (PPFD) during day time. Inside the polychamber, without humidification, sweet potato plants experienced HTS of 36 to 41.8°C with 42-55% RH and 780-1225 µmol m^{-2} s^{-1} photosynthetic PPFD during day time (10 am to 4 pm). Plants under humidified polychamber conditions experienced >65% RH with a temperature range of 34-37°C. On cloudy days, PPFD was 280-370 µmol m^{-2} s^{-1}, temperature 31°C and 67% RH

outside the chamber and PPFD was 150 µmol m^{-2} s^{-1}, temperature 30°C and 68% RH under polychamber conditions. Plants under open field conditions were irrigated when there was water deficit stress, whereas plants under polychamber conditions were regularly irrigated. Photosynthetic rate was the maximum in plants under polychamber with humidification (21.83-26.93 µmol m^{-2} s^{-1}). Furthermore, spraying sweet potato plants with $CaCl_2$ (0.2%) enhanced photosynthetic capacity. Photosynthetic rate was reduced by 32.51-36.19% and 42.08-49.45% in plants under open field and polychamber without humidification conditions respectively, relative to polychamber with humidification. Vine length (200-239 cm), LAI (1.8-4.6) and HI (0.5-0.65) were maximum in plants under polychamber with humidification relative to plants under open field and polychamber without humidification. The crop was harvested at 16 weeks after planting. Under all the conditions, greater tuber yield was recorded in plants under polychamber conditions with humidification. Higher tuber yield was recorded due to spraying of $CaCl_2$ (0.2%) irrespective of the different conditions like, open field (13.24 t ha^{-1}), polychamber with humidification (16.80 t ha^{-1}) and polychamber without humidification (11.45 t ha^{-1}). Foliar spraying of $CaCl_2$ resulted in 20.90- 43.20% higher tuber yield relative to control plants with water spray. Tuber yield was reduced by 13.50 -25.20% and by 31.90-42.50% in plants under open field and polychamber without humidification conditions respectively, relative to polychamber with humidification.

Effect of nutrients on soil microbes, enzyme activities and yield of *Colocasia* in marshy/low lands of eastern India

A field experiment was laid out during *Kharif* 2018 at ICAR–CTCRI, Regional Centre, Bhubaneswar with 14 treatment combinations (control, FYM @ 10 t ha^{-1}, FYM @ 10 t ha^{-1} + $N_{40}P_{15}K_{40}$, N_{40}, N_{80}, N_{120}, P_{30}, K_{40}, K_{80}, K_{120}, $N_{80}P_{30}$, $N_{80}K_{80}$, $P_{30}K_{80}$, $N_{80}P_{30}K_{80}$) to study the impact of nutrients on soil microbes, enzyme activities and yield of *Colocasia* in an Alfisol. Graded doses of N significantly increased the cormel yield of *Colocasia* up to 120 kg N ha^{-1} with a yield response of 21.50, 37.60 and 39% due to application of 40, 80 and 120 kg N ha^{-1}, respectively over control. Higher yield response in terms of cormel yield (14.81 t ha^{-1}) was observed due to application of graded doses of K up to 120 kg K_2O ha^{-1} rather than N doses. Combined application of NK has recorded higher yield response (70.10%) rather than PK (50.40%) and NP (41.10%), whereas application of NPK has higher yield response (82.60%) over that of other nutrient combinations.

Incorporation of FYM @ 10 t ha^{-1} resulted in a yield response of 35.40% over control and higher yield response in comparison to single application of N, P and K @ 40, 15 and 40 kg ha^{-1}, respectively. Combined application of lower doses of NPK @ 40, 15 and 40 kg ha^{-1} along with incorporation of FYM @ 10 t ha^{-1} ^{1} resulted in significantly highest cormel yield (19.28 t ha^{-1}), with an yield increase of 4% over that of $N_{80}P_{30}K_{80}$. Significantly highest dry matter (24.51%) and starch (11.69%) were observed due to application of FYM @ 10 t ha^{-1} + N, P and K @ 40, 15 and 40 kg ha^{-1}. Combined application of NPK resulted in highest starch (11.49%) over that of NK (10.94%), PK (10.58%) and NP (10.20%). Total sugars ranged from 0.91 to 1.34%, with highest being due to application of 80, 30 and 80 kg ha^{-1} of N, P and K, respectively. The results indicated that application of lower doses of NPK along with FYM produced highest crop yields with good quality tubers of *Colocasia* over that of higher doses of chemical fertilizers alone. Combined application of NPK showed higher yield response in *Colocasia* rather than single application of nutrients.

Response of tuber crops to elevated CO_2

The parameters like net photosynthetic rate (*Pn*), stomatal conductance (g_s) and intercellular CO_2 (*Ci*) were studied in seven varieties of yam, 15 cassava genotypes and one variety of yam bean under ambient (400 ppm) and three levels of eCO_2 at five levels of photosynthetic photon flux densities (PPFDs measured at 30°C) using portable photosynthesis system LI-6400, LICOR, USA.

Photosynthetic response of cassava to eCO_2

With the exception of certain variety like Sree Athulya, the Pn rate steadily increased at CO_2 between 400 and 800 ppm, but declined at 1000 ppm. Maximum increment in *Pn* was recorded at CO_2 between 400-600 ppm, CO_2 relative to 400 ppm in varieties Sree Jaya (23%) and H-226 (21%). In all the varieties *Ci* steadily increased between 400 and 1000 ppm CO_2. With exceptions like the varieties Sree Jaya and H-165 *gs* declined between 400 -1000 ppm CO_2. The

post illumination CO_2 efflux (PICE) was recorded in five genotypes at CO_2 between 400 -1000 ppm. In all genotypes, PICE was lesser than 5 µmol m^{-2} s^{-1} CO_2.

Photosynthetic response of yam to eCO_2

The maximum *Pn* of seven yam varieties viz., four white yam (*Dioscorea rotundata*) varieties, including two dwarf white yams, Sree Dhanya, Sree Swetha, two trailing white yams, Sree Priya and Sree Haritha and three greater yam (*D. alata*) varieties, Sree Shilpa, Sree Karthika, Sree Nidhi was recorded at PPFD of 1500 µmol m^{-2} s^{-1}. Maximum increase of *Pn* was observed between 400-600 ppm in Sree Dhanya (33.26%), Sree Karthika (33.05%) and Sree Haritha (32.93%). In all varieties *Ci* increased steadily between 400 and 1000 ppm CO_2. With exceptions of the variety Sree Dhanya, *gs* declined between 400 -1000 ppm CO_2. The average *Pn* rate of these yam varieties were 18.99, 26.35, 29.54 and 31.95 µmol CO_2 m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. The *Pn* had positive correlation with external CO_2 (R^2 = 0.827; r = 0.87), *Ci* (r = 0.86; R^2 = 0.742), but poor correlation with *gs* (r = 0.09; R^2 = 0.0019). The yam varieties had the average g_s of 0.717, 0.944, 0.991 and 0.715 mol H_2O m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. The mean *Ci* of seven yam vars. were 328.67, 507.85, 655.19 and 863.77 µmol CO_2 mol^{-1} air at 400, 600, 800 and 1000 ppm CO_2 respectively. The average transpiration rates of yam varieties were 5.81, 5.64, 5.70 and 5.33 mmol H_2O at 400, 600, 800 and 1000 ppm CO_2 respectively. The correlation between transpiration and g_s was poor (r = 0.082; R^2 = 0.0072).

Photosynthetic response of yam bean to eCO_2

The maximum *Pn* of yam bean variety Rajendra Mishrikand-1 (RM-1) was recorded at PPFD of 1500 µmol m^{-2} s^{-1}. The *Pn* steadily increased at increasing CO_2 concentrations of 800 ppm but decreased at 1000 ppm. The *Pn* rate was 34.45, 39.6, 36.16 and 34.54 µmol CO_2 m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. The *Ci* steadily increased from 324.15 µmol CO_2 mol^{-1} to 909.69 15 µmol CO_2 mol^{-1} between 400 and 1000 ppm CO_2 respectively. The *gs* increased little between 400 and 800 ppm external CO_2, but decreased at 1000 ppm. Global dimming and reduction in solar radiation is one of the effects of climate change. On sunny days, the mean PPFD was 1351.06, 1893.63 and 1403.07 µmol m^{-2} s^{-1}, whereas on cloudy days, the mean PPFD was 756, 896.99 and 796.95 µmol m^{-2} s^{-1} at 9-9.30, 12-12.30 and 3-3.30 h of the day, respectively. This amounts to a reduction in solar radiation on cloudy days and therefore the interactive effect of CO_2 and PPFD on *Pn* was studied. At CO_2 concentrations viz., 400, 600, 800 and 1000 ppm the *Pn* steadily increased due to increase in PPFD from 100 to 1500 µmol m^{-2} s^{-1} and the maximum P_n rate (34.45 µmol m^{-2} s^{-1} at 400 ppm – 39.6 µmol m^{-2} s^{-1} at 600 ppm) was under 1500 µmol m^{-2} s^{-1}. The differences in *Pn* across PPFDs were statistically significant (P<0.001). The P_n rate of yam bean was significantly reduced (11.1 – 679.4 %) as the PPFD decreased from 600 to 100 µmol m^{-2} s^{-1} relative to 1500 µmol m^{-2} s^{-1}. The P_n rate of yam bean was greater (25.68-29.38 µmol m^{-2} s^{-1}) at PPFDs between 600 and 800 µmol m^{-2} s^{-1} with maximum under 600 and 800 ppm CO_2 (26.80 – 32.13 µmol m^{-2} s^{-1}) relative to ambient CO_2. This revealed that eCO_2 up to 800 ppm can benefit *Pn* at lower light intensities < 600 µmol m^{-2} s^{-1} prevailing on cloudy days. The post illumination CO_2 efflux recorded at CO_2 between 400-1000 ppm was lesser than 5 µmol m^{-2} s^{-1}.

Climate smart agriculture (CSA) practices for tropical tuber crops

Significantly higher tuber yield was recorded in CSA practice (28.60 t ha^{-1}) than conventional practice (CP) (21.40 t ha^{-1}; 33.64% yield increase). Economics of the two production systems has been worked out. Greenhouse gas (GHG) emission estimates of the two production systems using the GHG accounting tool, CCAFS-MOT, have been worked out. Carbon footprint (CF) estimation and Life cycle assessment (LCA) of the two production systems were done. The changes in carbon footprint of cassava cultivation in India over the past 50 years are depicted in Fig. 52.

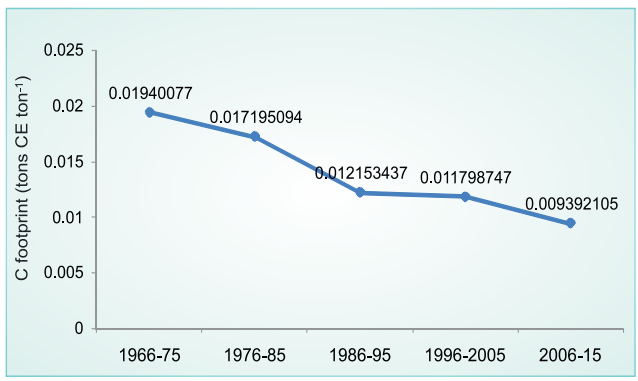


Fig. 52. Carbon footprint of cassava cultivation in India over the past 50 years

The potential of CSA practice in reducing greenhouse gas (GHG) emission compared to conventional practice is clearly evident from Fig. 53, which shows the total carbon emission from major inputs of cassava cultivation will be reduced, if we follow CSA in comparison to CP. The carbon efficiency of climate smart agriculture (CSA) practice vis-à-vis conventional practice is depicted in Fig. 54. The results clearly showed the superiority of CSA in reducing GHG emission compared to the conventional practice.

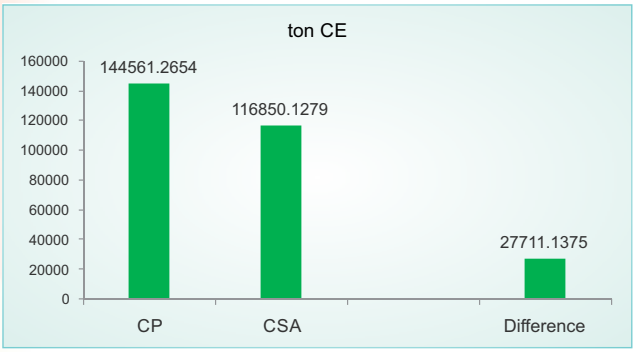


Fig. 53. Total carbon emission from major inputs of cassava cultivation under CP and CSA

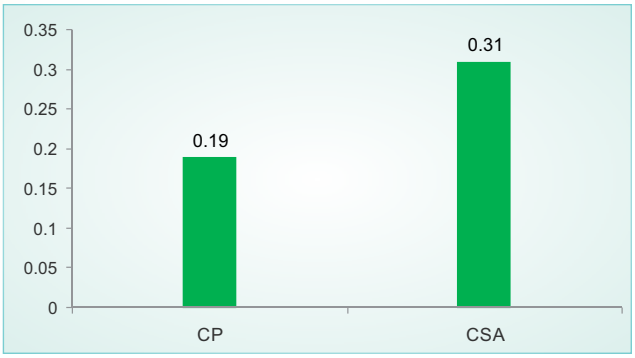


Fig. 54. The carbon efficiency of climate smart agriculture and conventional practice of cassava cultivation

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_i, physiological, growth and yield parameters of cassava grown under normal and water deficit stress (WDS) conditions. Results of the second year of study with ten cassava varieties showed that there was vast difference between growth of plants under normal and WDS conditions. Under irrigated conditions at 3, 4 and 5 MAP, Sree Reksha outperformed other varieties in terms of plant height (107.24, 146.56 and 186.5 cm), number of leaves (81, 126 and 146) and leaf area index (3.49, 4.41 and 5.71). Physiological parameters also showed significant differences among varieties and water regimes. Under irrigated and WDS conditions, cassava genotypes had the average net photosynthetic rate (P_n) of 28.40 and 15.75 µmol CO2 m^{-2} s^{-1} (44% reduction in stressed plants over control), respectively, while, under irrigated and WDS conditions, cassava genotypes had the average stomatal conductance (g_s) of 0.30 and 0.15 mol H_2O m^{-2} s^{-1} (50 % reduction in stressed plants over control) respectively. In irrigated condition, transpiration varied from 7.90-13.63 mmol H_2O m^{-2} s^{-1}, whereas it ranged from 3.76-7.66 mmol H_2O m^{-2} s^{-1} in stressed plants. Under irrigated conditions, intercellular CO_2 concentration (C_i) varied from 187.18 – 226.20 ppm and on the other hand it varied from 186.69–239.0 ppm in stressed plants. Considering the overall performance of the varieties, Sree Reksha variety was observed to perform better under irrigated as well as water deficit stress conditions.

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

Study on the effectiveness of microbes on whitefly

The microbes isolated from rhizosphere of tuber crops and cowdung against different stages of whitefly depicted that three fungi, *Penicillium citrinum, Beauveria bassiana* and *Metarhizium anisopliae* (Fig. 55); two bacteria, *Bacillus cereus* and *Bacillus pumilus* were effective in whitefly management. *Penicillium citrinum* (9.1 x 10^7 cfu ml^{-1}) had shown 68% mortality of the insect 10 days after treatment, whereas *Beauveria bassiana* (2.5 x10^6 cfu ml^{-1}) and *Metarhizium anisopliae* (1.6 x 10^6 cfu ml^{-1}) resulted in 80% and 77% mortality respectively. In the case of bacteria, *Bacillus cereus* and *Bacillus pumilus* showed 65% and 61% mortality of the whitefly respectively.

Fig. 55. Microscopic view of fungi grown on whitefly

Identification and characterization of different whitefly biotypes

Whiteflies infesting tuber crops were identified as *Bemisia tabaci* (Fig. 56) (cassava, sweet potato), *Aleurodicus rugioperculatus* (Fig. 57) (arrowroot) and *Aleurodicus dispersus* (Fig. 58) (cassava) through molecular methods.

Fig. 56. *Bemisia tabaci*

Fig. 57. *Aleurodicus rugioperculatus*

Fig. 58. *Aleurodicus dispersus*

Genetic variability study on cassava whitefly (*Bemisia tabaci*) from different AICRP centres showed that all belonged to Asia II5 biotype (having up to 2% sequence variation). Highest cassava mosaic disease severity (score 3-5) was observed in Yethapur and Thiruvananthapuram.

Residue analysis of promising insecticides using LCMS and GCMS used for whitefly management in different cassava plant parts after their field application had shown significant reduction in their concentration 48 hours after treatment.

Identification of eco-friendly chemicals for the management of major pests of tuber crops

Impact of chemical insecticides and biopesticides on the oviposition and hatching of sweet potato weevil

Commercially available six synthetic insecticides viz., Imidacloprid, Chlorpyrifos, Fenvalerate, Ekalux, Dimethoate and Dichlorvos; six biopesticides like Abtech, Guard, Agro bioplus, Nimbicidine, Neem and *Nanma* were selected to study their impact on egg laying and hatching of sweet potato weevil (SPW). Synthetic insecticides at four different concentrations (0.0001, 0.001, 0.01 and 0.05%) and biopesticides at 1, 3 and 5% were tried. Sweet potato tubers (100-150 g) were dipped in these insecticides for 5 min. and after air drying the tubers were transferred into separate plastic containers. Sweet potato weevil, 6 females and 10 males, were released into it for feeding and oviposition. Observations on egg laying and hatching were taken on 1, 3, 5, 7, 9, 15 days after treatment (DAT).

Oviposition

In the case of chemical insecticides used, Imidacloprid and Fenvalerate were most toxic to egg laying of SPW. In these treatments, no eggs were noticed in all the four concentrations for 15 days. Efficacy of Chlorpyrifos, Ekalux and Dichlorvos were on par, and egg laying started 7 DAT at 0.01%. The efficacy of Dimethoate was least among the 6 insecticides used, since egg laying started on 3 DAT. Among the biopesticides used, Agro bioplus was very effective even at 1% in preventing egg laying by the weevils for 15 DAT, whereas in the case of *Nanma* 1%, although no eggs were observed till 7 DAT, on an average 3.3±0.5 eggs were found at 5% on 9 DAT, and it was 4.6±0.5 and 7.3±1.1 at 3 and 1% respectively. The efficacy of neem oil was on par with *Nanma.* Of all the six biopesticides, the least efficacy was observed with Abtech in all the three concentrations used.

Hatching

Among the six insecticides used, Ekalux had greater ovicidal activity and hatching at 0.0001% but in Imidacloprid, Chlorpyrifos and Fenvalerate, the embryonic mortality was meagre and 90% hatching was noticed (Fig 59a). At higher concentration (0.05%), no hatching was observed in the case of Dichlorvos treatment, whereas it was 20, 50 and 75% in Ekalux, Dimethoate and Imidacloprid , whereas in Fenvalerate and Chlorpyrifos 80% was noticed.

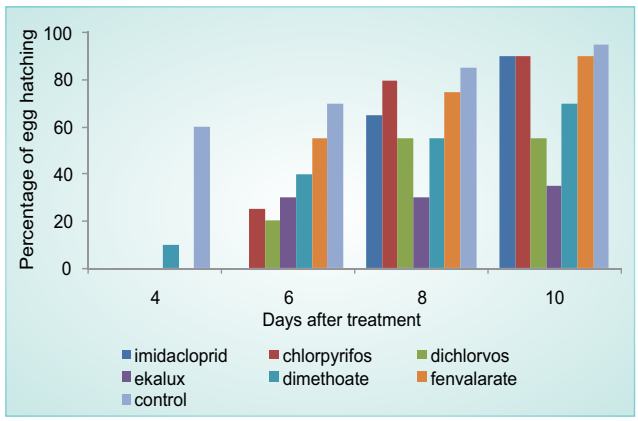


Fig. 59a. Ovicidal effect of synthetic insecticides (0.0001%) in sweet potato weevil

A delayed incubation period was observed both in synthetic and organic insecticide treated batches. In the control, the incubation period was 4 days, but when the eggs were exposed to insecticides, hatching was observed between 6-10 days.

Low hatching was observed in the treatment with *Nanma* and Nimbicidine. On 8 DAT, 95% hatching was observed in the control, whereas no hatching was noticed in the treatment with *Nanma* at 3 and 5%. But the emergence at 1.0% was only 20% in Nimbicidine and 30% in *Nanma*. No significant ovicidal effect was noticed in the treatment with Abtech (Fig. 59b).

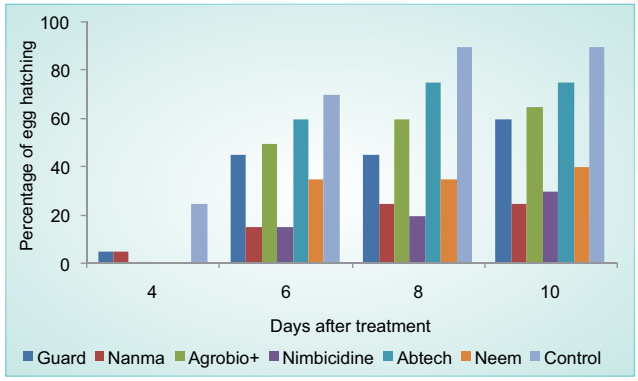


Fig. 59b. Ovicidal effect of biopesticides (1%) in sweet potato weevil

Feeding of sweet potato weevil

Generally, when the insecticide treated tubers were exposed to weevil, no feeding was observed until 18 days at 0.001, 0.01, 0.05, however at 0.05% concentration of Chlorpyrifos, Dichlorvos and Ekalux, feeding by the weevils started on 7 DAT. In the case of treatment with Chlorpyrifos at 0.0001%, the feeding started on 3 DAT, whereas it was 5 DAT in Dichlorvos and Ekalux. Dimethoate was least toxic to weevil as it started feeding in all the treatments.

Tuber treatment with biopesticide showed that Agro bioplus at 1, 3 and 5% had no feeding until 20 DAT, and all the exposed weevils died. Treatment with *Nanma* (5%) and Nimbicidine (3 and 5%) protected the plants for 7 DAT. No feeding inhibition was observed in the treatment with Abtech at all the concentrations treated.

Effect of synthetic insecticides on rooting in sweet potato cuttings

Effect of insecticides on root formation in sweet potato vines was studied. Six synthetic insecticides were prepared in three concentrations, 0.001, 0.01 and 0.05% and sweet potato vines of 15 cm length were dipped into it for 30 min., 1, 3, 6, 15 and 24 h. Rooting was significantly affected when the cuttings were dipped in 0.05% Dichlorvos and Ekalux and the length of the roots were 10.33 and 4.00 cm, respectively as against 18.67 cm in control. When the exposure time was increased, rooting was severely affected in Dichlorvos and no rooting was observed in the vines dipped for one hour and above. Imidacloprid did not affect the root length.

In the case of treatment with Ekalux, the rooting was reduced from 10.33 cm to 3.03 cm when the time of exposure was increased from 30 min. to 24 h. Exposure of sweet potato vine to Dimethoate 0.05% up to 15 h resulted in no rooting. The rooting was least affected in the batch treated with Imidacloprid and Chlorpyrifos at 0.001%.

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

Sweet potato weevil is the most important pest of sweet potato. Hence the identification of host plant resistance related genes is one of the alternate pest management strategy. This experiment was designed with an objective to identify the genes coding for various proteinase inhibitors in sweet potato plants related to sweet potato weevil infestation. Plant proteinase inhibitors (PPIs) act as anti-metabolic proteins against phytophagous insects and microorganisms. They are induced in plants in response to injury or attack by insects or pathogens. A total of 25 sweet potato genotypes including released varieties and germplasm accessions were used for the experiment. The validation of gene expression of cysteine proteinase inhibitor and proteinase inhibitor were studied under controlled conditions in sweet potato varieties viz., Sree Kanaka, Sree Vardhini, Sree Arun, Kanhangad, Bhu Sona, Bhu Krishna and 19 sweet potato genotypes. All the plants, both control and weevil infested samples, were kept in growth chamber (Temperature-28°C, Relative Humidity-80%, Light-2 lux) under controlled conditions with replicates. RNA was isolated from sweet potato weevil infested as well as control plant samples and cDNA was synthesized for Reverse Transcriptase-PCR (RT-PCR). Ubiquitin extension protein (UBI) -209bp, ADP-ribosylation factor (ARF) – 185bp, Cytochrome c oxidase subunit Vc (COX) – 159bp were used as reference genes. Out of the 25 genotypes, the proteinase inhibitor gene was amplified from 15 genotypes and the cysteine proteinase inhibitor gene was amplified in six genotypes (Fig. 60 and 61). The proteinase inhibitor genes were expressed in sweet potato varieties such as Sree Kanaka, Sree Vardhini, Howrah, Bhu Sona, Bhu Krishna and Kanhangad. The cysteine proteinase inhibitor gene was amplified in sweet potato genotypes, S-1661, Howrah, Bhu Sona, Bhu Krishna and Kanhangad. The Cytochrome c oxidase subunit Vc (COX) reference gene was amplified in all the sweet potato weevil infested as well as control samples.

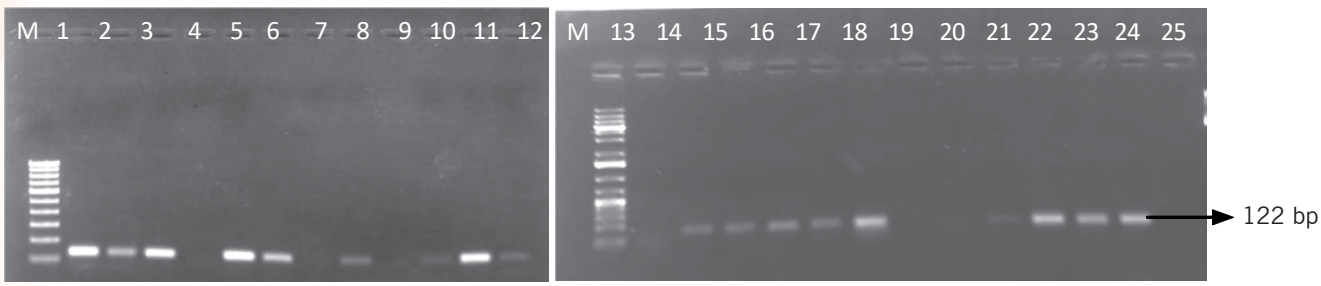


Fig. 60. PCR amplification of proteinase inhibitor gene from sweet potato weevil infested samples

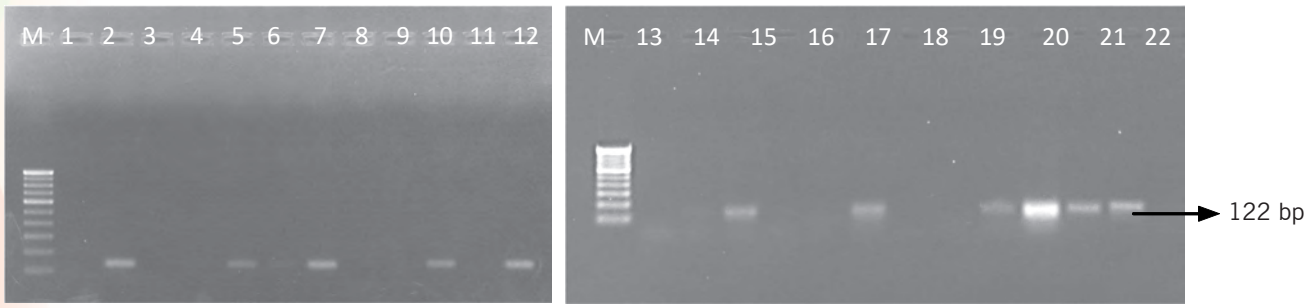


Fig. 61. PCR amplification of proteinase inhibitor gene from control samples

M-100 bp ladder, 1-S-1582, 2-S-1584, 3-S-1589, 4-S-1700, 5-SIB400/22, 6-S-1603, 7-S-1661, 8-S-1596, 9-Kisan, 10-Sree Kanaka, 11-SreeVardhini, 12-Howrah,13-Hubs84, 14-S-1401, 15-S-1586, 16-S-1587, 17-S-1588, 18-S-1607, 19-S-1712, 20-S-1660, 21-Bhu Sona, 22-Bhu Krishna, 23- Kanhangad, 24-BX-46, 25-Sree Arun

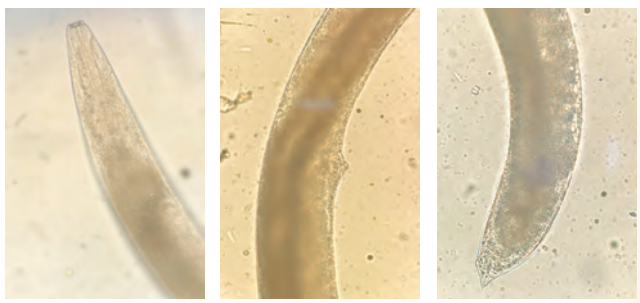
Survey, collection and identification of plant parasitic nematodes associated with tuber crops in India

Eighteen soil samples were collected from elephant foot yam fields in ICAR-CTCRI during April 2018 to February 2019. Five genera of plant parasitic nematodes were identified viz., *Pratylenchus coffeae*, *Meloidogyne incognita*, *Helicotylenchus* sp. *Tylenchorhynchus* sp. and *Rotylenchus* sp. Out of which, *P. coffeae*, and *M. incognita* were the predominant species with prominence values of 40.02 and 36.69, respectively. A total of 14 soil samples were collected from elephant foot yam fields of Wayanad, Kerala during August 2018. Five genera of plant parasitic nematodes were observed viz., *M. incognita*, *Pratylenchus* sp., *R. reniformis*, *Helicotylenchus* sp., and *Tylenchus* sp. Of which, *M. incognita* and *Pratylenchus* sp. were observed in maximum frequency (27.78 and 22.22) and abundance (34.51 and 22.12), respectively. Nine soil samples from elephant foot yam fields were collected from Chettiyampalayam, Gobi, Erode, Tamil Nadu during December 2018, where four genera of plant parasitic nematodes were observed viz., *Pratylenchus* sp., *Hemicycliophora* sp., *Xiphinema* sp. and *Tylenchus* sp. Lesion nematode, *Pratylenchus* sp. and sheath nematode, *Hemicycliophora* sp. were the most predominant nematodes with prominence values of 68.04 and 45.36, respectively. Five soil samples were analyzed from Chinese potato fields of Ambasamudhram, Tamil Nadu during January 2019. The most predominant nematode was *Meloidogyne incognita* with a population density of 1.5 nematodes per gram of soil.

A new strain of entomopathogenic nematode (EPN) was isolated from a soil sample from Kattakada, Thiruvananthapuram. Based on morphological characterization it was identified as *Steinernema siamkayai*. The new strain was characterized by the presence of tail mucron in both first and second generation males and females, double flapped epiptygma in both generation of females, post anal swelling in second generation females and 7 lateral lines in infective juveniles (Fig. 62).

Steinernema siamkayai

Infective juveniles emerging *en masse* from insect cadaver



Anterior region | First generation female vulva showing double flapped epiptygma | Tail with post anal swelling

Fig. 62. Morphology of *Steinernema siamkayai*

Management of nematodes in tuber crops

A field experiment was conducted for sterilisation of nematode infected soil by soil solarisation. A thin polythene sheet (100 µm) was spread over the moistened soil for two months. The initial nematode population of *Meloidogyne incognita* in the field was 120 nematodes per 100 g soil sample. After two

months, the root knot nematodes reduced significantly to 80 per 100 g soil.

A natural infection of bacterial parasite, *Pasteuria* sp. on *Meloidogyne incognita* was recorded from a soil sample in Thiruvananthapuram. All nematodes in the sample including *Rhabditid* and *Tylenchid* nematodes were infested. Live infective juveniles of *M. incognita* were attached with bacterial endospores. On an average, 25 endospores were adhering to the cuticle of second stage infective juveniles of *M. incognita* throughout the body. In the initial stages of infection, nematode movement got severely reduced and later got paralyzed completely (Fig. 63).

Pasteuria sp. endospores on J_2 of *Meloidogyne incognita*

Pasteuria sp. endospores on a *Rhabditid* nematode

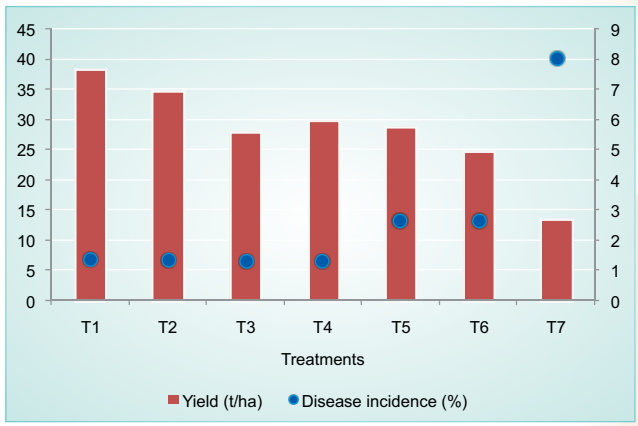
Fig. 63. *Pasteuria* sp. infection in nematodes

Development and Refinement of Integrated Disease Management and Forecasting System for Improved Tuber Crop Production

Management of fungal diseases of aroids

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

The experiment was laid out in elephant foot yam (var. Gajendra) with seven treatments involving various combinations of fungicides and bioagents. Vermicompost fortified with bioagents (10^{12} cfu g^{-1} substrate) was applied @ 100 g per plant. The lowest disease incidence of 1.30% was noticed with all four treatments, which received corm treatment either with *T. asperellum* or *B. amyloliquefaciens* as against 8% in control (Fig. 64). The maximum yield was recorded in the corm treatment with *T. asperellum* + application of vermicompost fortified with *T. asperellum* (38.40 t ha^{-1}), followed by corm treatment with *T. asperellum* + drenching the collar region with 0.2% fungicide (Mancozeb 63% + Carbendazim 12%) (34.73 t ha^{-1}). These treatments also showed supremacy over the other treatments during the last three years.



T_1- Corm treatment with *Trichoderma* + *Trichoderma* fortified vermicompost; T_2- Corm treatment with *Trichoderma* + fungicide 0.2%; T_3- Corm treatment with *B. amyloliquefaciens* + *B. amyloliquefaciens* incorporated vermicompost;T_4- Corm treatment with *B. amyloliquefaciens* + fungicide 0.2%; T_5- Corm treatment with *Nanma* 0.7% + *T. asperellum* incorporated vermicompost; T_6- Corm treatment with *Nanma* 0.7% + *B. amyloliquefaciens* incorporated vermicompost; T_7- Control.

Fig. 64. Collar rot incidence and yield due to various treatments in elephant foot yam

Etiology of post-harvest rot in elephant foot yam

Studies on etiology of post-harvest rot in elephant foot yam showed nine types of symptoms in disease affected corms collected from 68 locations (Fig. 65). Brown lesions turning into powdery mass of tissue in later stages was the most common symptom. Twenty two samples showed this kind of symptom (32.30%) causing 5% to 30% damage in affected corms. Pathogenicity test was proved with 15 isolates out of 33 morphologically dissimilar isolates obtained from all locations. Major symptoms produced by these isolates were discolouration, rotting and softening of corms. Isolates were identified up to generic level through colony and spore morphology, mycelial growth rate, sporangiophores and pigmentation (Fig. 66).

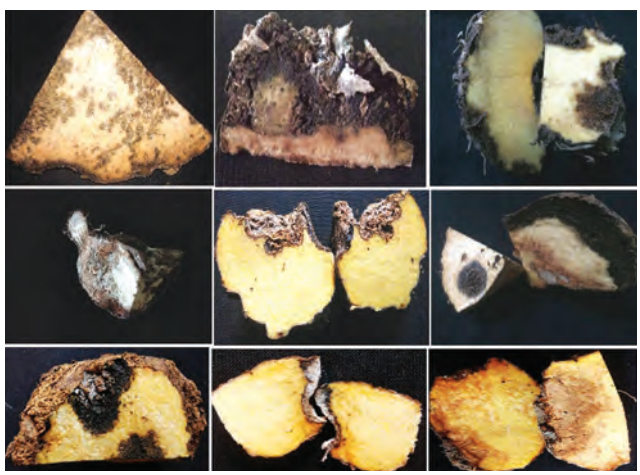


Fig. 65. Symptoms of corm rot in elephant foot yam

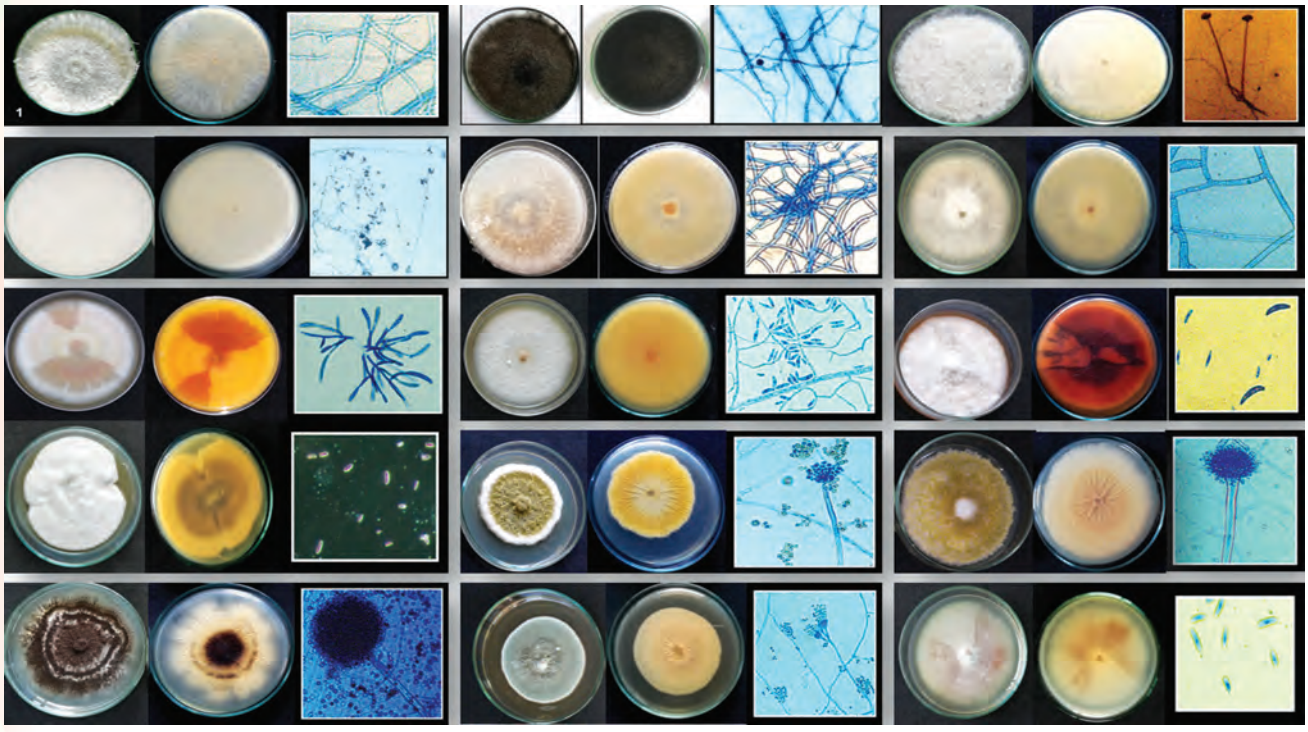
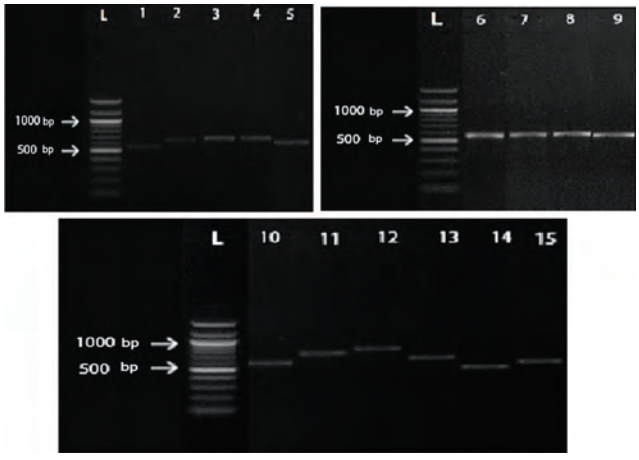


Fig. 66. Morphology of mycelia and spores of pathogens causing corm rot in elephant foot yam

The species level identification of the pathogens was done by amplifying the r DNA ITS region using ITS1 and ITS4 primers (Fig. 67). The pathogens were identified as *Athelia rolfsii*, *Lasiodiplodia theobromae*, *Rhizopus oryzae*, *Cunninghamella elegans*, *Rhizoctonia solani*, *Ceratobasidium* sp., *Fusarium brachygibbosum*, *Fusarium solani*, *Fusarium oxysporum*, *Colletotrichum gloeosporioides*, *Aspergillus tamarii*, *Aspergillus nomius*, *Aspergillus niger* and *Penicillium citrinum*.

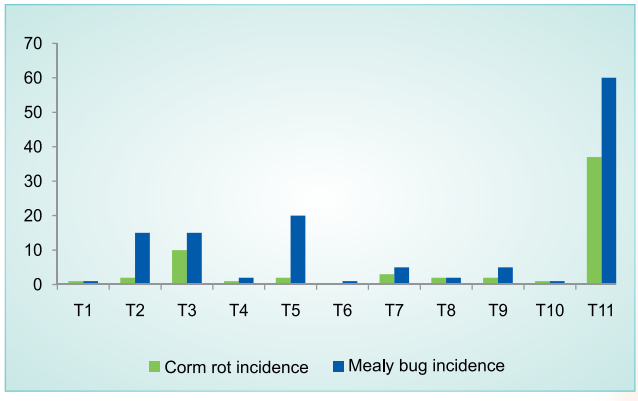


L: 100bp plus DNA ladder 1 to 15: isolate 1 to 15

Fig. 67. Amplification of ITS region of isolates using universal primer ITS 1 and ITS 4

Management of post-harvest rot in elephant foot yam

A storage study was undertaken to develop management strategy for post-harvest rot in elephant foot yam var. Gajendra. Corms were subjected to 11 treatments, which comprised fungicides and bioagents, before storing. The pre-storage treatment with bio-agent as well as fungicide could effectively mitigate the post-harvest loss in elephant foot yam. Minimum pathogen infection (only one spot) and least mealybug incidence was noticed with the treatment, Mancozeb + Carbendazim 0.2% (T_6) as against 37% of the corms showing spots in control (Fig. 68 to 70).



T_1-*Trichoderma* in cow dung slurry; T_2-*Trichoderma* in rice starch water; T_3-Cow dung slurry; T_4-Mancozeb 0.15%; T_5-Carbendazim 0.05%; T_6-Mancozeb (63%) + Carbendazim (12%) 0.2%; T_7-*Nanma* 0.7%; T_8-Mancozeb 0.15% + *Nanma* 0.7%; T_9-Carbendazim 0.05% + *Nanma* 0.7%; T_{10}-Mancozeb (63%) + Carbendazim (12%)- 0.2% + *Nanma* 0.7%; T_{11}-Control

Fig. 68. Incidence of corm rot and mealybug in elephant foot yam corm

Fig. 69. Corms treated with 0.2% of Mancozeb 63% + Carbendazim 12%

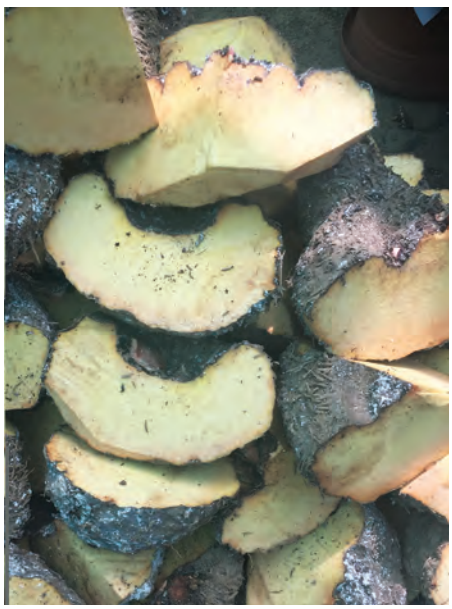


Fig. 70. Corms without pre-harvest treatment

Epidemiological studies on taro leaf blight

The onset and development pattern of taro leaf blight was studied in two susceptible varieties released by ICAR-CTCRI viz., Sree Rashmi and Sree Kiran and a resistant variety, Muktakeshi during 2018-2019. The initiation of the infection was delayed by almost 45 days compared to previous years. Initial symptom of TLB was noticed in the second week of July and the incidence continued throughout the season (Fig. 71). Highest percent disease index (PDI) was recorded during December-January period. The susceptibility score value was calculated based on AUDPC (Area Under the Disease Progress Curve) for the varieties by means of PDI and it rated Muktakeshi as resistant (score 0.96) and Sree Rashmi as the most susceptible variety with the score 6 (Fig. 72).

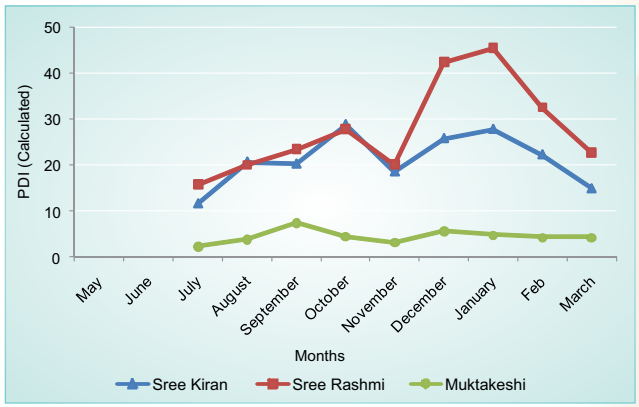


Fig. 71. Taro leaf blight incidence over time

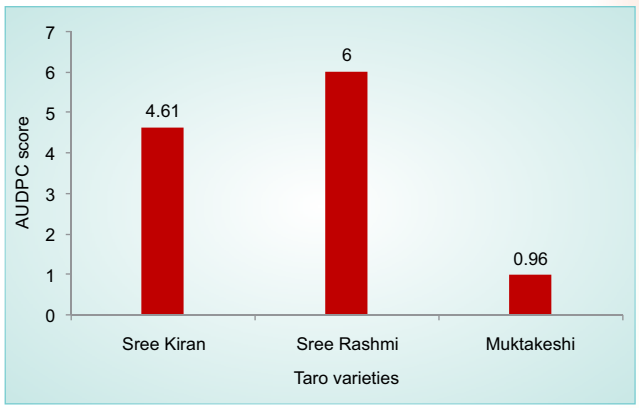


Fig. 72. AUDPC score for TLB incidence in taro

Characterization of secondary metabolites of potential endophytes

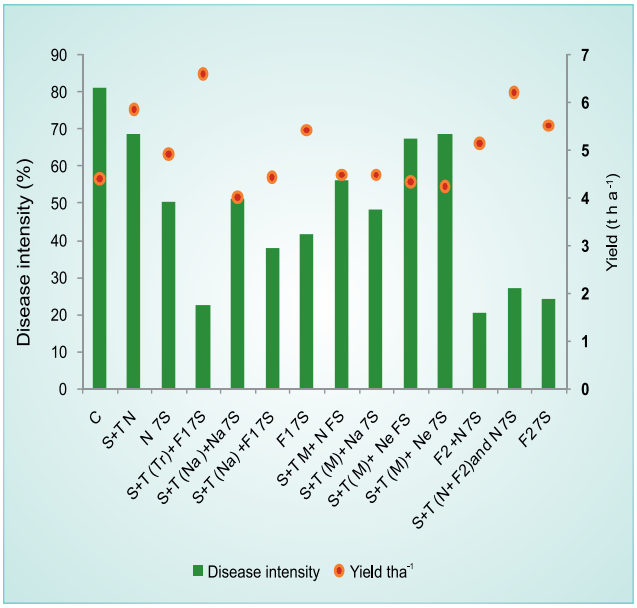
Secondary metabolites responsible for antifungal activity in most efficient endophytes against *P. colocasiae* viz., *Nigrospora oryzae* and *Bacillus subtilis* were characterised. The acetone fraction of *B. subtilis* and ethyl acetate fraction of *N.oryzae* showed antifungal activity. In the case of *B. subtilis*, three bands were observed and the compound 1 (2.8 Kda) exhibited high antifungal activity. Upon MALDI – TOF analysis, 20 amino acids with molecular mass of 2049 Da was obtained. The peptides showed 100% identity to fragments of the spore coat protein. The partially purified secondary metabolite from *N. oryzae* was characterized by TLC followed by GC-MS analysis. The metabolite was identified as oxaspiro compound.

Management of greater yam anthracnose

Field management

Field trial on the management of anthracnose in greater yam with 14 different treatments of combination of

bio-rationals and fungicide, Carbendazim (0.05% and 0.025%) 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* and neem were tested in the field for the first season against anthracnose in greater yam var. Orissa Elite. Both disease intensity and yield were not significantly different among the treatments. However, there was reduction in intensity and increase in yield in all the treatments compared to control. Among the treatments, spraying 0.025% Carbendazim and *Nanma* (0.7%) seven times showed highest reduction in disease intensity (75%), which was closely followed by the soil and tuber treatment with *Trichoderma* and spraying Carbendazim seven times first three at fortnight interval and further monthly after symptom initiation (69%). When we consider bio-rational alone, soil and tuber treatment with *Nanma* and spraying *Nanma* seven times reduced the intensity by 48%. Eventhough the yield was insignificant, soil and tuber treatment with *Menma* and spraying *Nanma* weekly resulted in maximum increase in yield (34.71%), which was closely followed by soil and tuber treatment with *Nanma* along with spraying Carbendazim seven times (34.41%). The soil and tuber treatment with *Nanma* and spraying *Nanma* seven times increased yield by 24% (Fig. 73)



C: Control; S: Soil treatment; T: Tuber treatment; Tr: *Trichoderma*; Na: *Nanma*; Ne: Neem oil ; F1: Fungicide (Carbendazim 0.05%); F2: Fungicide (Carbendazim 0.025%); 7S: Seven sprays; FS: Fortnightly spray

Fig. 73. Effect of biorationals and Carbendazim on the intensity of anthracnose and yield in greater yam

Evaluation of potential endophytes isolated from tuber crops against *Colletotrichum gloeosporioides* causing greater yam anthracnose

From a total of 37 and 39 isolates of bacterial and fungal endophytes isolated from tuber crops, two bacterial endophytes, MaL1 and SrS1 from arrowroot leaf and Chinese potato stem showed maximum potential. They were utilised to manage anthracnose in pot trial. The two potential endophytes were identified through amplification of 16s r RNA and Rec A regions as *Bacillus subtilis* (MaL1) and *Bacillus cereus* (SrS1). Species specific primers were designed for the isolates for further amplification.

The tissue culture raised greater yam (Orissa Elite) plants were treated with endophytes as root dip and spraying to confirm the colonisation. The conventional isolation as well as amplification of DNA isolated from the plants using species specific primers showed the colonisation of endophytes in roots and leaves.

In pot trial, *Bacillus cereus* and *Bacillus subtilis* were utilised to manage anthracnose with four different applications, viz., tuber treatment, soil treatment, spraying and the combination of all. Present package of soil and tuber treatment with *Trichoderma* and spraying Carbendazim seven times showed highest reduction (92.80%). *Bacillus cereus* ranked first in reducing disease intensity (87.07%) followed by *Bacillus subtilis* (64%), which showed their potential in managing the disease as well as promoting the growth.

Endophytes from medicinal plants

Altogether 197 bacterial and 157 fungal endophytes were isolated from 10 commonly available medicinal plants, viz., *Sida acuta, Andrographis paniculata, Asparagus racemosus, Tridax procumbens, Aloe vera, Eclipta alba, Solanum torvum, Piper longum, Phyllanthus niruri* and *Boerhavia diffusa*. From that 90 bacteria and 84 fungi were used for screening *in vitro* against *Colletotrichum gloeosporioides* based on morphological differences and among them 8 and 3 showed more than 80 and 75 per cent inhibition respectively, which will be utilized further for managing the disease.

Epidemiology

A field experiment was laid out for the fourth year with an aim to develop decision support system and

advise the farmers for managing anthracnose based on weather parameters. The development and spread of anthracnose in three released varieties of greater yam, viz., Orissa Elite (Highly susceptible), Sree Karthika and Sree Keerthi (Tolerant) were studied in field. The disease severity was observed at weekly intervals till 9th month of planting (Fig. 74) and the susceptibility score value based on AUDPC were 0.13, 0.33 and 5 respectively, which indicated that Sree Karthika and Sree Keerthi were resistant to anthracnose.

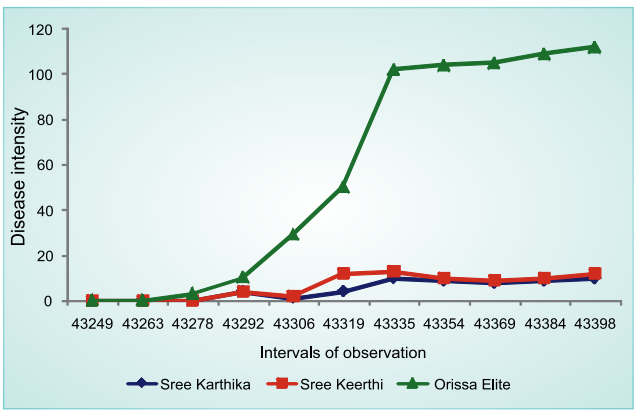
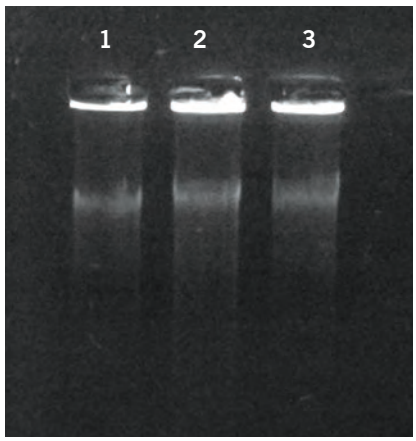


Fig. 74. Disease development in greater yam

Characterization, diagnosis and management of viruses of tuber crops

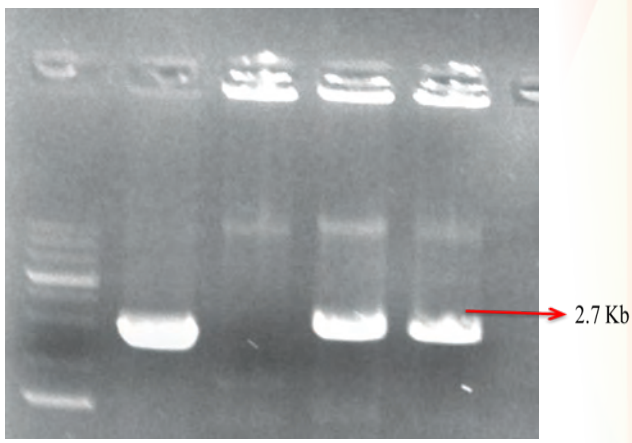
Partial genome of *Taro bacilliform virus* was cloned using different primer sets and sequenced. Sequence analysis showed 100% similarity with *Taro bacilliform* China isolates.

Sweet potato samples (35 nos.) with symptoms of virus infection were collected from fields of ICAR-CTCRI, Thiruvananthapuram and Bhubaneswar. These samples had common symptoms such as vein clearing, upward and downward curling, generalized yellowness, vein swelling and blister formation. The total DNA was isolated from these infected leaf samples and the PCR based detection method was adopted for disease diagnosis. SPLCV partial coat protein primers were used for the screening of sweet potato samples, which showed positive for SPLCV infection in 22 samples. Rolling Circular Amplification (RCA) was carried out to obtain whole genome sequence of *Sweet potato leaf curl virus* (Fig. 75a and b). The S1336 sample selected for whole genome amplification were cloned in PBS2KS+ and confirmed by polymerase chain reaction with SPG4/G3, M13F/G4, G3/M13R, SPG1/G2 and PW285.1/2. Restriction digestion with *BamHI* was also performed to confirm the clones. Sequencing was done with PW285. 1/2, SPG1, SPG4 and M13 primers. Sequencing of S1336 sample showed 90% similarity with *Sweet potato leaf curl virus* Greece isolate (KF697069.1).



Lane 1-Sree Nandhini; Lane 2- S731; Lane 3- S1336

Fig. 75a. Gel image showing RCA product of sweet potato leaf curl virus



Lane 1-Restricted PBS2KS; Lane 2-Sree Nandhini; Lane 3-S731; Lane 4- S1336

Fig. 75b. Gel image showing Restriction digestion of RCA product of SPLCV using Bam H1

Fig. 76. Multiple shoot induction from callus derived elephant foot yam

Field experiment was conducted to observe the progress of Dasheen mosaic disease and yield loss in elephant foot yam. The incidence of Dasheen mosaic disease was 4.3%, which caused 25.50% reduction in yield. Callus was developed from meristem culture of elephant foot yam (var. Gajendra) using tips and multiple shoot induction were done (Fig. 76).

Thermotherapy to manage DsMV

Based on the previous year results, the DsMV positive elephant foot yam tuber pieces were treated with hot water at 45°C for 15, 30 and 45 minutes and planted in grow bags. Tuber pieces, treated with normal water for 45 minutes were kept as control. Disease incidence was recorded based on DAS–ELISA of the leaf samples performed after three months of planting, which revealed that treatment for 45 minutes showed maximum reduction (33%) followed by both 30 and 15 min. (28%) compared to control.

Development of diagnostic kit for fungal pathogens infecting tuber crops

Loop mediated isothermal amplification (LAMP) was employed for rapid and effective detection of fungal pathogen. Gene target and LAMP Primer designing was carried out using *Sclerotium rolfsii* conserved region (Internal transcribed spacer 1). Designed 3 types of primers 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 LAMP technique, fungal DNA of *S. rolfsii* 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 was done in tube 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 was judged to be a suitable diagnostic kit for fungal pathogens infecting tuber crops.

Cassava Mosaic Disease – Variability, Diagnostic, Vector Relation and Management

Molecular mechanism of cassava mosaic virus infection

Full genome amplification of *Sri Lankan cassava mosaic virus* (SLCMV) and *Indian cassava mosaic virus* (ICMV) from field collected samples was done using rolling circle amplification (RCA) technique. The whole genome of SLCMV DNA-A and its cognate DNA-B and ICMV DNA-A were amplified and cloned as pSLCMV A7 (2746 bp), pSLCMV B2 (2738 bp) and pICMV A5 (2740bp) respectively, in pUC19 vectors. The sequence of pSLCMV A (Genbank accession No.MK404225) showed maximum similarity of 99 % with SLCMV-[TVM1] and SLCMV B (Genbank accession No. MK404226) showed maximum similarity of 99% with 'SLCMV-[Ker20]' sequence. The sequence of ICMV A showed maximum similarity of 95% with'ICMV-[Mah]' sequence in NCBI blast. Infectious clones of SLCMV and ICMV were developed using bitmer strategy and tested for their infectivity with tobacco (*Nicotiana benthamiana*), which has shown infectious nature of these clones. Plants inoculated with both DNA A and DNA B, initially showed mild stunting and downward leaf curling at seven days of post inoculation (dpi) (Fig. 77). By 10 dpi, five out of six plants displayed severe stunting, downward leaf curling and yellow mosaic pattern in the newly emerged leaves. Mild stunting, upward leaf curling and yellow vein phenotype were observed after two weeks of inoculation.

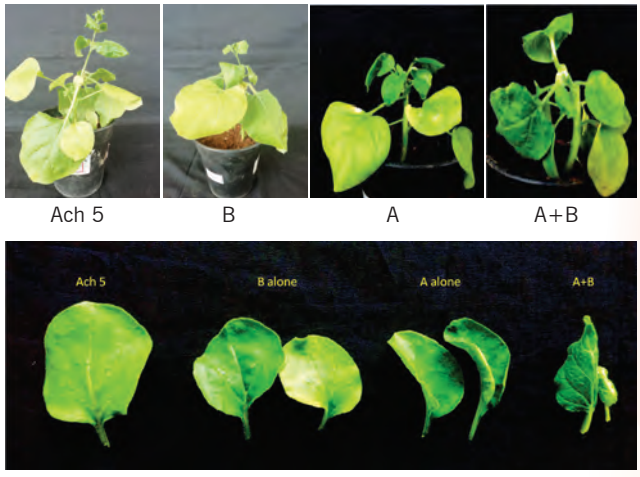


Fig. 77. Symptoms in *Nicotiana benthamiana* plants ten days after agro-inoculation with infectious clones of *SLCMV* A & B

With an aim of understanding the role of micro RNA in CMD development, next generation sequencing

(NGS) was performed with healthy and CMD infected cassava plants at Agrigenome, Kochi, Kerala. Total number of reads for all samples was greater than 10,000,000. Sequence length was 50bp and the GC distribution in the reads was above 50%. Average base quality (Phred score) of total data passed >= 30 phred score. Using this sequence data, identified the siRNA, known miRNA and novel miRNA aligning with cassava genome sequence as well as virus genome database.

Cassava mosaic virus infected leaves from five varieties of cassava viz., Sree Athulya, Sree Visakham, Sree Vijaya, Sree Swarna and a cultivar Malabar local were studied for physiological and biochemical changes with CMD severity. Maximum net photosynthetic rate (Pn) was recorded in healthy leaves of cassava genotypes. There was a steady decline of Pn with increasing severity of CMD in the leaves (Fig. 78). The leaf conductance (g_s) of cassava leaves also showed a similar trend like Pn (Fig. 79).The results showed that quantum efficiency of photosystem II was not altered greatly by CMD as there was only a negligible perturbation even in Score 4 in cassava genotypes studied. Non photochemical quenching increased with CMD infection in all the genotypes studied. Chlorophyll a & b contents decreased with increasing severity of CMD infection in all the genotypes. The total carotenoids content decreased significantly in diseased leaves compared to healthy ones.

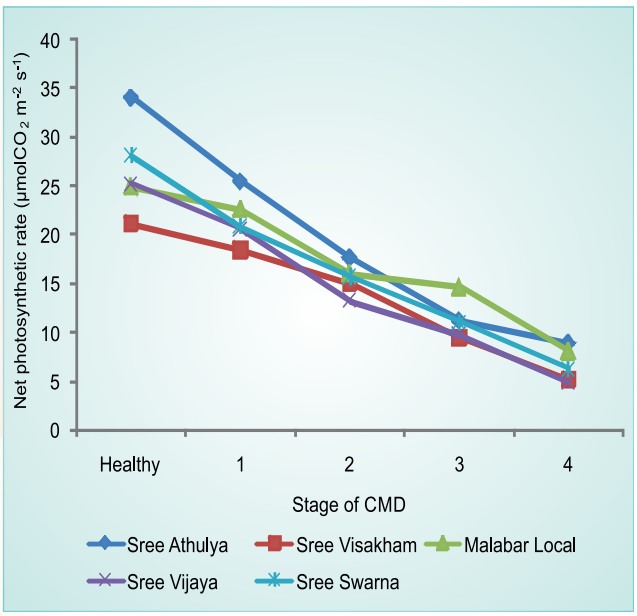


Fig. 78. Changes in net photosynthetic rate of cassava genotypes as affected by CMD

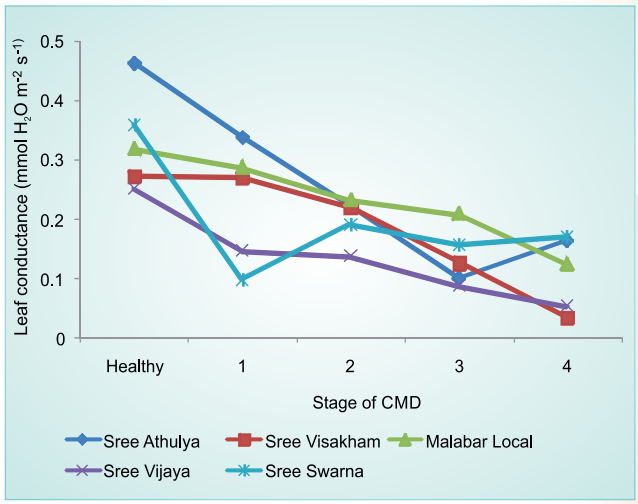


Fig. 79. Changes in leaf conductance of cassava genotypes as affected by CMD

Management of cassava mosaic disease through resistant varieties

Sixty cassava genotypes were screened for CMD incidence and visual scoring was done in a 0-5 range scale. Among the 60 accessions evaluated, 39 were resistant and 21 were susceptible. Cassava samples collected from ICAR-CTCRI were diagnosed for the presence of *Indian Cassava Mosaic Virus* (ICMV) and *Sri Lankan Cassava Mosaic Virus* (SLCMV) through multiplex PCR analysis and the results were in agreement with field screening results. Molecular marker analysis indicated the association of SSRY28 and SSRY44 with CMD resistance of these genotypes.

The pyramiding of different sources of CMD resistance genes was undertaken through marker assisted breeding. The second clonal progeny were evaluated for agronomic traits. The dry matter content of the resistant lines ranged from 8.06% (17S-97) to 47.70% (17S-2). The promising CMD resistant clones are 17S-146 (41.30%), 17S-20 (44%), 17S-39 (44.10%), 17S-241 (45.40%) and 17S-2 (47.70%). Fifty seven clones produced medium yield (5-9.90 kg plant^{-1}), 29 clones high yield (10.0-15 kg plant^{-1}) and 12 clones very high yield (>15 kg plant^{-1}). Highest yield per plant was recorded in 17S-148 (21 kg) followed by 17S-365 (20 kg), 17S-40 (19 kg), 17S-278 (17 kg) and 17S-101 (16.90 kg). Excellent culinary quality was observed in 17S-2, 17S-48, 17S-36, 17S-43, 17S-106, 17S-180, 17S-365 and 17S-209. The promising clones, 17S-143. 17S-347, 17S-322 and 17S-248 were selected (Fig. 80).

Fig. 80. Promising CMD resistant clones of cassava

Amplification of *MeNAC* family genes in cassava infected by *Cassava mosaic virus*

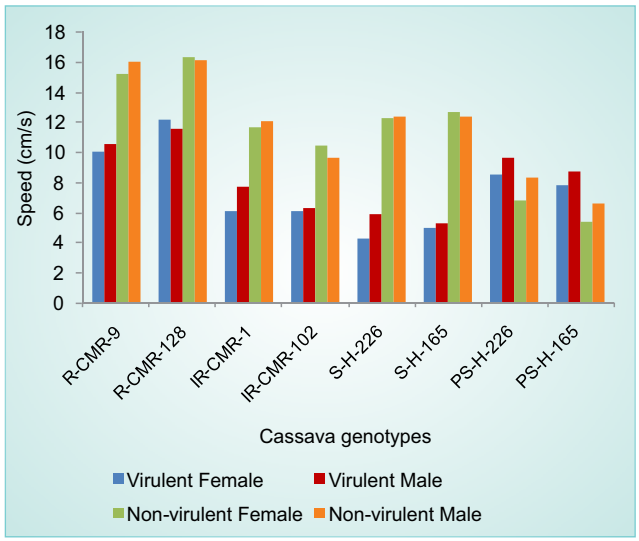
Analysis of *Cassava mosaic virus* infected transcriptome datasets revealed that 19 out of 36 SNAC genes were induced under virus infection. Among 19 SNAC genes, eight genes (*MeNAC22*, *MeNAC28*, *MeNAC61*, *MeNAC62*, *MeNAC63*, *MeNAC75*, *MeNAC79*, and *MeNAC121* displayed more than two fold induction during virus infection than the control plants.

Virus - vector relationship and vector management

Bioinformatic analysis (QIIME and MG-RAST) of endosymbionts in whitefly populations showed variations in *Enterobacteriaceae* (important bacteria in endosymbiont-virus interaction studies) based on samples from different agroecological zones (85.01% in plains and 8.34% in hilly zones).

Study on dispersal and settling pattern of *Bemisia tabaci* in six different cassava genotypes indicated that fastest movement was observed in non-virulent female in resistant cassava genotype CMR-128 (16.25 cm s^{-1}) and slowest was in susceptible genotype H-226 (4.28 cm s^{-1}) by virulent female (Fig. 81). The difference in speed of movement between virulent and non-virulent insects; male and female and cassava genotypes was significant.

Study on feeding pattern of *B. tabaci* in six different cassava genotypes showed that for virulent female, the highest number of stylet sheaths (Fig. 82) were observed and it was in susceptible genotype, H-226 (65) and lowest was for virulent female fed on resistant cassava genotype CMR-128 (2.67) (Fig. 83).



R-Resistant, IR-Infected but recovering, S-Susceptible, PS-Purposefully virus infected susceptible. Average of one week observations using ten insects (Unit-cm/s)

Fig. 81. Dispersal and settling pattern of *Bemisia tabaci* on different cassava genotypes

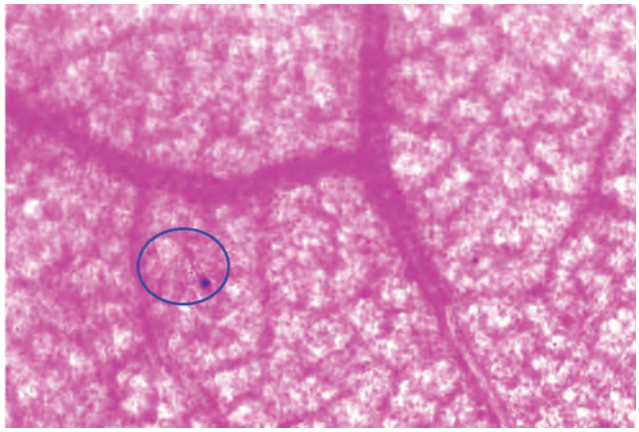
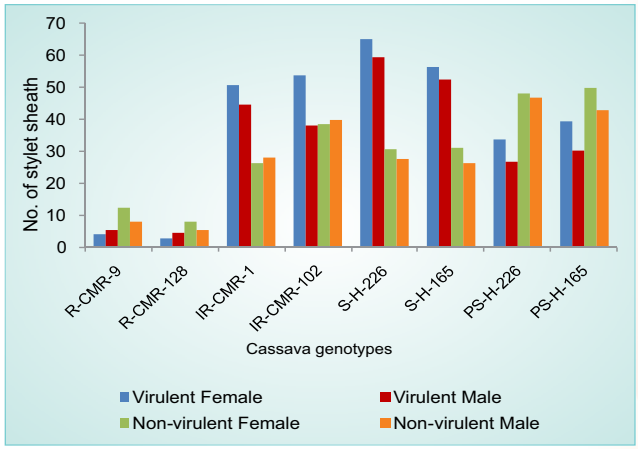


Fig. 82. Stylet sheath of *Bemisia tabaci* in cassava leaves



R-Resistant, IR-Infected but recovering, S-Susceptible, PS-Purposefully virus infected susceptible. Average of observations using ten insects. Unit - Number of stylet sheaths per plant

Fig. 83. Feeding pattern of *Bemisia tabaci* on different cassava genotypes

The feeding pattern between virulence and non-virulence, sex of the insect and different cassava genotypes were significantly different. Significant interaction effect was observed between virulence and non-virulence and different cassava genotypes. There were no significant interactions observed between factors, virulence and sex; sex and cassava genotypes; and all the three.

Integrated management of cassava mosaic disease

Field experiment on the effect of micronutrients on cassava mosaic disease in cassava variety Mulluvadi depicted significant reduction in CMD symptom expression from 70.50% at sprouting to 39% at 6 MAP with nutrients in the order as Phosporous (P)<Boron (B)<Zinc (Zn)<Silicon (Si)<Calcium(Ca). The disease severity in P, B, Zn, Si and Ca applied treatments were 46.27, 51.45, 54.55, 56.64 and 57.35% respectively, whereas the tuber yield were 59.91, 58.38, 55.27, 52.25 and 47.25 t ha^{-1} in Ca>Zn>P>B>Si respectively. A pot study conducted with H-165 using plant nutrients indicated the reduction in disease intensity from 95% at sprouting to 9.20% at 8 MAP with nutrients in the order Ca<P<Zn<K<Si and Mg, with mean values as 31, 31.20, 32.10, 33.60, 34.20 and 34.60% respectively (Fig. 84).

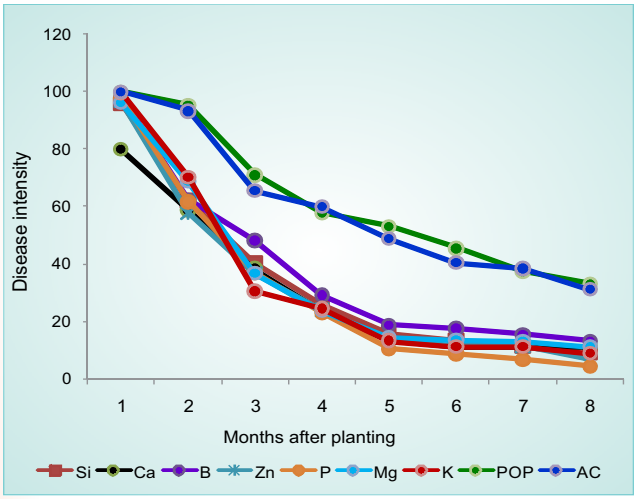


Fig. 84. Role of micronutrient in reduction of CMD over eight months period

In the disease free cassava production, cassava mosaic virus free planting materials of cassava varieties viz., Sree Vijaya (4500 stems) and Sree Jaya (3500 stems) were produced and indexed for virus. The rate of re-infection of cassava mosaic virus was recorded by planting virus free cassava in the varieties, Sree Vijaya and Sree Jaya. The disease incidence was nil up to two months and it was 8 and 10% at third month and 17 and 19% at fourth month and 39 and 43% at eighth month after planting respectively. Planting of virus infected cassava materials showed that the virus symptoms were noticed at first month itself and the disease incidence was 19 and 22% at second month, whereas it was 38 and 41 at third month, 44 and 53 at fourth month and 73 and 86% at eighth month after planting the varieties, Sree Vijaya and Sree Jaya respectively.

Production of synthetic seed in cassava

Short/medium-term storage of cassava synthetic seeds was studied. The shoot tips and nodes containing axillary buds from *in vitro* grown cassava variety, H-226 were encapsulated with 3% sodium alginate polymerized in 100 mM calcium chloride. These synthetic seeds were sealed aseptically under a laminar flow chamber in sterile (autoclaved) polythene bags (Fig. 85) and were subjected to short/medium-term storage studies at room temperature (25±2°C). Stored synthetic seeds were sown *in vitro* at seven days intervals up to 63 days and 70.51% sprouting and optimum growth of the plants from 42 days stored synthetic seeds were observed (Fig. 86). After 63 days of storage, a total of 23.08% sprouting with very slow growth of the *in vitro* plants were observed. Hence, cassava synthetic seeds could be stored up to 42 days at room temperature. This protocol facilitates the easy exchange of genetic material among the researchers and also between the nations.

Fig. 85. Cassava synthetic seeds sealed in sterile (autoclaved) polythene bags

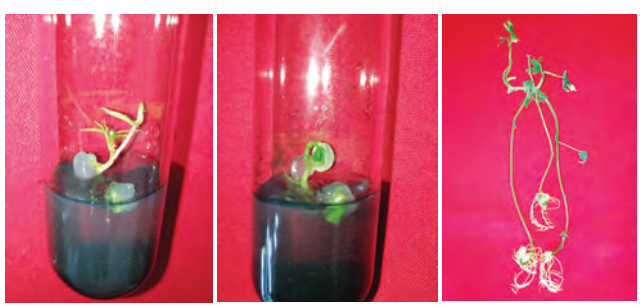


Fig. 86. *In vitro* sprouting of stored cassava synthetic seeds

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

Development of value added food products from tuber crops

Development of functional pasta from cassava based composite flour with modified starch as binder

Functional pasta was developed from the composite flour containing cassava flour, maida and soy flour along with the modified starch, octenyl succinylated cassava starch containing high resistant starch. The proximate composition, physical, textural, functional/ cooking characteristics and *in vitro* starch digestibility of the pasta were studied. The dietary energy for functional pasta was 315.70-407.20 kcal and for control pasta it was 349.30 kcal. The glycemic index (48-54) was lower than that of the control (54.60). The toughness and firmness of the cooked pasta were on par with those of the control.

The optimized conditions were as follows: 62.47% cassava flour, 19.76% maida, 5% modified starch and 7.75% soy flour. The resulting pasta had the following characteristics: starch 72.11%, sugar 6.63%, protein 7.41%, fat 1.61%, fibre 1.09%, moisture 4.96%, cooking loss 11.28%, swelling index 1.47%, total colour difference 26.21%, yellowness index 32.48%, energy value 363.9%, glycemic index 53.28 and firmness 49.81 g for cooked pasta.

Development of pasta from sweet potato based composite flour with low cost protein sources

Sweet potato-green peas pasta

Pasta was prepared from the composite flour containing sweet potato flour (50-65%), maida (20-30%), green peas (10-15%) and cassava starch (5%) (Fig. 87). The protein content varied from 7.50 to 9.10%, however for the control sample, it was 7.60%. Cooking loss was higher and it ranged from 13.95-16.18%, however it was 8.84% for the control sample.

Sweet potato-Bengal gram flour

Pasta was prepared from the composite flour containing sweet potato flour (50-65%), maida (20-30%), Bengal gram (10-15%) and cassava starch (5%) (Fig. 87). The biochemical properties, which included moisture, starch, sugar, protein, fibre and fat content and the cooking qualities like cooking time, cooking loss and swelling index were analyzed. The moisture (8.39-9.84%) and starch (54.20%-66.30%) contents of the developed pasta were significantly higher than that of the control sample (6.54% and 54.50%, respectively).

Sweet potato-casein pasta

Pasta was prepared from the composite flour containing sweet potato flour (60-70%), maida (20-30%), casein (5-10%) and cassava starch (5%) (Fig. 87). The starch, sugar and moisture contents of sweet potato-casein pasta were significantly greater than those of control pasta. The fat content (3.45 to 3.97%) was also significantly higher when compared to the control sample (1.85%). The protein content increased significantly from 7.60% for control pasta to 9.27-15.10% for the sweet potato casein pasta. Cooking loss was more (10.75% to 15.40%) than that of the control pasta (5%). The swelling index (1.29 to 1.65) was significantly lower than that of control sample (2.03), while there was no noticeable change in the cooking time.

Fig. 87. Sweet potato based composite flour pasta with low cost protein sources (a) green peas (b) Bengal gram (c) casein

Cassava-beetroot pasta

Functional pasta was developed from the composite flour containing cassava, maida, beetroot powder, whey protein concentrate and pre-gelatinized starch (Fig. 88). The starch (60.48 to 64.21%) and sugar (9.34 to 9.52%) in the samples were significantly higher than those of the control pasta (51.42% and 6.66%, respectively). Protein content was slightly higher than that of the control sample (11.55%), but not much variation was observed in the fat and fibre contents. The cooking time was lower and cooking loss was higher when compared to control.

Fig. 88. Pasta made from cassava-beetroot based composite flour (a) along with control (b)

Cassava-beetroot noodles

Functional noodles were developed from the composite flour containing cassava, soy flour as protein source, maida and beetroot powder (Fig. 89). The nutritional and cooking characteristics of the noodles were analyzed. Starch content in the noodles varied from 52.94 to 69.23%, however, in most of the samples, it was lower than that of the control (58.82%). Protein content varied from 8.05 to 13.30%, however, in most of the cases it was lower than that of the control (11.21%). There was a significant increase in fibre content (1.07 to 2.31%) when compared to control (0.76%).

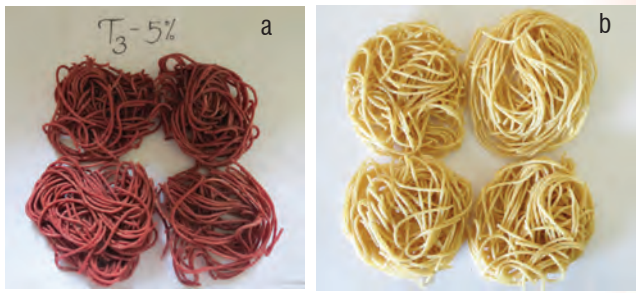


Fig. 89. Noodles from cassava-beetroot based composite flour (a) along with control (b)

Refinement of machineries for cultivation and processing of tuber crops

Production of high quality cassava flour by static pressing methods

A study was undertaken to produce high quality cassava flour (HQCF) by static pressing method in order to reduce the drying time of the tubers so that the quality of the flour will not be adversely affected. Different parameters used for the study were weight of the slices, pressure and pressing time. The moisture content was reduced from 63.80% for control to the range of 39.50 to 55.20% for the pressed cassava slices (Fig. 90). The starch loss due to pressing was very less and was in the range of 0.98 to 2.58%. The starch content in the HQCF was in the range of 64.30% to 81.81% and for the control flour, it was 64.28%. The solubility (2.87-8.06%) was lower and swelling power (0.50 to 1.52 g g^{-1}) higher for HQCF than those of the control flour (8.82% and 0.53 g g^{-1}, respectively). The whiteness index of cassava flour (89.85 and 88.83) was slightly higher than that of the control flour (87.09). Peak viscosity (1791-2926 cP) was higher than that of the control flour (1610 cP). The storage modulus and loss modulus were significantly less than that of the control. The optimized conditions for the production of HQCF were as follows: pressure-44.63 bar, pressing time- 24.13 s and loading weight-1312 g.

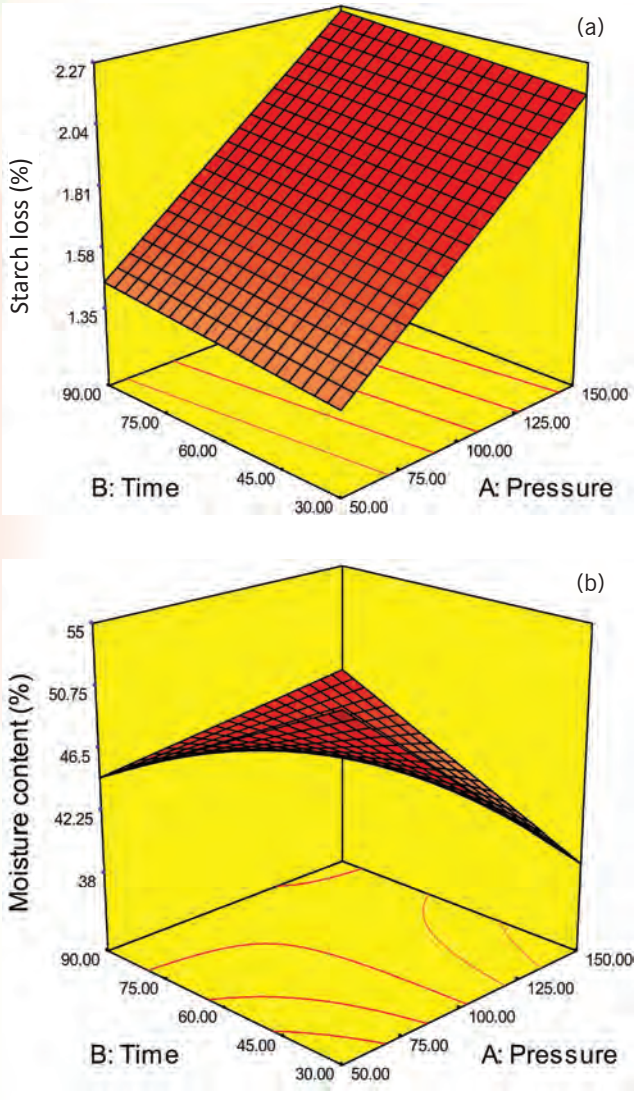


Fig. 90. Starch loss and moisture content after static pressing of cassava slices

Particle boards and adhesives from cassava by-products and starch

Particle board from cassava stems using cassava starch and wax

Cassava stem based particle boards were made with cassava starch as binder at a temperature of 100°C by varying concentrations of starch, wax, glycerol and pressure of moulding. The thickness of the boards ranged from 4.30 to 6.93 mm and density from 822 to 975 kg m^{-3}. The amount of water absorbed by the board after 2 h soaking ranged from 8.64-79.83%, whereas after 24 h of soaking, it was in the range of 44.29% to 106.65%. The modulus of rupture varied from 4.43 N mm^{-2} to 9.55 N mm^{-2}. The optimised conditions for the preparation of particle board with cassava starch, glycerol and wax were 5% starch, 5% glycerol, 6% wax and 120 bar pressure. This board has a density of 949 kg m^{-3}, moisture 12.45%, water absorption after 2 h 15.98%, water absorption after 24 h 75.42%, colour value 'L' 61.19, 'a' value 6.68, 'b' value 23.48 and modulus of rupture 6.39 N mm^{-2}.

Cassava stem based particle board using crosslinked starch as binder

Cassava stem based particle boards were made with crosslinked cassava starch as binder at a temperature of 100°C and pressing time of 7 min. The maximum thickness of 7.62 mm was obtained for the board made with 60 bar pressure, 10% starch and 10% glycerol. The optimised conditions for the production of particle boards which have properties in accordance with the approved BIS standards were as follows: starch-15%, glycerol-12.44% and pressure-46.86 bar and these boards have thickness 6.78 mm, density 911 kg m^{-3}, moisture content 8.88%, total colour difference 37.60, yellowness index 44.44, water absorption after 2 h 17.33%, water absorption after 24 h 127.60% and thickness swelling 17.68%.

Studies on postharvest physiological deterioration of cassava to enhance shelf life of storage roots

Four different types of waxes viz., paraffin, carnauba, microcrystalline (MC) and candellila waxes were tested for their suitability for surface coating of cassava roots to enhance the shelf life. Cassava tubers of 12 different cassava varieties/genotypes, in which proximal and distal ends were cut in order to simulate the wounding in actual harvesting, were used for the study. Coating with carnauba and candellila waxes became hard and brittle after drying. Paraffin and microcrystalline waxes were more suitable for the coating of tubers. The tubers could be stored without any PPD symptoms up to 2 weeks by this treatment and no significant effect of genotypes/varieties was observed.

Highest starch content was recorded in Sree Sahya roots coated with MC wax (75.10%) at 8 days after treatment and lowest of 45% in the control roots of CR-43-2 at 8 days after storage. Maximum sugar content was in candellila wax and MC wax (4.94, 4.83%) respectively and lowest in paraffin wax coated roots (3.83%). The low starch content in PPD affected roots were attributed to both primary physiological deterioration as well as microbial damage. The starch and sugar contents were negatively correlated with PPD symptom in control and wax treated roots at 8 days after storage (Fig. 91).

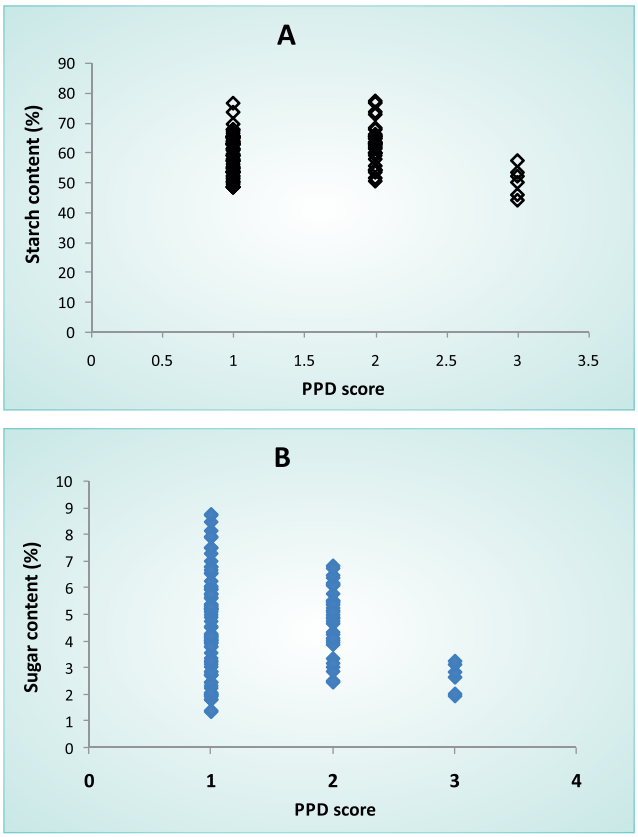


Fig. 91. Starch and sugar content in cassava tubers treated with different waxes in relation to PPD scores on storage

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

Sago (Sabudana) is a processed edible starch marketed in the form of small globules or pearls and it is an easily digestible food product. It is mainly used during festive season and as thickener in several food preparations. Sago is not a balanced food for human consumption as it is deficient in protein and vitamins. To overcome this problem, functional sago was made using functional ingredients, namely beetroot powder and sweet potato leaf powder. The maximum incorporation level of the functional ingredients viz., beetroot powder and sweet potato leaf powder (Fig. 92) was optimized as 6% for sago production from reconstituted dry starch, wet starch and in combination of dry and wet starches.

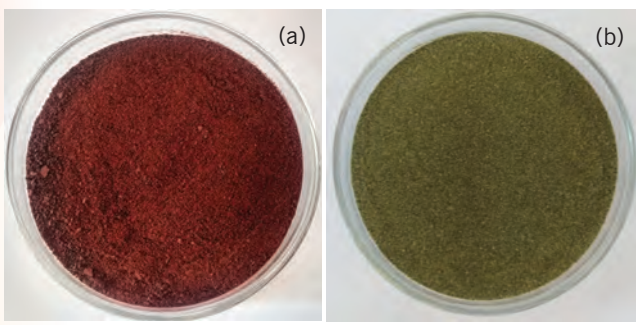


Fig. 92. (a) Beetroot powder and (b) sweet potato leaf powder

Functional sago from beetroot powder

The antioxidant activity and dietary fibre contents of the sago could be improved by the incorporation of beetroot powder (Fig. 93a). The total phenolic content (0.03 g g^{-1}) and antioxidant activity (IC_{50}- 39.13 mg) was maximum for the sago prepared from 94% reconstituted dry starch and 6% beetroot powder. The maximum resistant starch content of 19.46% was obtained for the sago prepared from 100% wet starch, whereas the total dietary fibre content was greater for the sago prepared from reconstituted dry and wet starches (94%) and beetroot powder (6%). The slowly digestible starch (SDS) and resistant starch (RS) contents were more in the sago prepared using beetroot powder.

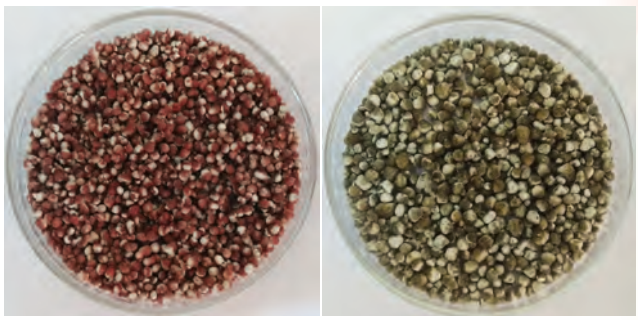


Fig. 93. Functional sago prepared using (a) beetroot powder and (b) sweet potato leaf powder

Functional sago from sweet potato leaf powder

Based on the functional dietary fibre and resistant starch contents, sago made from reconstituted dry starch (94%) and sweet potato leaf powder (6%) was found to be the best (Fig. 93b). The dietary fibre content and *in vitro* antioxidant activity were comparatively higher in the functional sago made using sweet potato leaf powder.

Production of biochar from agricultural biomass and nutrient and biological enrichment

The effect of biochar on soil fertility and tuber yield of two sweet potato varieties, Sree Arun and Sree Kanaka, grown in pots was investigated under well irrigated and water deficit (WDS) conditions (Fig. 94). Plant growth, leaf area, leaf chlorophyll content, leaf gas exchange, chlorophyll fluorescence kinetics and tuber yield were assessed. Soil organic carbon, enzyme activity and nutrient content were positively

influenced by biochar application. Application of biochar at 2% and 5% soil dry weight basis did not alter the soil pH. The organic carbon, calcium and potassium contents of the soil improved markedly with biochar application (Fig. 95). Soil microbial activity parameters such as soil dehydrogenase activity (DHA) and soil acid phosphatase activity (SPA) were positively influenced with biochar application.

Net photosynthetic rate (P_n) increased significantly with 2% biochar application in both varieties (Fig. 96). Tuber fresh and dry weights significantly increased with biochar application in both WDS and well irrigated conditions (Fig. 97). Under WDS stress conditions, tuber dry weight increased by 47.60% and 65.90% for Sree Arun and 28.70% and 5.40% for Sree Kanaka at 2% and 5% biochar application over control.

Fig. 94. Control and water deficit stress (WDS) of sweet potato varieties, Sree Arun and Sree Kanaka with zero, 2% and 5% biochar application

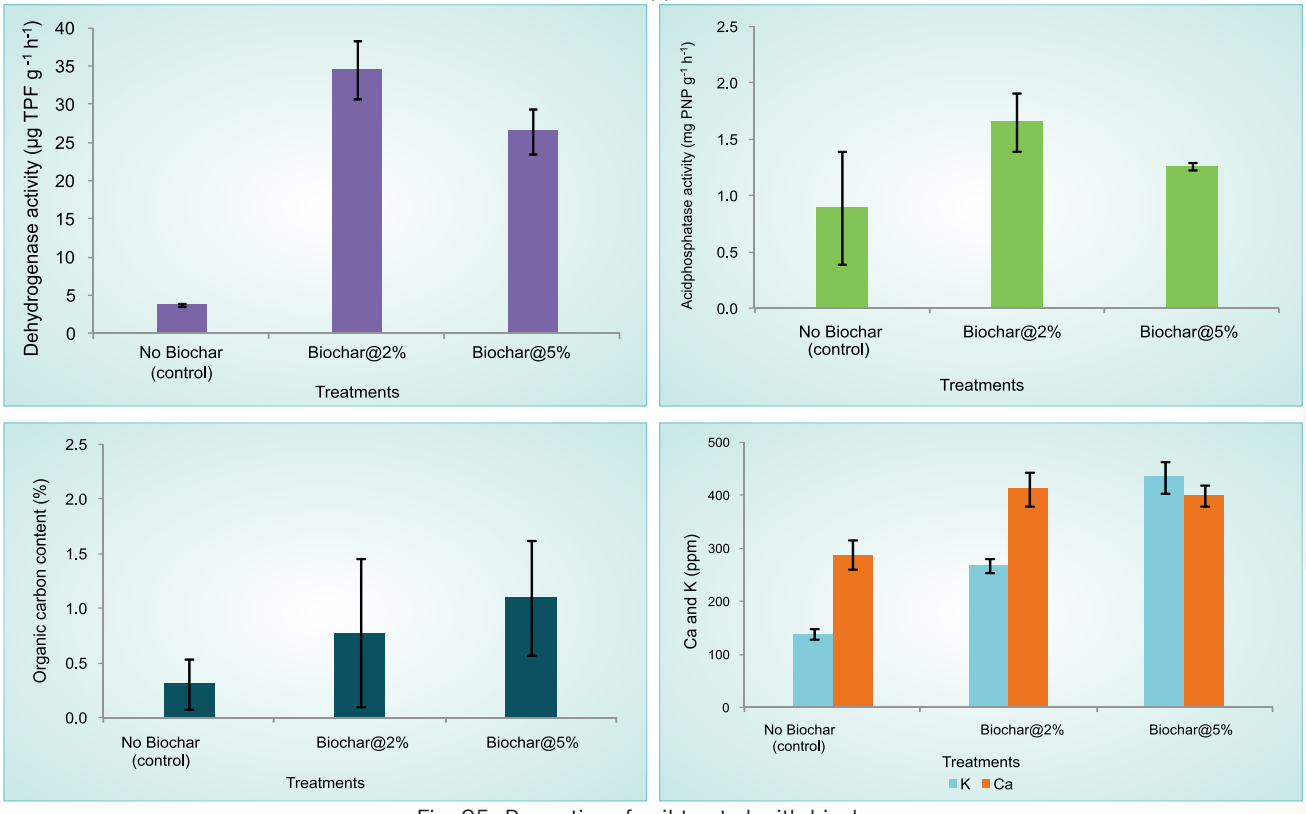


Fig. 95. Properties of soil treated with biochar

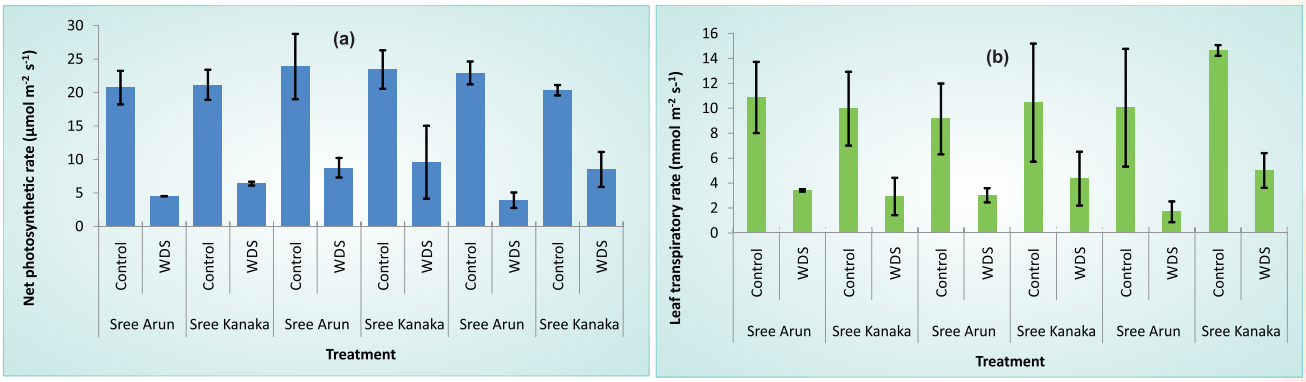


Fig. 96. Changes in (a) net photosynthetic and (b) leaf respiratory rate in control and water deficit sweet potato varieties with biochar application

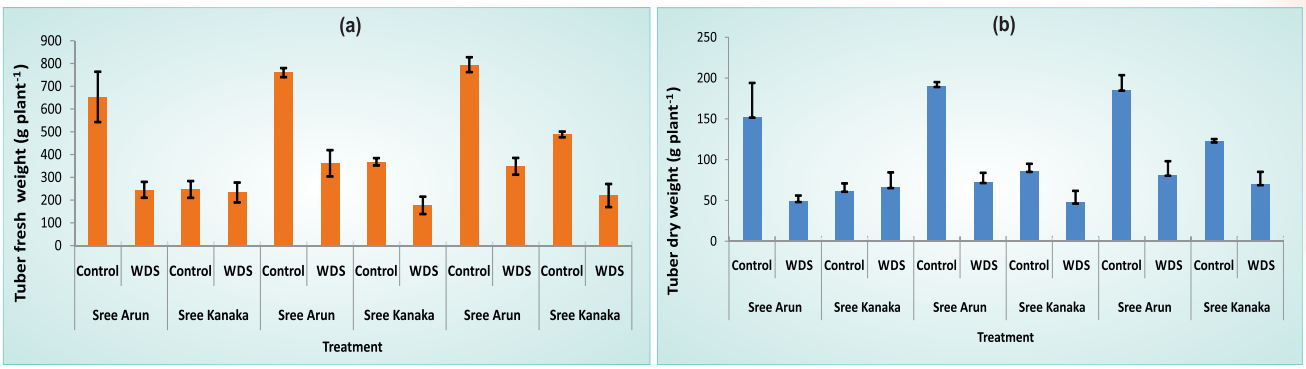


Fig. 97. Tuber fresh weight and dry weight in control and water deficit sweet potato varieties with biochar application

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 sheet from cassava starch-wax composites

Thermoplastic sheets were developed from cassava starch-wax composites by adding glycerol as plasticizer and the process conditions were optimized. At 65% of relative humidity, moisture sorption isotherm was in the range of 0.97 to 24.15% and it increased with increase in humidity. The highest ultimate tensile strength of 4.758 N mm^{-2} was obtained for the sheet made at 140°C and 140 bar with 40% glycerol and 5% wax and the highest % elongation (32.91%) was for the sheet made at 140°C and 120 bar with 30% glycerol and 10% wax. The optimised conditions were as follows: temperature 130°C, pressure 140 bar, glycerol content 36.61% and wax content 5%. At these conditions, the TPS sheet had a moisture content of 7.06%, density 1237 kg m^{-3}, total colour difference 48.34, yellowness index 27.19, expansion index 67.99%, solubility 7.58%, hygroscopicity 12.95%, 24.21% and 27.95% at 75%, 85% and 95% RH levels respectively, water activity 0.509, ultimate tensile strength 3.118 N mm^{-2} and peak load 52.86 N (Fig. 98).

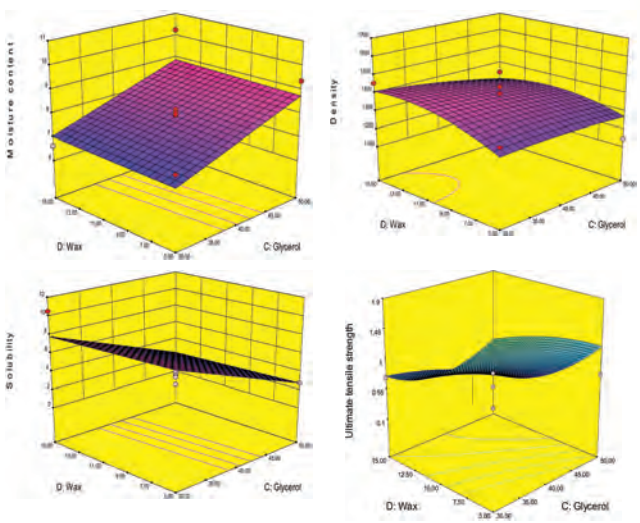


Fig. 98. Properties of thermoplastic sheets made from cassava starch-wax composite

Thermoplastic sheet from oxidised cassava starch

Thermoplastic sheets (TPS) were developed from cassava starch oxidised with sodium hypochlorite

and the process conditions were optimized. Tensile strength ranged from 0.29 N mm^{-2} to 0.66 N mm^{-2} and elongation from 10.82 to 16.65%. The maximum elastic modulus of the sheet was observed as 25898 N m^{-1}. The optimised conditions for the production of sheet was as follows: temperature 117.12°C, pressure 110 bar and glycerol 22.64%. The resulting sheet has the following properties: thickness 1.35 mm, density 1214 kg m^{-3}, moisture content 13.44%, expansion index 34.50%, solubility 16.48%, total colour difference 34.18, yellowness index 19.41, water activity 0.627, and hygroscopicity of 9.18%, 18.11% and 26.40% respectively at 75%, 85% and 95% relative humidity levels.

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

Synthesis and characterization of RS4 type resistant starches by chemical modification with citric acid

The effect of chemical modification with citric acid on the physico-chemical properties and formation of resistant starch in five diverse starches viz., potato, cassava, sweet potato, banana and lentil were studied. The crystalline pattern and granule morphology did not show substantial changes due

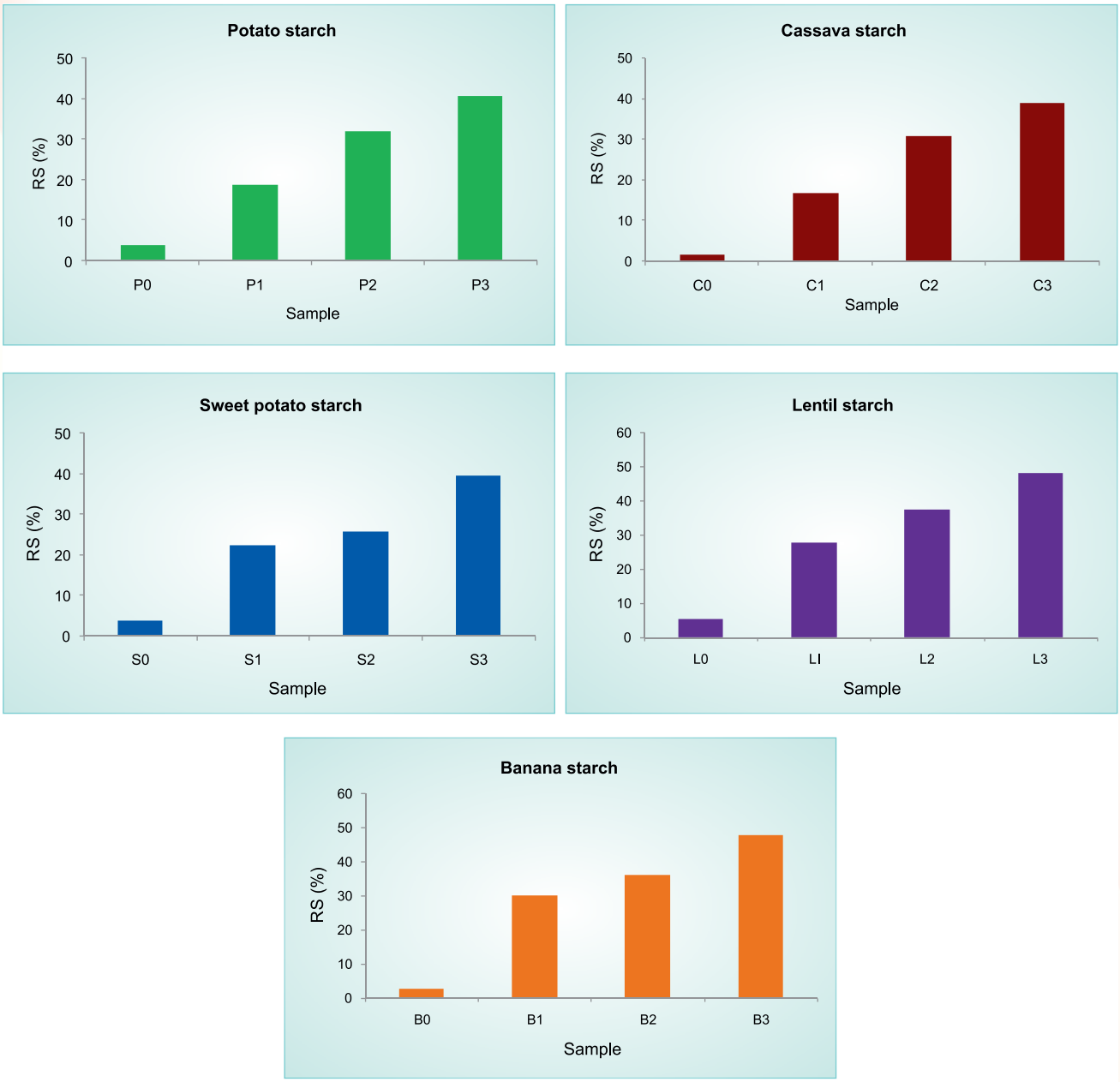


Fig. 99. Resistant starch content in different starches before and after modification

to modification, however, there was alteration in relative crystallinity depending on the starch source. The modified starches exhibited increased water binding capacity, weak gel properties and flat pasting curves in the RVA profile.

There was a significant increase in the slowly digestible starch (SDS) and resistant starch (RS) contents in all starches after modification, with a corresponding decrease in estimated glycemic index (EGI). Lentil and banana starches showed higher RS content after modification when compared to tuber starches (Fig. 99). The EGI decreased from 91.30% for the native starch to 59.40% for the modified cassava starch and from 86.30% for the native starch to 59.60% for the modified sweet potato starch. Eventhough the glycemic index of native starches of potato, cassava and sweet potato were different, after modification all of these exhibited EGI values, which were on par. However, lentil and banana starches showed even lower values of glycemic index (55.80 and 55.60%, respectively).

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

Standardisation of process for production of functional pasta

Dry pasta is a traditional cereal based food that has become increasingly accepted worldwide for the reason of its convenience, palatability and nutritional superiority. Functional pasta was prepared from elephant foot yam flour, suji and finger millet flour and the process conditions were optimized using response surface methodology (Fig. 100). The proximate composition of pasta was analysed. The protein content ranged from 10.33 to 15.62%, fat content from 1.92 to 2.30%, starch content from 33 to 40% and sugar content from 1.95 to 3.32%. The iron and calcium contents were 3.15 to 5.80 mg $100g^{-1}$ and 320 to 390 mg $100g^{-1}$, respectively. The process for production of pasta from sweet potato-pseudo millet based composite flour was standardized. The flours used were sweet potato flour (55%), millet flour (15%), maida (30%) and starch (5%) along with quinoa and buckwheat flour.

Sensory evaluation for overall acceptability (colour, texture, aroma and taste) and cooking qualities such as cooking time, solid loss and rehydration ratio of the pasta prepared from sweet potato-pseudo millet based composite flour was carried out. The cooking time of pasta was in the range of 4.25 to 5.10 min. The solid loss varied from 4.56 to 8.20% and rehydration ratio from 1.70 to 2.45.

Ready-to-cook sweet potato based paratha mix

The recipe for ready-to-use paratha mix from sweet potato flour was standardized (Fig. 101). The

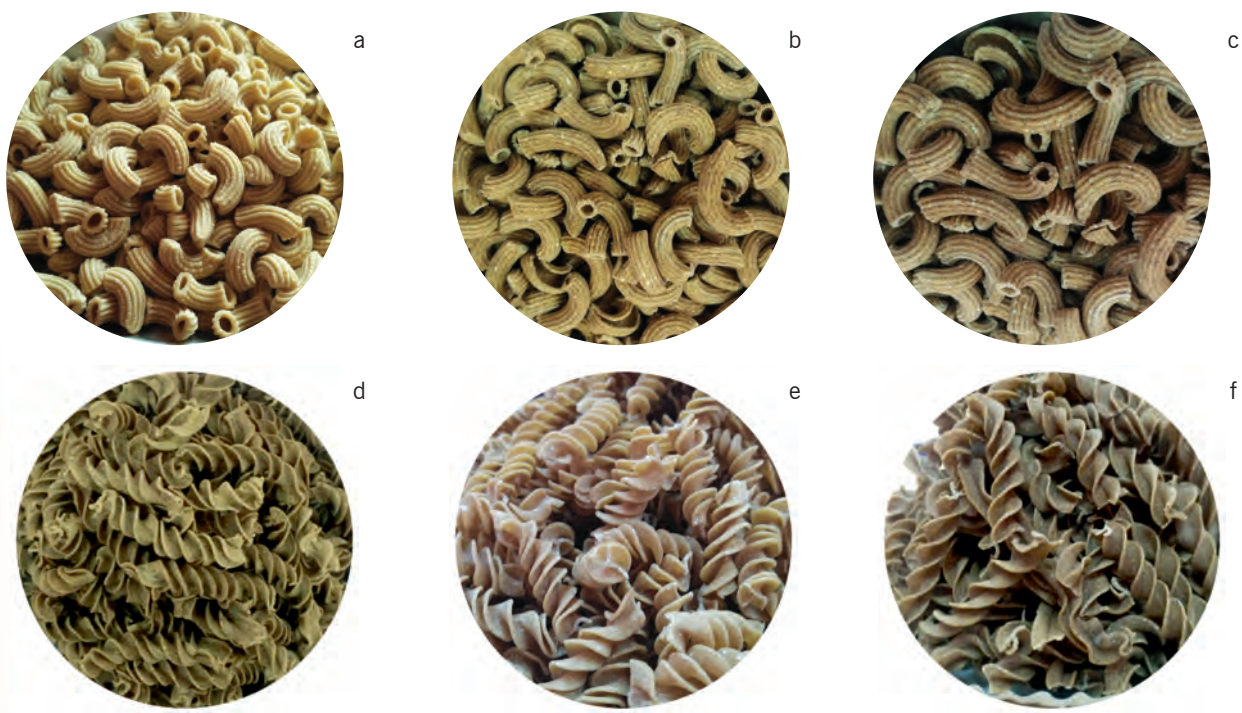


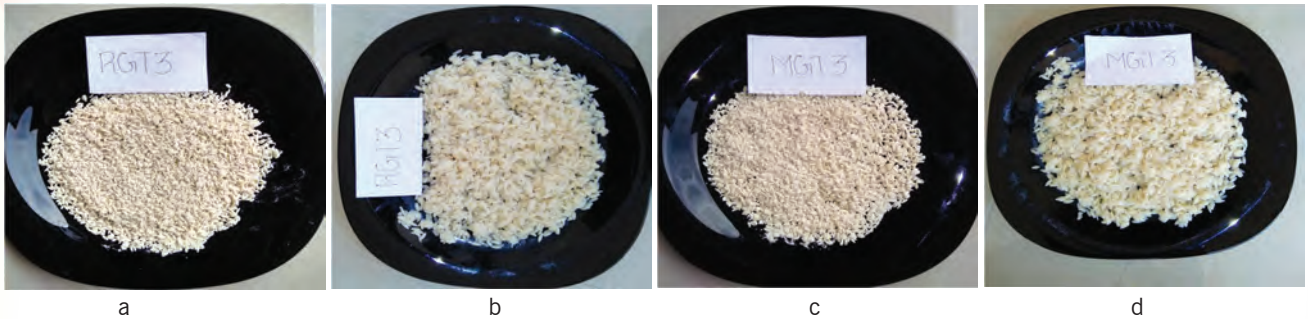
Fig. 100. Pasta made from sweet potato-quinoa based composite flour (a to c); Pasta made from sweet potato-buckwheat based composite flour (d to f).

optimized composition was sweet potato flour-50%, millet flour-15%, multigrain flour-30% and dried spices-5%. Sensory evaluation for colour, texture, aroma, taste and overall acceptability of paratha was carried out.

Fig. 101. Sweet potato flour based paratha mix

Rice analogue from cassava based composite flour

Rice analogue was prepared from the composite flour containing cassava flour (45-60%), rice flour/ maida (25-40%) and guar gum (0-0.5g) (Fig. 102). In addition, 5% gelatinized starch and 10% whey protein concentrate were also added to the dry mix. The starch and sugar contents varied from 57.69% to 66.66% and 3.67% to 4.03% respectively for different treatments. The crude protein content was greater in the rice analogues prepared with higher concentration of rice flour. Crude fibre, ash and crude fat contents, cooking qualities such as swelling index and cooking loss also were determined for various samples. The rice analogue prepared from the composite flour containing cassava-maida-whey protein concentrate-guar gum was more acceptable by sensory evaluation.



a b c d

Fig. 102. Rice analogue from cassava based composite flour with rice and guar gum [(a) raw and (b) cooked]; Maida and guar gum [(c) raw and (d) cooked]

EXTENSION AND SOCIAL SCIENCES

Developing Methodologies and Tools for Assessment and Transfer of Tuber Crops Technologies

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

Technological interventions in tuber crops

Demonstrations on improved varieties of cassava, sweet potato, taro and Chinese potato, integrated management of pseudostem weevil of banana and mealybug in cassava using cassava based bio-formulations were established in Tamil Nadu, Kerala, Meghalaya and Arunachal Pradesh involving 35 farmers for proving the technical feasibility and economic viability of the improved technologies. Farmers were trained to adopt scientific crop management practices. Pests and diseases viz., mealy bug, spiralling white fly and cassava mosaic disease, sweet potato weevil and leaf eating insects in sweet potato and sucking insects and nematode in Chinese potato were controlled with integrated pest, disease and nematode management practices.

Front line demonstrations on improved cassava varieties

Fifteen frontline demonstrations on improved varieties of cassava viz., Sree Jaya, Sree Vijaya, Sree Swarna, Sree Pavithra, Sree Athulya and Sree Apoorva were established in Kanyakumari, Salem and Namakkal districts of Tamil Nadu (Fig. 103).

Front line demonstrations on improved varieties of cassava conducted at Kanyakumari district of Tamil Nadu revealed that Sree Pavithra produced the highest yield (36.50 t ha^{-1}) followed by Sree Swarna (34.50 t ha^{-1}), Sree Jaya (33.00 t ha^{-1}) and Sree Vijaya (29.75 t ha^{-1}). Productivity of improved varieties

Fig. 103. Demonstration plots on improved cassava varieties

(32.70 t ha^{-1}) was higher by 14.70% over that of local varieties (28.50 t ha^{-1}). In Salem district, Sree Athulya yielded the highest (38 t ha^{-1}), followed by Sree Apoorva (36.50 t ha^{-1}), Sree Pavithra (35 t ha^{-1}), Sree Jaya (34 t ha^{-1}) and Sree Vijaya (32.50 t ha^{-1}). Yield of improved varieties of cassava (35.20 t ha^{-1}) was higher by 14.70% than that of local varieties (30.70 t ha^{-1}). Demonstrations in Namakkal district showed that Sree Athulya produced maximum yield of 40.50 t ha^{-1}, followed by Sree Pavithra (38 t ha^{-1}),

Sree Apoorva (36 t ha^{-1}), Sree Vijaya (34 t ha^{-1}) and Sree Jaya (33.50 t ha^{-1}). Yield of improved varieties of cassava (36.40 t ha^{-1}) was higher by 17 % than that of local varieties (31.10 t ha^{-1}). Gross income realized from improved varieties of cassava in Kanyakumari, Salem and Namakkal districts were ₹ 2.62 lakhs ha^{-1}, ₹ 2.20 lakhs ha^{-1} and ₹ 2.29 lakhs ha^{-1} in comparison to income obtained from local varieties ₹ 2.14 lakhs ha^{-1}, ₹ 1.92 lakhs ha^{-1} and ₹ 1.96 lakhs ha^{-1} respectively.

Scarcity of skilled labour, non availability of quality planting materials and quality inputs, price fluctuation, lack of awareness about value addition, water shortage, incidence of pests and diseases and attack from wild animals were the major constraints as reported. Overall, the productivity and profitability of cassava farming with improved varieties was higher than the existing local varieties.

Front line demonstration on improved Chinese potato variety

Demonstrations on improved variety of Chinese potato viz., Sree Dhara were conducted at Alvan Thulukapatti in Tirunelveli district of Tamil Nadu (Fig. 104).

Fig. 104. Demonstration plots with Chinese potato (var. Sree Dhara)

Yield of Sree Dhara (26.70 t ha^{-1}) was higher (16.6 %) than the yield of local varieties (22.90 t ha^{-1}). Net income realized from Sree Dhara was ₹ 1.79 lakhs ha^{-1} (B:C ratio: 2.77) in comparison to local varieties, which was ₹ 1.43 lakhs ha^{-1} (B:C ratio: 2.46). The productivity and profitability of improved variety of Chinese potato was higher over the existing local varieties. Harvested tubers were distributed to the neighbouring farmers for establishing seed villages (2 nos.) for meeting the demands of good quality planting materials of improved variety, Sree Dhara in the next season. (Fig. 105).

Fig. 105. Distribution of Chinese potato to farmers (var. Sree Dhara)

Non availability of good quality planting materials of improved varieties, incidence of nematode, price fluctuation, lack of pre and post-harvest machineries for harvesting and grading, unorganized marketing system and attack from wild animals were the major constraints perceived by the farmers of Chinese potato in Tirunelveli district.

Overall, the productivity and profitability of improved varieties of tuber crops were significantly higher than 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.

Cohort analysis on consumption of tuber crops

Fifty farmers were selected using simple random sampling from Kanyakumari district of Tamil Nadu for analyzing the consumption pattern of tuber crops. Data were collected using structured interview schedule and focus group discussions during January 2019 to March 2019. Majority of the farmers (70%) were old aged (>50 years), and all (100%) were literates, 72% had nuclear family, majority (74%) were small and marginal farmers, and 56% were cultivating tuber crops viz., cassava, elephant foot yam and yam.

Rice was consumed frequently (> 2 times per day) by the respondents followed by rice flour, wheat flour, rava, millet flour, bread, noodles and pasta, oats, corn flakes and semiya. The per capita consumption (kg/month) of rice was 5.77 followed by wheat flour (0.92), rice flour (0.72), semia (0.4), rava (0.35), bread (0.23), noodles and pasta (0.19), millet flour (0.08), oats (0.08) and corn flakes (0.05). The age of the respondents was negatively correlated with per capita consumption of rice (-0.484**).

Tuber crop viz., potato was frequently (5-6 per week) consumed by the respondents followed by cassava, sweet potato, greater yam, elephant foot yam and taro. Per capita consumption (kg/month) of potato was 0.56 followed by cassava (0.54), sweet potato (0.26), elephant foot yam (0.22), taro (0.16) and greater yam (0.10) (Fig. 106). Age of the respondents was negatively correlated with per capita consumption of potato (-0.481**) and sweet potato (-0.440 **). Family size was positively correlated with per capita consumption of potato (0.299*), cassava (0.333*) and sweet potato (0.455**) .

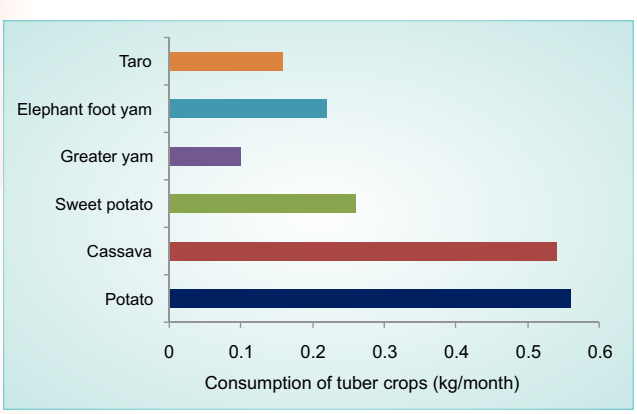


Fig. 106. Per capita consumption of tuber crops (kg/month)

Sustainable livelihood analysis of tuber crops farmers

Sixty elephant foot yam growers and 60 banana growers were selected using snow ball sampling from two districts viz., East Godavari and West Godavari for analyzing the sustainable livelihood of farmers. Data were collected using PRA tools, interview schedule and focus group discussions during August 2018 to January 2019. Livelihood sustainable index was worked out using the DFID methodology.

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

Demographics of elephant foot yam and banana farmers

The elephant foot yam and banana farmers did not differ significantly in most of their socio-economic attributes. The average age of the respondents was below 50 years, with the average household size of 4 to 5 members. More than 50% of the available cultivable land area was used for banana and elephant foot yam cultivation.

However, the household size and farming experience for elephant foot yam and banana growers differ significantly at 10% and 1% respectively. The yield and cost of cultivation for banana was greater than the elephant foot yam and significant differences were observed at 1% level. No significant difference was observed in cost of production and net profits realized from elephant foot yam and banana. The cost of cultivation of banana was ₹ 2.20 lakhs ha^{-1}, whereas for elephant foot yam it was ₹ 1.76 lakhs ha^{-1}. The net profit realized from banana cultivation was ₹ 1.58 lakhs ha^{-1} and ₹ 1.62 lakhs ha^{-1} for elephant foot yam. On an average, the elephant foot yam farmers realized 2.7% greater net profits than the banana growers.

Sustainable Livelihood Index of elephant foot yam and banana growers

Under human capital, the index was higher for education (55) and health (57) for elephant foot yam

farmers, whereas for banana growers, experience in farming (73) and knowledge (62) was more. Labour availability was almost similar for both. Training index was more for banana farmers as they had undergone trainings.

Physical capital index was more or less similar. All the selected villages (100) had electricity, which is an indicator for development. Transport facilities were less (60) in the villages, where elephant foot yam was grown as those were interior. The housing type of banana growers was better than elephant foot yam growers.

Social capital index was more (66) for banana growers, when compared to elephant foot yam farmers (61). Access to agricultural information was more (60) for banana growers, when compared to elephant foot yam farmers (57). Communication facilities were more in the villages, where banana cultivation was done (71).

Financial capital influences the other capitals. The household income was more (69) for banana growers, whereas for elephant foot yam farmers it was 66. The overall financial capital index was more for banana growers (69). These areas needed intervention through credit institutions.

Among the natural capital, the index for ownership of land was more for banana growers (94) as compared to elephant foot yam growers (88). The index for land area owned by elephant foot yam growers was 56, whereas it was 53 for banana growers. The natural capital index was 70 for both the farmers.

The rural livelihood sustainability index for banana growers was slightly higher (69) than the elephant foot yam growers (66). Physical and natural capital indices were more in both the cases. In the order of merit, human capital index was less among all the capitals. The association or similarities of different capitals between elephant foot yam and banana growers is given in Fig. 107. Similarities between capitals of elephant foot yam and banana growers are in the decreasing order with respect to physical, natural, financial, social and human capitals.

Major sources of livelihood as reported by both the farmers were, agriculture, employment in government/ private sector and small business. The vulnerability factors were price fluctuation, crop failure due to weather aberrations and increased labour cost.

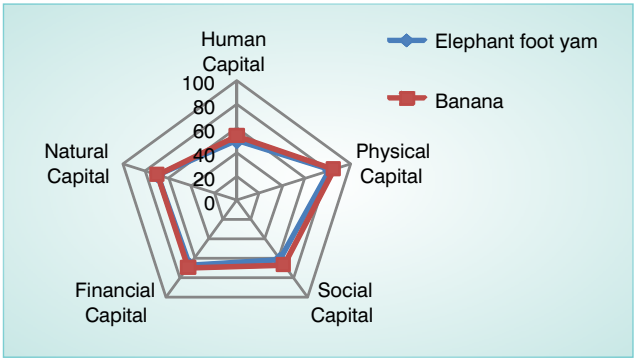


Fig. 107. Livelihood capital asset pentagon for elephant foot yam and banana growers

The trends observed were price rise (input cost), climate change and labour shortage. The constraints perceived by the farmers in elephant foot yam and banana cultivation were ranked based on mean score. The constraint 'non availability of skilled labourers' was ranked first (2.63 mean score out of maximum score of 3) followed by non availability of quality planting materials of improved varieties (2.48), price fluctuation (2.33), interference of middlemen in the market (2.23), weather aberrations (2.12), lack of marketing facilities (2.07) etc. as opined by the elephant foot yam growers. Non availability of quality planting materials (2.53), non availability of skilled labourers (2.48), incidence of pests and diseases (2.43), weather aberrations (2.38), price fluctuation (2.30), interference of middlemen in the market (2.27) etc. were perceived as major constraints in banana cultivation.

Development of ICT applications in tuber crops

Artificial intelligence algorithm was used for developing self learning sweet potato crop growth model. Data of sweet potato variety Sree Bhadra, grown at Regional Centre, ICAR-CTCRI, Bhubaneswar during the three seasons 2013-2014, 2014-2015 and 2015-2016 were used in the study. The crop was planted on 20 September 2013, 21 September 2014 and 20 September 2015 during the first, second and third seasons respectively. The harvest was done on 02 January 2014, 03 January 2015 and 02 January 2016 during the first, second and third seasons respectively.

Independent parameters of the model:

1. Days after planting (DAP)
2. Growing degree days (GDD)
3. Solar radiation (MJ m^{-2} day^{-1})
4. Precipitation (mm)

Dependent parameter:

1. Tuber yield (g plant^{-1})

Predictive analysis of the data was done to develop the model. The code for developing the model was written in python and tensorflow libraries.

The accuracy of the model was tested against the observed values. It was found that the accuracy of prediction increases regularly when more datasets are used for prediction (Fig. 108). This model is ideal one to be used in the IoT device e-Crop. It helps the device to learn about crops from the data collected from the field real-time.

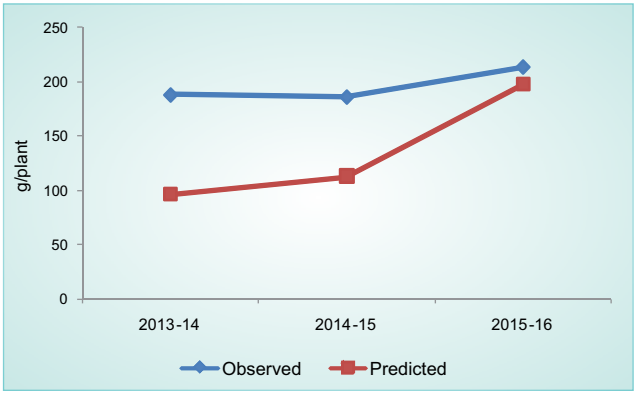
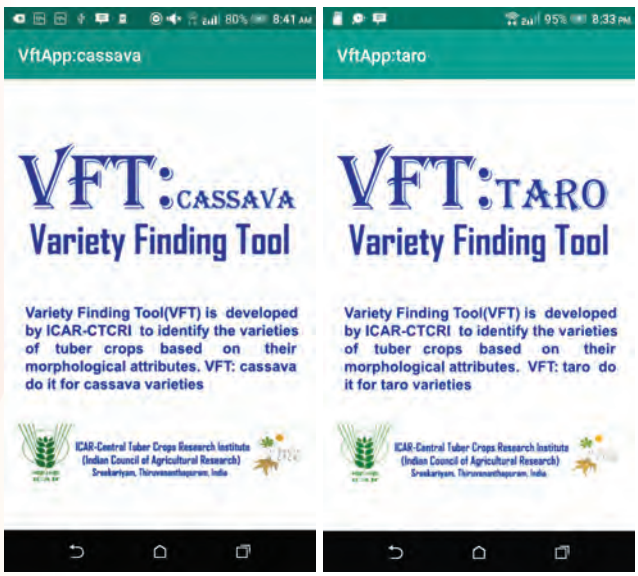


Fig. 108. Comparison of tuber yield observed Vs predicted using self learning model

Developed two mobile apps **VFT:cassava** and **VFT:taro** (Fig. 109) for identifying varieties of cassava and taro respectively from the images of leaves. These apps use the Convolutional Neural Network (CNN) image classification model, which uses deep learning algorithm of artificial intelligence



(a) (b)

Fig. 109. Mobile apps, VFT:cassava and VFT:taro

for classifying the images. CNN image classification model for cassava was developed using the pictures of emerging leaves (top view) of four cassava varieties viz., Vellayani Hraswa, Sree Vijaya, Sree Pavithra and Sree Sakthi. This model was used in **VFT:cassava** mobile app to identify the varieties. Similarly CNN image classification model was developed using leaf images of Muktakeshi and Sree Pallavi varieties of taro and the model was included in **VFT:taro** mobile app to identify taro varieties.

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

R-package for soil quality index (SQI)

R-package was developed, which computes the SQI based on ANOVA and Principal Component Analysis. The number of soil characteristics to be included in the minimal dataset (MDS) and the number of PCAs are the parameters of the function for computation of SQI. The functions sqianova(), sqicorr(), sqipca(), scoring1(), scoring2(), sqi (x, scoring =" ", num_pca= " ", num_MDS=" ") are included in the package. The view of R studio and the front end of the R environment for statistical computing after installation of the package is shown in Fig. 110.

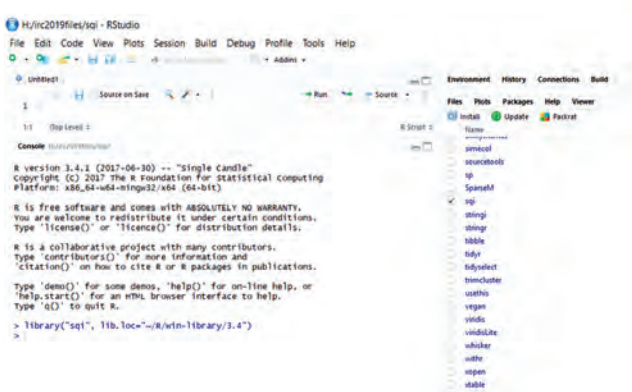


Fig. 110. The front end in R Studio, which displays the installed package SQI

Deep learning methods for prediction of soil parameters

The data for the analysis was obtained from the International Soil Reference and Information Centre (ISRIC), which is a Globally Distributed Soil Spectral Library of Visible Near Infrared Diffuse Reflectance Spectra along with the physical and chemical soil characteristics. Different regression models (Cubist regression tree, Partial Least Square Regression (PLSR)) were applied for prediction of soil properties

such as organic C, cation exchange capacity (CEC), pH and clay using spectral data. Cubist and PLSR models were implemented in R using the packages cubist and PLS. Before training the Cubist and PLS models, the spectral data were pre-processed using a series of methods commonly used in the literature, such as converting reflectance to apparent absorbance (a = −log10(r)), Savitzky–Golay smoothing using a window size of 11, and a second order polynomial, edges trimming (< 500 nm and > 2450 nm) to discard noisy data and applying a standard normal variate transformation. With the calibration sample size of 200, for PLSR model the ranking from the highest to lowest in terms of R^2 were, CEC (R^2=0.83), pH (R^2=0.78) and organic C (R^2=0.70). Using the Cubist model and calibration sample size of 200, the best performance of the model in terms of R^2 were, CEC (R^2=0.78), pH (R^2=0.72) and organic C (R^2=0.68). Simultaneous prediction of soil parameters and application of deep learning techniques are in progress.

Devising stakeholder oriented technology commercialisation strategies: A Comparative assessment

Documentation of technology commercialisation strategies

Currently, India has 1932 agricultural startups, of which agri-tech startups constitute 48% followed by organic agriculture, food processing, dairy farming and others. A survey of agricultural start-ups in India indicated the presence of five categories of agristartups in India: (i) Upstream (input) marketplace start-ups (ii) Downstream (output) farm-to-fork supply chain start-ups (iii) IoT and Big data led innovation start-ups (iv) Engineering-led innovation startups and (v) Farming as a Service (FaaS) startups.

Technologies commercialisation strategies assessment framework

An initial model technologies commercialisation strategies assessment framework was developed for assessing the effectiveness of technology commercialisation strategies of ICAR Institutes/ SAU. This framework follows the entrepreneurial ecosystem model suggested by Isenberg (2011) and specific components were identified through systematic review of published entrepreneurship literature and thematic analysis of open access startup stories. The systematic review was conducted using the method suggested by Tranfield et al. (2003) which were later analysed using thematic analysis to identify broad themes within the framework of the entrepreneurial ecosystem. To investigate pattern of research studies conducted in different regions of India across the entrepreneurship ecosystem domains, a Chi-square analysis was conducted and results are displayed in Table 3.

Table 3. Chi-square analysis of distribution pattern of studies in different regions of India

Entrepreneurship ecosystem domain	Region						
	Multiple states	North India	South India	North Eastern India	Eastern India	Central India	χ^2
Culture 18 (51.43)	3(16.17)	5 (27.78)	8 (44.44)	0 (0.00)	1 (5.56)	1 (5.56)	53.737**
Support 9 (25.71)	6 (66.67)	2 (22.22)	0 (0.00)	0 (0.00)	1 (11.11)	0 (0.00)	
Finance 3 (8.57)	2 (66.67)	1 (33.33)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	
Policy 1 (2.86)	0 (0.00)	0 (0.00)	0 (0.00)	1 (100)	0 (0.00)	0 (0.00)	
Human Capital 2 (5.71)	0 (0.00)	2 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	
Total 35	12 (34.29)	11 (31.43)	8 (22.86)	1 (2.86)	2 (5.71)	1 (2.86)	

** Significant at 1% level

The Pearson Chi-square was significant indicating that the pattern of research work conducted on different entrepreneurship domains across various regions of India were different (X^2 = 53.737; $p<0.01$). Among the entrepreneurial ecosystem domains, about half of the papers (51.43%) focused on cultural domain, followed by support (25.71%). Over half of the papers in the support, finance and other domains were pan-India studies. In the cultural domain, over one-third of works were conducted in south India (44.44), while all works on human capital and policy were conducted in north and north east India respectively. Most of the support system studies were conducted on pan India level (66.67%), with a significant number in north India (22.21%). Under the finance domain, a large number (66.67%) focused on multi-states, while the rest were conducted in north India (33.33%). The only study on policy domain was from north eastern India.

This trend indicates that the entrepreneurship is still confined to preliminary stages to understand, what drives entrepreneurship decision among youth. In the cultural domain, the studies focused on the demographic, psychological and socio-cultural factors creating entrepreneurial intention and determine their success.

Among the established entrepreneurs, their family background and prior business experience contributed to their choice of entrepreneurship and success. However, they had inadequate entrepreneurial qualities such as achievement orientation, risk taking propensity, innovativeness and self-confidence in doing business. Therefore, there is a need to design capacity building programmes for the entrepreneurs for developing these attributes.

Tropical tuber crops based food and foreign trade: India *vis-à-vis* other countries

Decadal Compound Growth rates for cassava, sweet potato and tuber crops based products were estimated. There was significant growth in productivity and production of cassava during the 1961-2017, while declining trend in area during the same period was observed. In the case of sweet potato, both area and production showed declining trend, while productivity showed significant growth trend during the same period. Cassava productivity showed significant growth in all the decades, except during 2011-2017 and non-significant during 1971-1980. Sweet potato productivity showed significant growth in all the decades, except during 1971-1980.

There was no continuous export of tropical tuber crops in different forms in all the years. Among different forms, tapioca and substitutes (1971-2018), sago starch (1995-2018), sweet potato tubers (1996-2018) and flour meal of sago (1987-2018) individually showed significant growth in exports from India, both in quantity and value of exports. Cassava starch showed significant decline in quantity of exports, while significant growth in cassava starch imports, both in terms of the quantity (32.50%) and value (43.90%) was observed during 2003-2018. Very high starch import growth was recorded during 2011-2018 (55% in quantity terms and value terms). Thailand and Vietnam are the countries from which cassava starch is being imported.

Revealed Symmetric Comparative Advantage (RSCA) was estimated for various forms of tuber crops exports from India and compared with the other countries in selected regions (SAARC, ASEAN, BRICS, IOR-ARC, etc.). India has comparative advantage in SAARC region for exporting cassava starch; sweet potato; roots and tubers nes and flour roots and tubers nes; in case of ASEAN region for sweet potato exports and roots and tubers nes; in case of BRICS region for cassava dried exports and in case of IOR-ARC, for sweet potato, flour roots and tubers nes and roots and tubers nes exports during 1995 to 2016.

EXTERNALLY AIDED PROJECTS

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

The objective of the project was to develop genotypes to adapt in new environments (climate change, pest and disease outbreaks) and to satisfy market needs. Fifty exotic taro genotypes received under the project from SPC, Fiji are being maintained *in vitro* as well as in field. Out of these, 32 lines were selected and used for participatory evaluation encompassing seven different locations in three districts (Khorda-2, Cuttack-3, Puri-2) of Odisha. Among the 50 lines, morphotypes varied such as eddoes-10 lines, dasheens-35 lines and intermediates-5 lines. All the 50 exotic lines and indigenous lines were grouped into six groups based on key petiole colour characters. Flowering was recorded in 22 exotic accessions. The selected 32 lines showed higher yield potential (18-25 t ha^{-1}) during participatory evaluation. Hybridization was done between the exotic and indigenous lines as well as among the exotic taro lines. Hybrid seeds were raised (Fig. 111) from the parental lines viz., CE/IND/12 x Bhu Kripa, CE/IND/06 x Bhu Kripa and BL/SM/151 x Muktakeshi. The hybrid lines yielded 300-600 g $plant^{-1}$ and showed resistance to leaf blight.

The limitations of taro breeding owing to asynchrony in flowering could be overcome using cryo-preserved pollen as well as maintaining perennial parental plants. Hybrids recovered using cryo-preserved pollen was found to be on par with the hybrids raised conventionally. On evaluation, some of the hybrids recorded early maturity and blight resistance with yields of 600–950g $plant^{-1}$.

Wide diversity in Indian taro through DNA fingerprinting revealed two distinct gene pools with divergent genetic variability in the North Eastern states of India. Physico-chemical characterization had shown high Mg, K, P and Ca contents in diploid and Cu, Mn, Zn and Fe micronutrients in triploid taros. The K contents were also higher (1.44 to 3.24%) in Indian accessions. Such information are a 'boon' to taro growers to address the burning issues of food, nutrition and livelihood security. The project has been concluded.

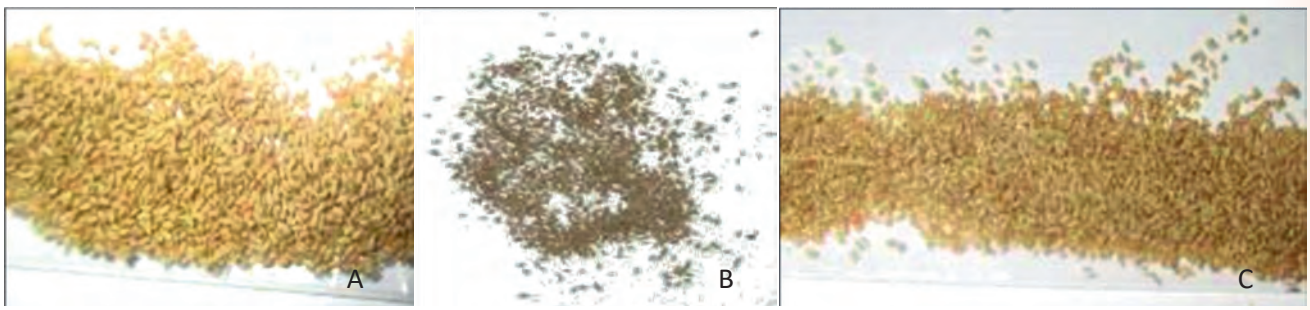
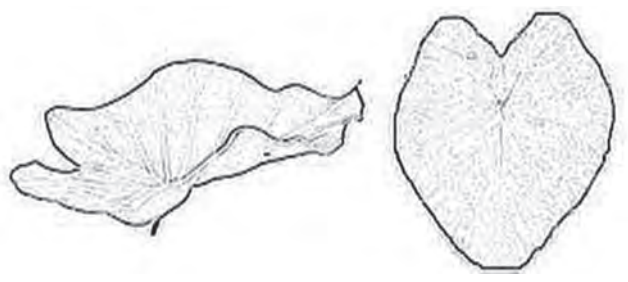


Fig. 111. Taro hybrid seeds extracted from the combinations CE/IND/12 x Bhu Kripa (A), CE/IND/06 x Bhu Kripa (B) and BL/SM/151 x Muktakeshi (C)

2. Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro (PPV & FRA, New Delhi; PI: Dr. Archana Mukherjee; Co-PIs: Drs. Kalidas Pati, J. Tarafdar (BCKV, Kalyani))

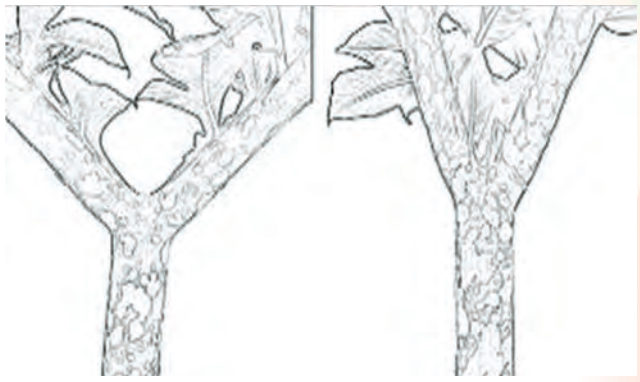
DUS guidelines were developed for taro and elephant foot yam and approved. DUS testing guidelines of taro included 51 primary characteristics of which four traits, viz., plant growth habit, leaf type, petiole type and corm characteristics, were selected as grouping traits (Fig. 112).

DUS testing guidelines for elephant foot yam included 41 characteristics including four grouping traits viz., plant growth habit, leaf type, petiole/ culm type and corm characteristics (Fig. 113). Reference varieties are being maintained in the varietal gene bank of both the crops. DUS testing of farmers' varieties are in progress. The project has been concluded.



1. Cup shaped 2. Erect - apex down

Fig. 112. Position of leaf in taro



1. V-type 2. Y-type

Fig. 113. Rachis pattern in elephant foot yam

3. Establishment of varietal gene bank and development of standards of DUS testing in yam bean (*Pachyrhizus erosus*) and greater yam (*Dioscorea alata*) (PPV & FRA, New Delhi; PI: Dr. Archana Mukherjee; Co-PIs: Drs. M.N. Sheela, Kalidas Pati, Vivek Hegde, M. Nedunchezhiyan, P.P. Singh (RAU, Dholi))

To develop distinct, stable and uniform morphological characters for differentiating various varieties/clones of yam bean and greater yam, a 'varietal gene bank' was established at ICAR-CTCRI, both at the Regional Centre, Bhubaneswar and Head Quarters, Thiruvananthapuram.

The final DUS guidelines have been submitted for approval. DUS testing guidelines of greater yam included 28 characteristics, of which five traits, viz., petiole colour, leaf shape, tuber shape, tuber cortex colour and tuber flesh colour (Fig. 114), were selected as grouping traits. DUS testing guidelines for yam bean included 20 characteristics, including five grouping traits viz., leaflet shape, flower colour, tuber shape, seed colour and seed shape (Fig. 115). Reference varieties for both the crops are being maintained.

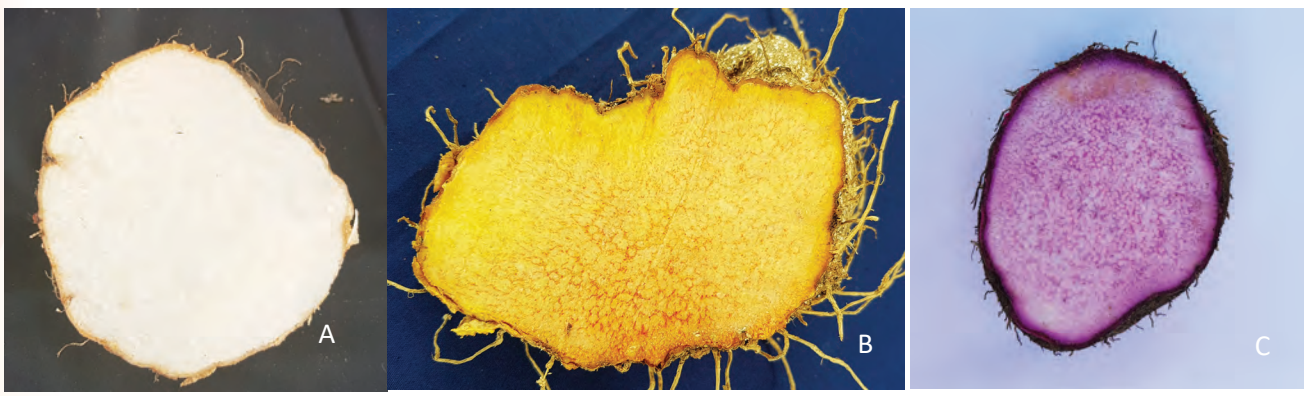


Fig. 114. Flesh colour in greater yam: white (A), yellow (B) and purple (C)

Fig. 115. Seed shape in yam bean: square (A) and flattened (B)

4. Establishment of varietal gene bank and development of standards of DUS testing in cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*) (PPV & FRA, New Delhi; PI: Dr. M.N. Sheela; Co-PIs: Drs. Archana Mukherjee, Kalidas Pati, K.I. Asha, Krishna Radhika, Shirly Raichal Anil, A. Asha Devi)

The gene bank of reference varieties of cassava (55) and sweet potato (52) are being conserved in the field. DUS testing guidelines of both cassava and sweet potato were standardised. DUS testing guidelines of cassava included 30 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 25 characteristics, including six grouping traits viz., plant growth habit, vine pigmentation, mature leaf shape, tuber shape, predominant skin colour of tuber and tuber flesh colour. All the reference varieties were harvested and replanted. Farmers were sensitized to do registration of cassava and sweet potato varieties.

5. ICAR-CTCRI-CIP collaborative work plan activity on crop improvement and varietal selection of sweet potato (CIP, New Delhi; PI: Dr. Shirly Raichal Anil; Co-PI, Visalakshi Chandra C.)

As part of the work plan between ICAR and CIP under the MoU on cooperation in the Field of Agriculture Research and Education, ICAR-CTCRI and CIP have taken up a Collaborative Activity on Crop Improvement and Varietal Selection of Sweet potato. Under this activity, 20000 true seeds of sweet potato (obtained from controlled crosses) were received from CIP, Peru through NBPGR, New Delhi. Six thousand seeds were germinated by acid scarification method and 400 hybrids were selected based on preliminary screening for orange flesh colour and high dry matter. Selected clones are being maintained as duplicates in pots for evaluation trial in field.

6. Gene expression profiling of taro (*Colocasia esculenta* L. Schott) and role of transcriptional activators of epicuticular wax in host resistance against *Phytophthora* leaf blight disease (Department of Biotechnology, Government of India, Ministry of Science & Technology; PI: Dr. Vivek Hegde; Co-PI: Dr. P. Sethuraman Sivakumar)

The project has been sanctioned under DBT Twinning Programme-2017 for a period of three years at a total budget of ₹68,77,992. The amount of ₹41,29,996 was allotted to parent institute, ICAR-Research Complex for NEH Region, Manipur Centre (PI: Dr. M.R. Sahoo) and ₹ 27,47,996 was sanctioned for collaborating institution, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram (PI: Dr. Vivek Hegde). The work has been initiated in 2019.

7. Applied mutagenesis in cassava for improved agronomic, disease resistance and post-harvest traits (Board of Research in Nuclear Sciences, Department of Atomic Energy, Government of India; PI: Dr. A.V.V. Koundinya)

This project was initiated during January 2019 with an objective to identify and isolate putative mutant clones of cassava with disease resistance, high yield and better post-harvest properties. The amount sanctioned is ₹ 23,03,900 for a period of three years. A Junior Research Fellow has been recruited under this project. The gamma irradiation treatment followed by planting and screening of two cassava varieties will be carried out in the upcoming year.

8. All India-Network Programme on Organic Farming (AI-NPOF) (ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut as Lead Centre; PI: Dr.

G. Suja; Co-PIs: Drs. G. Byju, S. Sunitha, S.S. Veena, A.N. Jyothi, M.N. Sheela)

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.

Of the four systems, cassava-groundnut was the most remunerative. In cassava-vegetable cowpea, 100% inorganic was the most profitable followed by 50% organic + 50% inorganic. However, with premium price, 100% inorganic followed by 75% organic + innovative practices were profitable. In cassava-groundnut system, 100% inorganic followed by 75% organic + 25% inorganic were profitable. When premium price was accounted, 100% organic was the most remunerative for this system.

In cassava-vegetable cowpea, 100% inorganic resulted in the highest equivalent energy and 75% organic+25% inorganic in production efficiency. In cassava-groundnut system, 100% inorganic resulted in highest equivalent energy and production efficiency. In taro-green gram and taro-black gram systems, 100% organic and 75% organic respectively generated highest equivalent energy. The integrated management options, 50% organic +50% inorganic for taro-green gram and 75% organic + 25% inorganic for taro-black gram resulted in higher tuber equivalent yield and production efficiency.

The available N and P status of the soil at the end of the various cropping systems was in general higher under organic or integrated management practices. Available K status was mostly higher under 100% inorganic or state POP. Whereas as expected, organic practices or towards organic practices enhanced the secondary and micro nutrient status of the soil after almost all cropping systems tested. Bacterial count was higher in 100% organic or 75% organic or 75% organic + 25% inorganic in all the cropping systems. The fungal and actinomycetes population was higher under state POP and inorganic practices.

Evaluation of varietal response of cassava to organic farming

Of the 12 varieties tested, Sree Reksha produced significantly higher yield (40.69 t ha^{-1}) followed by Sree Pavithra (29.49 t ha^{-1}). The variety, Sree Reksha also generated higher profit (₹4,42, 062 ha^{-1}) and B:C ratio (3.63) followed by Sree Pavithra (₹2,74,070 ha^{-1} profit and 2.63 B:C ratio) under organic mode.

Geo-referenced on-farm characterization of organic growers

Geo-referenced survey of 30 farmers practicing organic farming in Malappuram district of Kerala was conducted. The survey was carried out in Ponnani, Kuttippuram and Mankada blocks, Malappuram, Kerala (Fig. 116). Sixty per cent of the farmers belonged to the small and marginal group with a land holding size <2 ha. Average land holding size was 1.85 ha. Most of the farming situation surveyed was rainfed (60%), remaining were irrigated. The soil type was laterite (100%).

Being health conscious and aware of the quality of the organic produce, all the farmers used the organic produce for their house-hold consumption (100%), and the surplus was sold to the market by 93.33% of the farmers. Animal wastes were converted to excellent manures using biogas (in 30% cases) and vermicompost units (50% farms) (with an average capacity to produce nearly 200 kg

Fig. 116. Glimpses of geo-referenced survey of organic growers

compost per annum). Nutrient sources for organic farming constituted cow dung slurry/FYM (100%), poultry manure (60%), vermicompost (23.33%), biogas slurry (16.67%), neem cake (63.33%), groundnut cake (20%), coir pith compost (3.33%), bio-formulations like *Panchagavya* (10%), *Jeevamrutham* (16.67%), and green manuring (10%). Ash (40%) and bone meal (33.33%) were also used. Majority of farmers conducted soil testing before raising the crop.

Pests and diseases were managed through application of neem oil-garlic emulsion (43.33%), neem oil (16.67%), fish amino acid (46.67%), egg amino acid (23.33%), *Kanthari* emulsion (16.67%), neem soap (16.67%), *Beauveria* (56.67%), *Trichoderma* (73.33%), *Pseudomonas* (66.67%) and pheromone trap (20%). In addition, cultural methods, intercropping, trap crops on field bunds and some indigenous practices were also resorted to.

9. Enhancing the economic viability of coconut based cropping systems for land use planning in Kerala (Department of Agriculture, Government of Kerala; PI: Dr. K. Susan John; Co-PIs: Drs. S. Sunitha, S.S. Veena)

The objective of the project is to conduct on-farm validation trials of the customized fertilizers (CFs) developed for elephant foot yam and cassava in farmers fields. The CF formulations developed for elephant foot yam and cassava were tested in the on-farm validation trials of KVKs of Alappuzha, Kollam and Idukki districts (Fig. 117).

10. Response of cassava (*Manihot esculenta* Crantz) to polysulphates under Ultisols (Laterites) and Entisols (Sandy Plains) of Kerala (International Potash Institute-India Region; PI: Dr. K. Susan John; Co-PI: Dr. Jeena Mathew (ICAR-CPCRI))

ICAR-CTCRI

AEU 9(1)

AEU 9(2)

AEU 3(1)

Fig. 117. A view of the experiment at different locations

To explore the possibility of polysulphates in tropical tuber crops, this study was conducted to evaluate the effect of polysulphates in cassava in the major cassava growing laterite and sandy soils of Kerala. The effect of polysulphates on tuber yield, tuber quality, soil physico-chemical and biological properties and nutrient uptake are being studied to recommend this multi-nutrient rich product as a better soil amendment for Kerala soils, which are deficient in K, Ca, Mg and S.

Six experiments were initiated in two locations (Chettikulangara, Alappuzha) of AEU 3 and four locations in AEU 9 (two each in Pathanamthitta and Thiruvananthapuram, one on station at ICAR-CTCRI) as per the technical programme, which included 9 treatments replicated thrice in RBD. The experiments are in progress.

11. Higher productivity and profitability from coconut gardens through soil health management in tuber crops

(Coconut Development Board, Government of India; PIs: Dr. G. Byju and Dr. G. Suja; Co-PIs: Drs. Archana Mukherjee, D. Jaganathan)

On-farm validation of organic farming (OF) technology was done in five coconut farms of 50 cents each in Thiruvananthapuram district. The OF technology was demonstrated in two coconut farms with greater yam as intercrop and another three farms with cassava as intercrop. On-farm validation of customised fertilizers (CF), developed based on SSNM technology, was done in five coconut farms of 50 cents each in Thiruvananthapuram district. The CF technology was demonstrated in two coconut farms with greater yam as intercrop and another three farms with cassava as intercrop. Biometric data were recorded, soil samples were collected and analysed. Harvest of greater yam is completed. Harvest of cassava will be completed by May.

12. Climate smart natural resource management of cassava (*Manihot esculenta* Crantz) using geoinformatics tools (KSCSTE, Government of Kerala; PI: Dr. G. Byju)

Field experiment for the calibration and validation of WOFOST model has been completed. Soil quality studies of SSNM field experiment has been completed. Effect of SSNM on soil nutrient fractionation (calcium and magnesium) was studied using ICP. Fig. 118 shows the partitioning of drymatter of three cassava varieties studied as a part of calibration of WOFOST model.

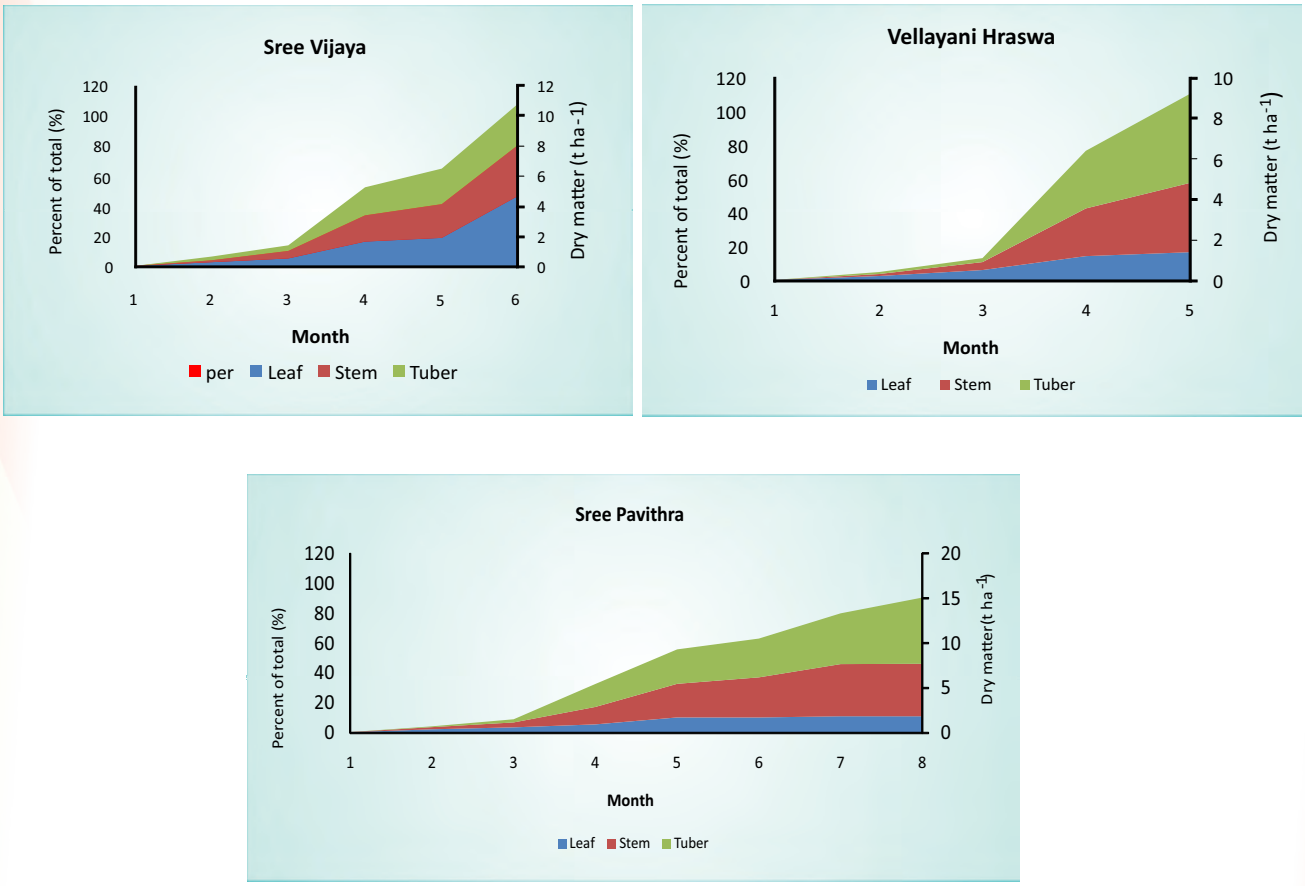


Fig. 118. Dry matter partitioning of three cassava varieties at monthly intervals

13. Potential impact of climate change on tropical root crops yield in the major growing areas of India (DST-WOS-A, Govt. of India; Woman Scientist: Dr. P. Raji; Scientist Mentor: Dr. G. Byju)

Trend analysis of sunshine duration over peninsular (P) and north east (NE) India showed a declining trend (Fig. 119). Observed a dimming of sunshine over NE during monsoon, autumn, and summer seasons at the rate of -0.53, -0.25, and -0.19 hour per decade. Dimming detected in the P region during autumn, monsoon, and summer seasons: -0.16, -0.12, -0.06 hour per decade. The highest decline in sunshine duration calculated for the NE and P regions: -5.3 and -2.9% during monsoon season with highest variability observed in the NE. The impact of sunshine dimming on growth of cassava using WOFOST model was observed as-9%.

Irrigation schedules and crop water production function (CWPF) for cassava over southern peninsular India were also developed. The optimal water requirement simulated by CROPWAT was 308, 606 and 648 mm in Thiruvananthapuram, West Godavari and Salem respectively based on the soil, crop and climatic parameters. The derived crop water production function (CWPF) for Thiruvananthapuram is, $Yield = 0.071ET_c + 13.43$, ET_c-crop evapotranspiration.

A meta-analysis of the climate resilience of cassava showed that the crop can tolerate a temperature level of up to 40°C. Already established cassava can tolerate a salinity level of up to 150 mM and the

younger plants can tolerate up to a level of 40 mM. There was a strong positive influence of elevated CO_2 up to 700 ppm on the rate of photosynthesis and yield of cassava.

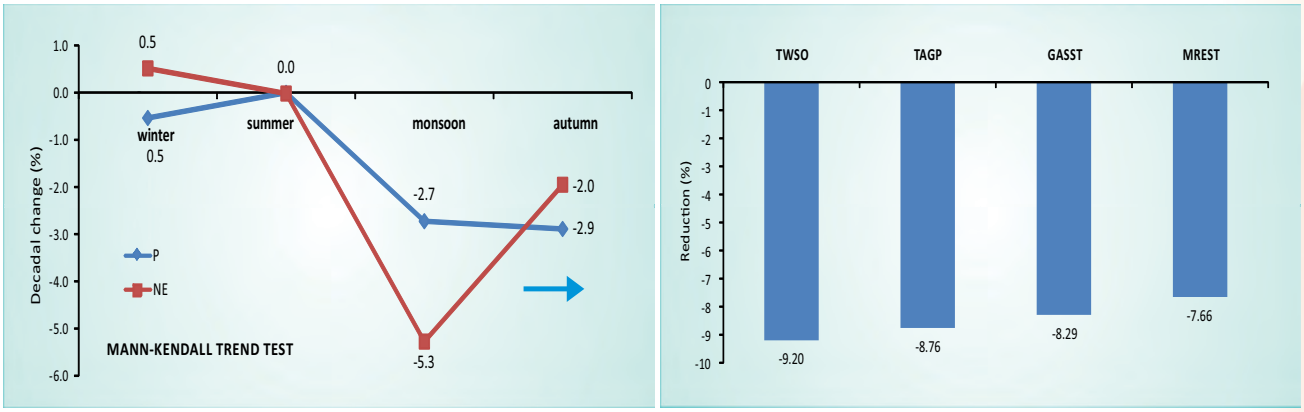


Fig. 119. Decadal changes in sunshine and its impact on cassava

14. Assessment of soil fertility and preparation of soil fertility maps for various agro-ecosystems of Odisha (RKVY, Government of Odisha; PI: Dr. K. Laxminarayana; Co-PI: Dr. M. Madhumita Das (ICAR-IIWM))

The soil fertility status of profile soils (surface and sub surface soils) representing 6237 Gram Panchayats from 314 blocks in 30 districts of Odisha were assessed. GIS based soil fertility maps were prepared with the support of Odisha Space Applications Centre, Bhubaneswar for physico-chemical properties like pH, electrical conductivity, organic C, available N, P, K, exchangeable Ca and Mg for surface (0-30 cm) and sub surface (30-100 cm) soils. GIS based soil fertility maps for profile soils (0-100 cm) in respect of S, Fe, Cu, Mn, Zn, B and Mo have been prepared.

About 53.90 and 58.40% of surface and sub-surface soils were slightly to moderately acidic, 43.20 and 38.60% of surface and sub-surface soils were neutral and < 2% soils were slightly to strongly alkaline in reaction. Majority of soils were non saline and very few soils were moderately to strongly saline in nature. The organic C content was deficient in 54 and 75% of surface and sub-surface soils, respectively, while it was high in 21 and 8% surface and sub-surface soils, respectively. The available N, P and K were deficient in 85, 19 and 8% of surface soils and 94, 28 and 16% of sub-surface soils, respectively. Very few soils contained high status of available N, whereas 30 and 53% of surface soils and 20 and 42% of sub-surface soils had high status of available P and K, respectively.

The exchangeable Ca was sufficient in 96 and 92% of surface and sub-surface soils, respectively and <1% soils were deficient in exchangeable Ca. However, the exchangeable Mg was deficient in 5 and 8% surface and sub-surface soils, respectively and 77 and 62% of surface and sub-surface soils contained sufficient levels of exchangeable Mg. The available S was deficient, medium and high in about 15, 22 and 63% of profile soils, respectively.

Toxic levels of available Fe and Mn were observed in the profile soils, in which 84 and 96% contained high levels of available Fe and Mn, respectively. About 98% of profile soils contained sufficient levels of available Cu, whereas 40% had high levels and 22% were deficient in available Zn. About 73% of profile soils were deficient in available B and 16% had sufficient levels of available B. Almost all the profile soils contained sufficient levels of available Mo and it was deficient in very few locations.

15. Popularization of climate resilient improved varieties of tuber crops for food, nutrition and doubling income with emphasis on wellness of tribal and marginal farmers in Kerala (RKVY-RAFTAAR, Government of Kerala; PI: Dr. V. Ravi, Dr. Archana Mukherjee, Dr. G. Byju and Dr. J. Sreekumar; Co-PIs: Drs. M.N. Sheela, C.A. Jayaprakas, Sheela Immanuel, G. Suja, K. Susan John, V. Ramesh, R. Muthuraj, Saravanan Raju, Sanket J. More, D. Jaganathan)

Flagging off the supply of planting material to ST farmers

Distribution of planting material to ST farmers at Moonnilavu, Kottayam Dt.

This project envisages developing infrastructure in the Institute for quality planting material production of improved varieties and establishing seed villages in tribal settlements in three districts of Kerala. The following root and tuber crops were cultivated in 17 acres at ICAR-CTCRI farm: Cassava: 7.5 acres; Yam: Sree Karthika, Sree Keerthi, Sree Shilpa, Sree Nidhi, Sree Dhanya and Orissa elite in 1.5 acres; Sweet potato: Bhu Krishna, Bhu Sona, Kanhangad, Sree Kanaka and Sree Arun in 1 acre; Elephant foot yam: Gajendra in 6 acres, Taro: Muktakeshi in 1 acre. Total quantity of 7875 cassava stems, 1325 kg of yams, 7700 kg of elephant foot yam and 1225 kg of taro were supplied to 63 contact ST farmers in Tribal Settlements in three districts viz., Thiruvananthapuram (Thodumala Panchayat, Panayam), Kottayam (Moonnilavu Panchayat) and Idukki (Upputhara Panchayat) of Kerala identified with the assistance of the State Department of Agriculture (Fig. 120). Infrastructure was developed by procuring one pH meter, one pressure washer, two water storage tanks of 10000 litre capacity, two aluminium ladders of 10 feet height, one water pump, 160 field boards, two weed cutters of 2.5 HP, one stem cutter, one conductivity meter, one DSLR camera, one LCD projector, one osmometer, four digital balances, one tractor 51 HP, one mould board plough, one ridger, one chisel plough, PVC pipes, coir and weed control sheets. In addition, fertilizers and chemicals (Urea, Factomphos, MOP, Rajphos, DAP, bone meal, neem cake, rock/ mussoorie phosphate, calcium nitrate, magnesium sulphate, boron, zinc sulphate, Stanprid, Nuvan, Redomil, SAAF, Tafgor and Renova) were procured. One bore well was dug in Block II. About 2.5 ha of land was levelled and the area

Distribution of planting material to ST farmers at Thodumala, Amboori, Thiruvananthapuram Dt.

Distribution of planting material to ST farmers at Upputhara, Idukki Dt.

Fig. 120. Distribution of planting material in three districts under RKVY

of cultivation was expanded in Block IV. One water pump was installed in a bore well in Block IV for irrigation. Concrete pillar and support structure was built for two water storage tanks. To facilitate seed village development in tribal villages, scientist-farmer interface and trainings are being conducted periodically at the site and also in the main campus.

16. Popularization of climate resilient and nutritionally rich varieties of tuber crops for economic development and nutritional security of farmers of Odisha (RKVY, Dept. of Agriculture & Farmers' Welfare, Government of Odisha; Co-ordinator: Dr. Archana Mukherjee; PI: Dr. M. Nedunchezhiyan; Co-PIs: Drs. K. Laxminarayana, Kalidas Pati, V.B.S. Chauhan, Shri. K. Hanume Gowda, Shri. V.V. Bansode, Drs. Sheela Immanuel, G. Byju, P.S. Sivakumar, D. Jaganathan, Shri. Bharat Kumar Sahoo, Shri. Bibhuti Das)

The project was conceptualized and formulated by the PIs, Dr. Rajasekhara Rao Korada and Dr. Archana Mukherjee. The project got approved by RKVY, Govt. of Odisha and launched during 2017. Consequent to Dr. Archana Mukherjee, the then, Head, Regional Centre, ICAR-CTCRI, Bhubaneswar joining as Director, ICAR-CTCRI as well as transfer of Dr. Rajasekhara Rao to ICAR-National Rice Research Institute, Cuttack, Odisha, the PI of the project is now Dr. M. Nedunchezhiyan, Head (i/c), Regional Centre, ICAR-CTCRI.

This project aims to disseminate nutritionally rich tuber crops to the farming communities in Dhenkanal, Nayagarh, Keonjhar, Bargarh, Koraput, Kandamahal, Navrangpur, Mayurbhanj districts of Odisha. Planting material production and distribution have already been initiated. One day brain storming workshop on 'Tuber crops area expansion: Scope and prospects in Odisha' was organized on 28 January 2019. KVK Scientists and OTELP/OPELIP staff from the above districts participated in the programme. A tractor and power tiller, a bush cutter and sprayer, weighing balances, two computers and printers, pH meter etc. were purchased under the project. To enhance seed production, greater yam was planted in 2 acres, elephant foot yam 2 acres, cassava 2 acres, taro 1 acre, yam bean 2 acres and sweet potato nursery 1 acre.

17. ICAR-CTCRI-Tribal Sub Plan on Livelihood improvement of tribal farmers through tuber crops technologies (ICAR, TSP Nodal Officer: Dr. Sheela Immanuel; PI: Dr. M. Nedunchezhiyan; Co-PIs: Drs. Archana Mukherjee, K. Laxminarayana, Kalidas Pati, V.B.S. Chauhan, Shri. K. Hanume Gowda, Shri. V.V. Bansode)

Gajapati district of Odisha is covered by hills and plateau lands. Maize is the major crop in this district. During the year 2018-19, 200 tribal farmers were selected from Mohana Block (Dimirijholi, Jubagaon, Andiragada and Anangadongra villages) and R. Udayagiri Block (Kharipada, Sinisingh, Lubursingh, Patrabasa Nayak Sahi and Lubursingh villages) of Gajapati district for demonstrating tuber crops based farming system (0.2 ha model). In this 0.2 ha model, the area of various crop components were as follows: maize 0.08 ha, greater yam + maize intercropping 0.03 ha, sweet potato 0.04 ha, yam bean 0.04 ha, cassava 0.01 ha. All the above crop components were

Tuber crops cultivation in Anangadongra village

Backyard poultry at Dimirijholi

Fig. 121. Various programmes under tribal sub plan (TSP) in Odisha

sown/planted during *kharif* season. Vegetables were grown in *rabi* season in 0.01 ha. Backyard poultry with 10 Vanaraja birds (45 days old) were also given to each farmer as demonstration (Fig. 121). For capacity building of the tribal farmers on tuber crops cultivation, eight on-farm trainings were organized. The tuber crops planting material like sweet potato 2,00,000 vine cuttings, cassava 5000 stems, greater yam tubers 3000 kg, maize 10 kg, red gram 10 kg and yam bean seeds 100 kg were distributed to 200 tribal farmers. Vegetable kits (that contained Amaranthus, bhendi, chilli, onion, cowpea, French bean, *Dolichos* and bottle gourd seeds) 300 nos. and 2000 poultry birds (Vanaraja) were also distributed to tribal farmers to supplement the farm income. Regular monitoring was carried out to address the problem faced by the tribal farmers.

In tuber crops based farming system demonstration, the average yield of maize was 3.98 t ha^{-1}, in yam + maize intercropping, the yield of yam and maize were 19.97 and 3.77 t ha^{-1}, respectively, sweet potato tuber yield was 12.55 t ha^{-1}, yam bean tuber yield 13.58 t ha^{-1}, cassava tuber yield 12.50 t ha^{-1} and vegetable yield 20 t ha^{-1} (Fig. 122). The tuber crops based farming system (0.2 ha model) resulted in average crop yield of 2.4 t and meat yield of 22 kg with 180 eggs from the poultry birds. The gross and net returns from the farming system were ₹ 37,405 and 25,580, respectively. The B:C ratio was 3.16 and the employment generated was 73 man-days. The tuber crops based farming system can be managed by the own family labourers, as the employment was distributed through-out the year.

To encourage tuber crops farming, a "Tuber Day" was organized on 09 January 2019. The programme was organized by Dr. M. Nedunchezhiyan, PI and Dr. James George, PC, AICRP (TC) was the Chief Guest. About 500 farmers and the representatives from the NGOs viz., Institute of Social Action and Research Activities and Community Alternative Learning also participated in the programme and addressed the gathering. Among the 200 adopted tribal farmers, five best farmers were awarded.

18. Indo-Swiss Cassava Network project

(Indo-Swiss Collaboration in Biotechnology, (ISCB), Swiss Agency for Development & Co-operation, Bern and New Delhi and Department of Biotechnology, Government of India, New Delhi; PIs: Drs. M.N. Sheela and T. Makeshkumar; Co-PIs: Drs. E.R. Harish, B.G. Sangeetha, C. Visalakshi Chandra)

Bottle gourd cultivation in Jubagaon

Yam bean harvest at Andiragada village

Onion cultivation in Lubursingh

Tuber Day organized at Chandragiri village, Odisha

Fig. 122. Demonstration of tuber crops technologies under TSP in Odisha

Virus resistance assessment of cassava mosaic disease (CMD) resistant transgenic cassava plants in green house was done through particle bombardment. Transgenic H-165 plant harbouring Rep hairpin construct was challenged with SLCMV by grafting with wild type plant infected with SLCMV from field, established in glass house. Transgenic plants showed negligible amount of viral load when compared with that of wild type in real time PCR analysis. At forty days post bombardment, control H-165 plants exhibited downward leaf curling and stunting, whereas transgenic plants exhibited only mild symptoms. PCR analysis showed expected amplification in control and transgenic plants. qPCR analysis showed the presence of high copy number of viruses in wild type lines, but were least in the CMD resistant lines.

On-farm trials conducted at Salem with CMD resistant lines during 2014-18 led to the identification of three CMD resistant varieties viz., 8S501-2, CR-24-4 and CR-43-2, which were well accepted by the farmers. The CMD resistant varieties had high starch yield (>20 t ha^{-1}) as compared to susceptible varieties (13.50-16.20 t ha^{-1}). 8S501-2 is a promising CMD resistant variety for irrigated plains of Tamil Nadu and is suitable for replacing the highly susceptible popular variety, H-226. According to farmers, it has drought tolerance too and it has already spread to more than 2.5 ha (Fig.123). Promising cassava varieties introduced from ETH, Zurich under this project were screened for CMD resistance. Two lines viz., KBH/2006/18 and KBH/2006/26 were found to be resistant and are being evaluated for agronomic traits (Fig. 124). On-farm trials of CMD resistant short-duration varieties along with popular short-duration CMD susceptible check

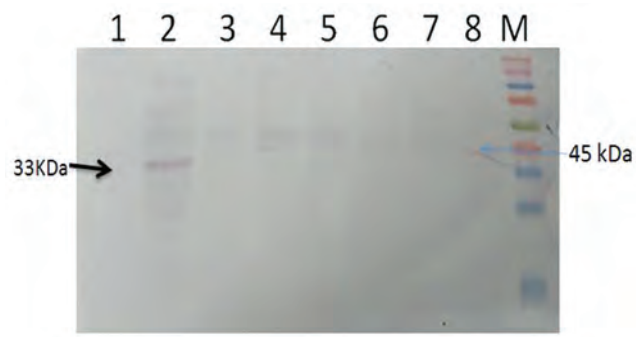
Fig. 123. Sri Seventheeswaran, farmer with the new CMD resistant variety, 8S501-2

Fig. 124. New CMD resistant varieties introduced from ETH, Zurich, KBH/2006/18 (left) and KBH/2006/26 (right)

variety, Vellayani Hraswa were planted in six farmers fields in Karadipatty, Dalavaipetty and West Rajapalayam in Salem during 18-19. The trials are in progress.

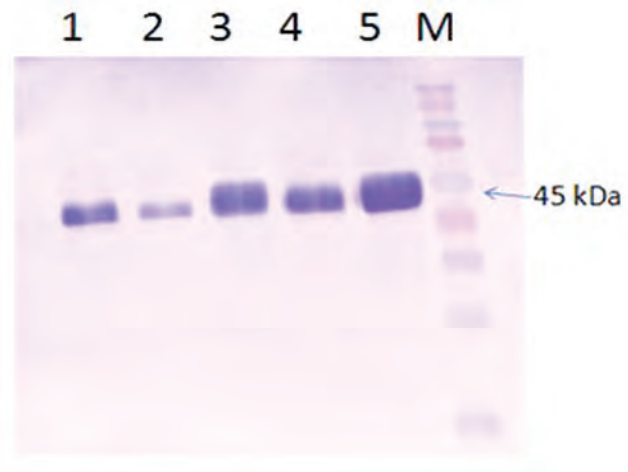
19. Development and application of diagnostics to viruses infecting tuber crops (*Amorphophallus*, cassava, sweet potato and yam) (ICAR; PI: Dr. T. Makeshkumar; Co-PIs: Dr. M.L. Jeeva, Shri. R. Arutselvan, Dr. R. Muthuraj)

Coat protein gene of *Sri Lankan cassava mosaic virus* (SLCMV) and *Dasheen mosaic virus* (DsMV) were expressed in bacterial expression system. Expressed proteins were purified (Fig. 125 & 126) and outsourced for antibody production. Validated LAMP based detection of SLCMV using 96 field collected symptomless samples and could detect the SLCMV infection in 73 samples. Also used



Lane 1: Uninduced control, Lane 2: Induced control crude lysate, Lanes 3 to 5: Purified elute eluted using buffer D, Lanes 6 to 8: Purified elute using buffer E, M-Broad range multicolor protein marker (Thermo scientific)

Fig. 125. Immuno blot analysis of purified SLCMV coat protein (expressed in bacteria) extracted from recombinant *E. coli* BL21 DE3 strain by Western blotting followed by BCIP/NBT staining



Lane 1: Purified elute 1 hr after induction, Lane 2: Purified elute uninduced control, Lane 3: Purified elute 2 hr after induction, Lane 4: Purified elute 3 hr after induction, Lane 5: Purified elute 4 hr after induction, M-Prestained protein marker (Thermo scientific)

Fig. 126. Immuno blot analysis of purified DsMV coat protein (expressed in bacteria) extracted from recombinant *E. coli* BL21 DE3 strain by Western blotting followed by BCIP/NBT staining

this technique for identifying virus free mother plants of cassava varieties and selected 76 cassava cultures of H-226, H-165, Kungumarose. Using rolling circle amplification method, full genome amplification of sweet potato leaf curl virus (SPLCV) was achieved, cloned and sequenced. Using this information, rapid diagnostic primers will be developed for quick detection of SPLCV infection. About 926 virus-free plants of cassava varieties, H- 226, H-165, Sree Athulya and Sree Apoorva were produced.

20. On-farm trials of cassava biopesticides against borer pests of banana in Kerala

(Department of Agriculture & Farmers Welfare, Govt. of Kerala; PI: C.A. Jayaprakas; Co-PIs: Drs. E.R. Harish, B.G. Sangeetha)

Training programmes were organised to popularise the cassava biopesticides among the farmers for the management of pseudostem weevil and rhizome weevil in banana and sucking pests of vegetable crops in five districts of Kerala viz., Thiruvananthapuram, Ernakulum, Thrissur, Wayanad and Kasaragod. A novel portable mixing and filling machine was designed and fabricated for the formulation of biopesticides *Menma* and *Shreya*. In collaboration with KVK-Mitraniketan, Vellanadu, Thiruvananthapuram, cassava bioformulations *Nanma* and *Menma* were tested in banana fields of farmers. A multilingual short video film in Malayalam, English, Kannada, Telugu and Russian on the "Biopesticides from cassava" was produced.

21. High Value Compounds/Phytochemicals

(ICAR Network Project; PI: Dr. A. N. Jyothi; Co-PIs: Drs. J. Sreekumar, Shirly Raichal Anil)

Preparation of anthocyanin capsules

Purified anthocyanins from the purple tubers of greater yam (*D. alata*, Acc. Da-340) and sweet potato (var. Bhu Krishna) were encapsulated with lactose and also with maltodextrin. These encapsulated anthoyanins were used for making gelatin capsules as nutrient supplement (Fig. 127). The concentration of anthocyanins was 5 mg per capsule. Disintegration study was conducted with the capsules and the results showed that complete disintegration of capsules occurred in 20 to 24 min. in aqueous medium.

Fig. 127. Sweet potato anthocyanin capsules

MTT assay of anthocyanins for *in vitro* anticancer activity

The MTT assay of anthocyanins from sweet potato tubers (var. Bhu Krishna), purple sweet potato leaves (Acc. S-1467) and tubers of greater yam (Acc. Da-340) have been carried out in three human cancer cells, viz., cervical cancer (HeLa), breast cancer (MCF-7) and colon cancer (DLD1) cells. All the anthocyanins showed comparatively higher activity on breast cancer cells. The sweet potato leaf anthocyanins were also found to have significantly higher activity on colon cancer cells. The LC_{50} of greater yam tuber, sweet potato tuber and leaves were 77.26, 115.12 and 118.76 µg ml^{-1}, respectively for breast cancer cells. The LC_{50} values of greater yam tuber, sweet potato tuber and leaves were 100.53, 240.53 and 187.84 µg ml^{-1}, respectively for

cervical cancer cells and 206.73, 184.70 and 138.78 µg ml^{-1}respectively, for colon cancer cells.

Utilization of tuber residue after anthocyanin extraction

The sweet potato and greater yam tuber residues after anthocyanin extraction were collected, dried and lyophilized. The dry matter present in the residue (flour) of sweet potato tuber and greater yam was 92.40 and 71.10% respectively. The fibre, crude protein and fat contents in sweet potato tuber flour were 3.92, 3.85 and 0.47%, respectively, whereas in yam tuber flour these were 3.20, 5.25 and 1.73% respectively. These flours were successfully used to replace up to three fourth of the maida in bakery products such as cookies (Fig. 128). This enables the simultaneous utilization of purple sweet potato and greater yams tubers for colorant extraction as well as flour production.

Fig. 128. Sweet potato flour and cookies prepared from tuber residues after anthocyanin extraction

22. Techno-Incubation Centre, ICAR-CTCRI

(SFAC, Government of Kerala; PI: Dr. M. S. Sajeev; Co-PI: Dr. T. Krishnakumar)

Thirty six on-campus training programmes organized at the Techno-incubation centre of ICAR-CTCRI for 926 participants (535 females and 391 males) (Fig. 129). Six off-campus training programmes were also organised at Kunnathukal, Pedikulam, Vamanapuram, Parassala, Poovachal and Nemom in Thiruvananthapuram district in coordination with Kudumbasree Mission, Govt. of Kerala. Twenty seven farmers/entrepreneurs utilized the incubation facilities for making various casava based products viz., pakkavada, sweet fries, muruku, crisps, hot crisps, pasta etc. MoUs were signed with three firms from Kerala for the technology for the production of snack foods. A one day seminar on 'Technological Empowerment of Women for Entrepreneurship Development in Tuber Crops based Value Added Products' was organised at ICAR-CTCRI, Thiruvananthapuram on 26 July 2018.

Fig. 129. Trainings at Techno-Incubation Centre, HQ, ICAR-CTCRI

23. Techno-Incubation Centre, ICARC-TCRI Regional Centre, Bhubaneswar

(RKVY, Government of Odisha; PI: Dr. M. Nedunchezhiyan; Co-PIs: Drs. M.S. Sajeev, V.V. Bansode)

Five on-campus trainings for about 100 people, and one off-campus training for 60 people were organised. About 3000 farmers/students from states like Manipur, Nagaland, Assam, West Bengal, Orissa, Jharkand, Chhathisgarh and Andhra Pradesh visited the incubation centre (Fig. 130).

Fig. 130. Trainings at Techno-Incubation Centre RC, ICAR-CTCRI

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

A entrepreneurial ecosystem survey conducted in Maharashtra, Uttar Pradesh, Kerala and Tamil Nadu indicated that obtaining finance was the critical component, which influences venture formation by AC&ABC trainees. A restructured AC&ABC system has been proposed with a focus on venture creation and job growth.

25. National Agricultural Innovation Fund (NAIF): (Component 1 Innovation Fund) (ICAR, New Delhi; PI: Dr. P. Sethuraman Sivakumar; Co-PIs: Drs. R. Muthuraj, Vivek Hegde, H. Kesava Kumar, T. Krishnakumar, D. Jaganathan, Shri. R. Bharathan)

Technology commercialisation

Value added fried products and fried chips from cassava and/or sweet potato on a technology licensing and consultancy mode was transferred to to three firms/individuals 1) Dora Food Industries, Kozhikode, Kerala; 2). JSJ Food Products, Thondernad, Korome, Wayanad; 3) Saji Varkey, Nirappil House, Ramapuram Bazar, Marangad, Kottayam. As well as five micronutrient foliar formulations for site-specific nutrient management in tropical tuber crops were transferred to M/s, Linga Chemicals, Madurai, Tamil Nadu.

Entrepreneurship promotion

- EDP programme on tuber crops technologies held on 07 September 2018 at Mukoodal, Tirunnelveli, Tamil Nadu for the benefit of 100 farmers and other stakeholders.
- EDP programme for B.Sc. (Ag.) Students of College of Agriculture, Vellayani during 24-26 September 2018 at ICAR-CTCRI, Thiruvananthapuram.
- CTCRI-AESA-CRISP-MANAGE-NAARM National Workshop on "Advances in Social and Behavioural Science Research" was conducted during 12–17 November 2018 at ICAR-CTCRI, Thiruvananthapuram for 37 participants.
- A Stakeholder Meet and Entrepreneurship Development Programme on Tuber Crop Technologies was organized in collaboration with NEHU and KVK, West Garo Hills at SMELC Building, Dakopgre, Tura on 01 December 2018.
- A Stakeholder Meet and Entrepreneurship Development Programme on Tuber Crop Technologies was organized in collaboration with KVK, Namsai at KVK, Namsai on 05 December 2018.
- Field day-cum-entrepreneur meet on Chinese potato was organized on 11 January 2019 at Alvan Thulukapatti, Alankulam, Tirunnelveli, Tamil Nadu for the benefit of 100 farmers and other stakeholders.
- Workshop on Intellectual Property Valuation of Agricultural Technologies on 22 March 2019 at ICAR-CTCRI with the participation of 80 people.

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 2018-2019.

Technology commercialisation

Eight technologies including five micronutrient foliar formulations for site-specific nutrient management in tropical tuber crops and three for the production of cassava fried snacks were transferred to four entrepreneurs in Tamil Nadu and Kerala. Value added fried products and fried chips from cassava and sweet potato on a technology licensing and consultancy mode were given to three firms/individuals 1) Dora Food Industries, Kozhikode, Kerala; 2) JSJ Food Products, Thondernad P.O., Korome, Wayanad and 3) Saji Varkey, Nirappil House, Ramapuram Bazar P.O., Marangad, Kottayam.

Exchange of MoU with M/s Linga Chemicals, Madurai

MoU with Dora Food Industries, Kozhikode

A special paid programme on social science research methodology was also organised. The revenue generated through various activities at the Institutional level in all modes is indicated in Table 4.

Table 4. Revenue generated through technology commercialisation and other professional service functions

Sl. No.	Activity	Revenue generated (₹)
1.	Technology licensing	2,50,000*
2.	Sale of technological products	11,500
3.	Professional training	2,24,423
4.	Consultancy	75,000*
5.	Students fees	24,90,360
	Total	**30,51,283**

*Excluding GST

Technologies/varieties developed

Varieties and potential genotypes

- **Sree Sakthi:** The cassava mosaic disease resistant variety "Sree Sakthi" (IC625794) has been recommended for central release for

cultivation in Tamil Nadu, Andhra Pradhesh, Maharashtra and Kerala under irrigated/rainfed upland for industrial use. It is a non branching variety with a duration of 9-10 months and is completely resistant to cassava mosaic disease caused by the *Indian cassava mosaic virus* and *Sri Lankan cassava mosaic virus*. It has cylindrical tubers with brown skin, cream rind and white flesh colour. It has high starch content of 29% (range: 26-32%). It has an average tuber yield of 43 t ha^{-1} with a potential yield of 80 t ha^{-1}.

- **Sree Suvarna:** The cassava mosaic disease resistant variety "Sree Suvarna" (IC6267768) has been recommended for central release for cultivation in Tamil Nadu, Andhra Pradhesh, Maharashtra and Kerala under irrigated/rainfed upland for industrial use. It is a non branching/ top branching variety with brown stem, dark purple petiole, light brown emerging leaves, conical to cylindrical tubers with brown skin, cream rind and white flesh colour. It has a duration of seven months and is completely resistant to cassava mosaic disease. It has medium starch, 25-27% (Range: 24-29.8%) and low cyanogens (45.01 ppm). It has an average tuber yield of 38 t ha^{-1} with a potential yield of 48 t ha^{-1}.
- Identified 10 high yielding yam bean lines.
- Identified 4 high yielding sweet potato lines.

Production technologies

- Production technology for rice-black gram-short-duration cassava.
- Production technology for rice-short-duration cassava + black gram system.
- Production technology for elephant foot yam + pulse system.
- Drip irrigation along with plastic ground cover mulching or soil application of super absorbent polymers like Pusa hydrogel for reducing the water requirement of elephant foot yam to 50% without adversely affecting the corm yield.
- For upland taro, drip irrigation @ 75% of the CPE for 24 weeks required for proper germination, growth, tuber initiation, tuber development and optimum cormel yield in taro.
- Soil test based application of NPK, Mg, Zn and B.
- Green manuring *in situ* with cowpea, coirpith compost, vermicompost as alternate organic sources to farmyard manure.
- Need based soil application of secondary nutrient Mg and micronutrients, Zn and B based on soil test.
- Four NUE cassava genotypes, 7III E3-5, CI-905, Sree Pavithra and CI-906 for saving NPK fertilizers to the extent of 75-100%.

Protection technologies

- Tuber treatment with Mancozeb 0.2%/ Carbendazim + Mancozeb 0.2% application of *Trichoderma* @ 5g kg^{-1} tuber for the management of post-harvest rot in elephant foot yam.
- IDM package for greater yam anthracnose.
- Optimized techniques on behavioural study of *Bemisia tabaci* in cassava plants.
- Protocol for short term storage of cassava synthetic seed.
- Reliable protocols for genetic transformation of farmer and industry preferred cassava cultivars from India.
- Fifty five lines of transgenic cassava plants having SLCMV RNAi constructs established in ICAR-CTCRI tissue culture facility.
- Standardisation of conditions and medium for hardening of transgenic lines imported from ETH, Zurich.
- Virus resistance assessment of CMD resistant transgenic cassava plants in green house through grafting and particle bombardment.
- Hardened ten transgenic lines (seventy plants) ready to be challenged by particle bombardment.
- Agroclones of *SLCMV* and *ICMV* for rapid screening of transgenics for their resistance against virus infection.
- Four CMD resistant lines through field trial in farmers' fields at Salem.
- LAMP based diagnosis of *SLCMV*.

Technologies for value added food products

- Cassava flour based pasta using low cost protein rich ingredients viz., green peas, Bengal gram, casein, beetroot, soy flour etc.
- Rice analogue from the composite flour containing cassava-maida-whey protein concentrate-guar gum.
- Noodles from cassava–millet based composite flour.

Technologies for industrial products

- Particle board from cassava stem using cross linked cassava starch as binder.
- Particle board from cassava stem using cassava starch-wax as binder.
- Continuous wet pressing screw press for making high quality cassava flour.
- Functional sago using sweet potato leaf powder and beetroot powder.
- Thermoplastic sheet from oxidized cassava starch and cassava starch-wax composites.
- RS4 type resistant starch of cassava and sweet potato of medium glycemic index (55-70), by modification with citric acid.

Models/Packages/ICT tools

- Technology commercialisation strategies assessment framework model for assessing the effectiveness of technology commercialisation strategies of ICAR Institutes/SAU.
- Modified methodology for assessing the sustainable livelihood analysis of tuber crop farmers using DFID methodology.
- R-package for Soil Quality Index.
- Three Mobile Apps: VFT-Cassava, VFT-Taro and *Sree Poshini*.

EDUCATION AND TRAINING

Education

ICAR-CTCRI is recognized as an approved Research Centre by the University of Kerala, Kannur University, Manonmaniam Sundaranar University, Utkal University and Orissa University of Agriculture & Technology, Bhubaneswar, Odisha for undertaking Ph. D. programme on tuber crops. During the period, the Institute has offered exposure training to students, imparted technical guidance for Ph.D. programme 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	118
B.Sc./B.Tech. internship	78
M.Sc. project work	48
M.Sc. Integrated Biotechnology	8
Ph.D.	30
PDF	3

- Dr. T. Krishnakumar passed the National Program on Technology Enhanced Learning (NPTEL) certificate course on 'Dairy and Food Process and Products Technology' with a consolidated score of 77%, conducted by Indian Institute of Technology (IIT), Kharagpur, during July to October 2018, Funded by the Ministry of HRD, Govt. of India.
- Dr. T. Krishnakumar passed Agriculture Massive Open Online Courses (agMOOCs) certificate course (4 weeks) with Distinction on 'Functional Foods: Concept, Technology and Health Benefits', conducted by Indian Institute of Technology (IIT), Kanpur and Commonwealth of Learning, Canada during November 2018.

Training programme

A total of 874 farmers, 426 students and 114 officials from different parts of the country were imparted training by ICAR-CTCRI. They were trained on the improved technologies of tuber crops for enhancing productivity and profitability in tuber crops farming.

On-campus training programmes

- Inter-state ATMA training on 'Improved technologies of tuber crops' as detailed below:

Sl. No.	No. of progressive farmers	Place	Date
1.	25	Gudalur, Nilgiris, Tamil Nadu	10-12 April 2018
2.	24	Gudalur, Nilgiris, Tamil Nadu	17-19 April 2018
3.	25	Thiruvarur, Tamil Nadu	27-29 June 2018
4.	25	Dindigul, Tamil Nadu	30 July–1 August 2018
5.	24	Trichy, Tamil Nadu	04-06 October 2018
6.	26	Pune, Maharashtra	08-10 October 2018
7.	22	Thiruvarur, Tamil Nadu	22-24 October 2018
8.	25	Dapoli, Maharashtra	26-28 February 2019
9.	105	Salem, Tamil Nadu	28 February – 02 March 2019
10.	15	Champaran, Bihar	20-23 March 2019

Participants from Pune, Maharashtra

- Entrepreneurship Development Programme (EDP) for agricultural students jointly organized by ICAR-CTCRI and College of Agriculture, KAU, Vellayani during 24-26 September 2018.
- On-job training on 'Improved technologies of tuber crops' for VHSS students, Thiruvallam, Thiruvananthapuram during 27-29 September 2018.
- RAWE programme for 11 B.Sc. (Ag.) students of College of Agriculture, Padanakkad, Kasaragod during 26-30 October 2018.

Participants of RAWE programme

- Stakeholders Interface Programme in connection with Tuber Crops Day and Farmers' Fair during 22-23 November 2018 at ICAR-CTCRI for the benefit of more than 150 farmers and other stakeholders.

Stakeholders' interface in connection with Tuber Crops Day

- Farmers day (Kisan Diwas) was celebrated on 23 December 2018 at ICAR-CTCRI for the benefit of more than 50 farmers and other stakeholders.

Participants of Kisan Diwas

- Training on Priority Setting, Monitoring and Evaluation of Agricultural Research Projects was jointly organized by ICAR-CTCRI and College of Agriculture, KAU, Vellayani on 19 January 2019 for PG and Ph.D. students (122 nos.) from College of Agriculture, Vellayani.

Inauguration of the Training on Priority setting, monitoring and evaluation of research projects to PG & Ph.D. students

- Training on Soil Analysis was conducted during 04-08 February 2019 for 20 officials of Soil Testing Laboratories of Kerala state. The participants included Scientific Assistants, Agricultural Officers and Assistant Soil Chemists of District and Mobile Soil Testing Laboratories in different districts of Kerala. The programme was conducted under the Soil Health Card Scheme 2018-2019 of National Mission for Sustainable Agriculture.

Participants of the training on Soil Analysis

- Stakeholders Interface in connection with ***"Pradhan Mantri Kisan Samman Nidhi" (PM-KISAN)***-cum-Live-web telecast on 24 February 2019 for the benefit of more than 500 farmers and other stakeholders.

Stakeholders Interface in connection with *PM-KISAN*-cum-Live-web telecast

Off-campus training programme

- Stakeholders Interface Programme on 'Improved technologies of elephant foot yam' was organized on 08 August 2018 in East Godavari district of Andhra Pradesh for the benefit of 80 farmers.
- Entrepreneurship Development Programme on Tuber Crops Technologies organized on 07 September 2018 at Mukoodal, Tirunelveli, Tamil Nadu for the benefit of 100 farmers and other stakeholders
- A Stakeholder Meet and Entrepreneurship Development Programme on Tuber Crop Technologies was organized on 01 December 2018 in collaboration with NEHU and KVK, West Garo Hills at SMELC Building, Dakopgre, Tura.
- A Stakeholder Meet and Entrepreneurship Development Programme on Tuber Crop Technologies was organized on 05 December 2018 in collaboration with KVK, Namsai at KVK, Namsai.
- Field day-cum-entrepreneurship meet on Chinese Potato was organized on 11 January 2019 at Alvan Thulukapatti, Alankulam, Tirunelveli dt of Tamil Nadu for the benefit of 100 farmers and other stakeholders.
- Stakeholders Interface Programme on 'Improved technologies of elephant foot yam' was organized on 13 February 2019 at Savaram village in West Godavari district of Andhra Pradesh for the benefit of 60 farmers and other stakeholders.
- Training module on 'Business plan development and bankable projects' was jointly organized by ICAR-CTCRI and College of Agriculture,

Trainee participants of AC & ABC scheme

KAU, Vellayani in connection with Agriclinic and Agribusiness Center scheme (AC & ABC) training during 25 February-03 March 2019 at College of Agriculture, Vellayani, Thiruvananthapuram.

In-house training for technical personnel and skilled support staff of ICAR-CTCRI

- Refresher training on 'Improved technologies of tuber crops' was organized for 28 technical personnel of ICAR-CTCRI during 08 to 10 January 2019 at ICAR-CTCRI, Thiruvananthapuram. The classes were handled by the scientists and other staff of the institute. Training and exposures were given to them in all the research and extension activities undertaken by the Institute.

Participants of the in-house training to technical personnel

- Training on 'Enhancing personal efficiency in job performance' was organized for 23 skilled support staff during 04 to 06 February 2019 at ICAR-CTCRI, Thiruvananthapuram. The classes were handled by the scientists and other staff of the Institute. Exposure was given to them in all research and extension activities undertaken by the Institute.

Participants of the in-house training to skilled support staff

Trainings organized by Techno-Incubation Centre, ICAR-CTCRI

- Thirty six on-campus training programme were organized at the Techno-incubation centre of ICAR-CTCRI, which were attended by about 926 participants (535 females and 391 males).
- Six off-campus training programmes were organised on tuber crops based food products at Kunnathukal, Pedikulam, Vamanapuram, Parassala, Poovachal and Nemom in Thiruvananthapuram district in coordination with Kudumbasree Mission, Govt. of Kerala.

On-campus and off-campus trainings conducted by Techno-Incubation Centre, ICAR-CTCRI.

- A one day seminar on 'Technological Empowerment of Women for Entrepreneurship Development in Tuber Crops based Value

Added Products' was organised on 26 July 2018 at ICAR-CTCRI, Thiruvananthapuram.

Trainings at ICAR-CTCRI RC, Bhubaneswar

- Training programme on 'Tuber crops technologies' for 22 M.Sc. (Life Science) students from Vidyasagar University, Midnapur, West Bengal on 04 June 2018.
- RAWE programme for final year B.Sc. (Ag.) students of the Institute of Agricultural Sciences, SOA, Bhubaneswar during 05-12 November 2018.
- Training on 'Improved technologies of tuber crops' for 52 progressive farmers of Bolangir district of Odisha on 20 June 2018.
- Training on 'Improved technologies of tuber crops' for 97 progressive farmers of Malkhangiri district of Odisha on 01 August 2018.
- Training on 'Improved technologies of tuber crops' for 30 progressive farmers of Balianta and Balipatna of Odisha on 31 August 2018.
- Training programme to the farmers of OTELP and IDTA, Koraput: A three days training on 'Tuber crops technologies and exposure visit' during 30 October 2018–01 November 2018.
- Training on 'Improved technologies of tuber crops'for 36 progressive farmers from different parts of Odisha on 15 November 2018.
- Training on 'Improved technologies of tuber crops' for 40 unemployed youths from different parts of Odisha on14 December 2018.
- Training on 'Improved technologies of tuber crops' for 40 farmers from Dhenkanal of Odisha on 27 December 2018.
- Tuber Crops Day at Chandragiri village, Mohana Block, Gajapati (Aspirational district) Odisha on 09 January 2019.
- Brain Storming Workshop on 'Tuber crops area expansion: Scope and prospects in Odisha' on 28 January 2019.
- Training programme on 'Processing and value addition of tuber crops'; A three days training programme supported by NABARD under CAT programme during 07-09 March 2019.
- A three days' training programme on 'Tuber crops technology for livelihood and nutritional security in watershed areas' was organized during 26-28 March 2019.
- Five on-campus trainings for about 100 people and one off-campus training for 60 people were organised at the Techno-Incubation Centre, Regional Centre, Bhubaneswar.

Trainings conducted by Techno-Incubation Centre, ICAR-CTCRI Regional Centre, Bhubaneswar, Odisha

Professional attachment training of newly recruited ARS Scientist

- Ms. Bhagya Vijayan, Scientist (Agricultural Extension), ICAR-Central Soil Salinity Research Institute, Karnal, Haryana has undergone professional attachment training during 16 April to 16 July 2018 at ICAR-CTCRI under the guidance of Dr. P. Sethuraman Sivakumar, Principal Scientist and Dr. D. Jaganathan, Scientist.
- Dr. Pampi Paul, Scientist (Agricultural Extension), ICAR Research Complex for NEH Region, Umiam, Meghalaya has undergone professional attachment training during 12 November 2018 to 11 February 2019 at ICAR-CTCRI under the guidance of Dr. P. Sethuraman Sivakumar, Principal Scientist and Dr. D. Jaganathan, Scientist.

Resource person in training programme

More than 200 classes on production, protection, processing and value addition aspects were handled by scientists of various divisions under different programme 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, postharvest management and value addition.

Exposure visit-cum-training programme

One day exposure visit-cum-training on 'Improved technologies of tuber crops' was organized for the benefit of 1223 farmers, 1464 students and 100 officials across the nation at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram. Exposure visits to the Institute were organized for the state department of agriculture/farmers' organizations. State wise number of farmers who visited the Institute for exposure visit is given in Fig. a. A total of 854 farmers from Kerala visited the Institute followed by Tamil Nadu (167), Andhra Pradesh (138) and other states (64). Similarly 100 officials and 1464 students from different parts of the country visited ICAR-CTCRI on exposure visits as given in Fig. b.

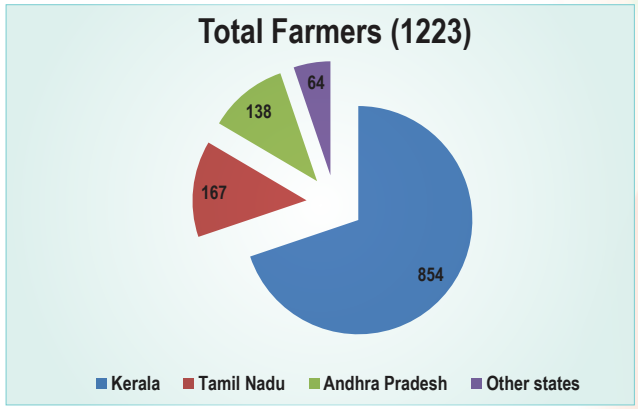


Fig. a. State wise exposure visits of the farmers to ICAR-CTCRI

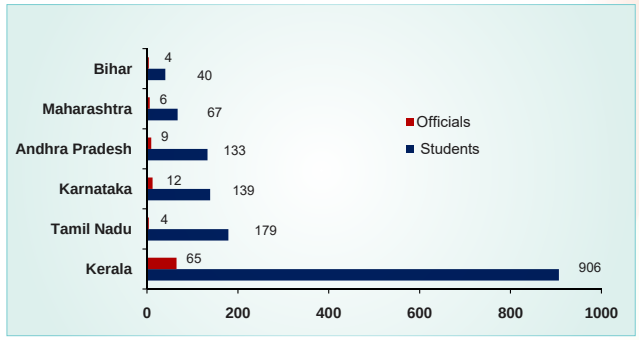


Fig. b. State wise exposure visits of the officials and students to ICAR-CTCRI

Farmers from Thiruvarur, Tamil Nadu

Farmers from West Godavari, Andhra Pradesh

Farmers from Kerala

Farmers from East Champaran, Bihar

Trainings attended by ICAR-CTCRI Staff

a. Scientific staff

Sl. No.	Name	Particulars of the training	Period
1	Dr. H. Kesava Kumar Dr. D. Jaganathan Dr. T. Krishnakumar Dr. K.M. Senthilkumar	Hindi Prabodh Contact Programme-II, All India Radio, Vazhuthacaud, Thiruvananthapuram	16-17 April 2018
2	Dr. P.S. Sivakumar	MDP on Supply Chain Analytics, Indian Institute of Management, Lucknow – Noida Campus	29-31 August 2018
3	Dr.Venkatraman Bansode	Food safety and Quality Management of Food Products with reference to HACCP, Value Addition and Quality Standards at Centre for Food Science and Technology, Banaras Hindu University, Varanasi, Uttar Pradesh	04 -24 September 2018
4	Dr. K. Susan John	Integrated Nutrient Management and Nutrient Budgeting through Advanced Models to Improve Crop Productivity at ICAR-Indian Institute of Soil and Water Conservation Research Centre, Ooty	22-26 October 2018
5	Dr. D. Jaganathan	Socio-economic Impact Assessment of Research Programmes at ICAR-National Academy of Agricultural Research Management, Hyderabad	25-27 October 2018
6	Dr. Vivek Hegde	Contemporary Approaches to Plant Genetic Resources Management at ICAR-National Bureau of Plant Genetic Resources, New Delhi	27 November-17 December 2018
7	Dr. B.G. Sangeetha	Next Generation Sequencing and its Applicaations in Plant Sciences at ICAR-National Research Centre for Plant Biotechnology, Pusa Campus, New Delhi	01-22 December 2018
8	Dr. M.L. Jeeva Dr. T. Makesh Kumar Dr. C. Mohan Dr. Saravanan Raju Dr. H. Kesava Kumar Dr. D. Jaganathan Dr. T. Krishnakumar	Hindi Praveen Contact Programme-I, AG's Office, Thiruvananthapuram	16-18 December 2018
9	Dr. T. Srinivas	Improving eGovernance in Agriculture at MANAGE, Hyderabad	04-08 February 2019
10	Dr. V.B.S. Chauhan	CAFT on Modern Statistical Techniques in Genetics at ICAR-Indian Agricultural Statistics Research Institute, New Delhi	01-21 February 2019

11	Dr. T. Krishnakumar Dr. D. Jaganathan	Analysis of Experimental Data using R at ICAR-National Academy of Agricultural Research Management, Hyderabad	21-26 February 2019
12	Dr. Vivek Hegde	Advances in Plant Biotechnology and Molecular Biology, Module II at ICAR - Research Complex for NEH Region Manipur Centre, Lamphelpat, Imphal, Manipur	05-11 March 2019

b. Technical staff

Sl.No.	Name	Particulars of the training	Period
1	Dr. S. Karhikeyan, Technical Assistant	Hospitality Management at ICAR-National Academy of Agricultural Research Management, Hyderabad	20-25 April 2018
2	Shri. K. Sunil Technical Assistant (Driver)	Automobile Maintenance, Road Safety and Behavioural Skills at ICAR-Central Institute of Agricultural Engineering, Bhopal	17-23 July 2018
3	Shri. S. Natarajan Technical Officer	Farm Management at ICAR-Indian Institute of Farming Systems Research, Modipuram, Uttar Pradesh	14-20 August 2018
4	Shri. Sushant Kumar Jata Junior Farm Superintendent	Recent Advances in Pressurized Irrigation System for Enhancing Water Use Efficiency at Orissa University of Agriculture and Technology, Bhubaneswar	30 October-08 November 2018
5	Shri. R. Bharathan, Chief Technical Officer Shri. V. S. Sreekumar, Senior Technical Officer 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 Shri. C.S. Salimon, Assistant Chief Technical Officer Shri. V.R. Sasankan, Senior Technical Officer Shri. B. Renjith Kishor, Senior Technical Officer Shri. V. Ganesh, 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	Refresher Training on Improved Technologies of Tuber Crops for technical personnel of ICAR- CTCRI	08-10 January 2019

	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, Technician		
6	Shri. V. Ganesh, Technical Officer	Motivation, Positive Thinking, Communication Skills and Personality Development for Technical Officers of ICAR Institution at ICAR-National Academy of Agricultural Research Management, Hyderabad	13-19 March 2019

c. Administrative staff

Sl.No.	Name	Particulars of the training	Period
1	Shri. Abhishek Rana, SAO	MDP on Administrative & Financial Management at ICAR-Indian Agricultural Statistics Research Institute, New Delhi	09-12 October 2018
2	Shri.Abhishek Rana, SAO	Programme on Pension & Other Retirement Benefits at Institute of Secretariat Training and Management, New Delhi	10-14 December 2018
3	Shri.Abhishek Rana, SAO Shri. P. Krishnakumaran, FAO Shri.T.V. Kurup, AAO	Sensitization/Training Programme for E-Office at ICAR-Indian Agricultural Statistics Research Institute, New Delhi	23-24 January 2019

d. Skilled support staff

Sl.No.	Name	Particulars of the training	Period
1	Shri. S. Radhakrishnan Nair Shri. D. Arun Raj Shri. S. Abhishek Shri. P. Aswin Raj Shri. A. Chandran Shri. T. Lawrence Shri. K. Sivadas Smt. S. Ushakumari Smt. J. Thenmozhi Shri. S. Sudhish Shri. Stiphin George Shri. Sreenath Vijay Shri. K. Sarathchandra Kumar Shri. L. Samynathan Ms. Rohini K. Nair Smt. Rini Alocious Smt. V.S. Remya Shri. G. Madhu Ms. C.P. Gayathri Smt. Nijamol R. Ms. Anjitha S. Smt. C.T. Chellamma Shri. K. Chandran	Enhancing Personal Efficiency in Job Performance for Skilled Support Staff of ICAR-CTCRI	04-06 February 2019

AWARDS AND RECOGNITIONS

Awards

- ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram bagged the 'Best Annual Report Award' under Small Institutes category.

Dr. Archana Mukherjee, Director, ICAR-CTCRI, receiving the Best Annual Report Award from Shri. Radha Mohan Singh, Hon'ble Union Minister for Agriculture & Farmers' Welfare in the presence of Dr. T. Mohapatra, DG, ICAR & other dignitaries

Best Annual Report Award 2017-18
(For Small Institute)

ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram has been awarded the Best Annual Report Award 2017-18 in the category of small institutes of ICAR. The ICAR- Central Tuber Crops Research Institute (ICAR-CTCRI) was established during the Third Five Year Plan in July 1963 at Sreekariyam, Thiruvananthapuram, Kerala and its Regional Centre was set up at Bhubaneswar, Odisha in 1976. The institute is continuing its 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.

The ICAR-CTCRI is the unique institute in the world which is solely dedicated to the research on tropical tuber crops. The Annual Report 2017-18 of the institute is adjudged best for its quality of content exhibiting originality, innovation and creativity. The impact of the research done is also clearly visible through lucid photographs, vivid graphical representations of important analysis, events & achievements. The details of the on-going activities and research papers published are cited with impressive illustrations. The information related to Annual Meetings, Foundation Day Celebrations, Workshops, Technology Conclaves and Seminars, etc. has been summarized adequately. The Annual Report was published in time, giving clear insight of research planning and future areas of thrust.

The citation of the award

Indian Council of Agricultural Research

Certificate

BEST ANNUAL REPORT AWARD 2017-18
(For Small Institute Category)

is presented to

ICAR-Central Tuber Crops Research Institute (CTCRI)
Thiruvananthapuram, Kerala

31st January, 2019
New Delhi

T. Mohapatra
Secretary (DARE) &
Director General (ICAR)

(Radha Mohan Singh)
Minister of Agriculture & Farmers Welfare
Govt. of India

The certificate of the award

Director with the Chief Editor, Ravi, V., and Co-editors, Jeeva, M.L., Jyothi, A.N., Ramesh, V., Asha Devi, A., Jaganathan, D., Sanket J. More, Hanume Gowda K., Karthikeyan, S. and Prakash Krishnan, B.S.

- Dr. G. Suja received the 'Indian Society of Agronomy (ISA) Fellow Award 2015' from the Indian Society of Agronomy, New Delhi in the 'National Symposium on Doubling Farmers' Income through Agronomic Interventions under Changing Scenario', held during 24-26 October 2018 at the Maharana Pratap University

of Agriculture and Technology, Udaipur, Rajasthan.

Dr. G. Suja receiving the ISA Fellow Award from Dr. Ramesh Chand, Member, NITI Aayog

- Dr. P. Murugesan was conferred as Fellow of the Indian Society of Seed Technology during the valedictory function of 'National Seminar on Strengthening of Seed Systems in the North-Eastern and Unreached Regions – Problems, Prospects and Policies' on 05 February 2019 at Imphal, Manipur.

Dr. P. Murugesan was conferred with Fellow of the Indian Society of Seed Technology

- Dr. K. Susan John secured the first place and won the 'International Plant Nutrition Institute (IPNI) Photo Contest Award 2018' in the category of micronutrient deficiency of crops for B deficiency in sweet potato. The award carried a cash award of USD 150, certificate and a USB flash drive collection of nutrient disorder images.

Typical B deficiency symptoms in sweet potato

- Dr. P. Murugesan was awarded the Best Poster Award for the research paper entitled 'Integration of digital image analysis for seed quality evaluation in sweet potato' (Authors: P. Murugesan, Archana Mukherjee, M.N. Sheela, V. Ravi, C. Visalakshi Chandra, H. Kesava Kumar, T. Krishnakumar, J. Sreekumar, Sheela Immanuel, P.S. Sivakumar and V.S. Santhosh Mithra) in the 'National Seminar on Strengthening of Seed Systems in the North-Eastern and Unreached Regions–Problems, Prospects and Policies' on 05 February 2019 at ICAR-Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal.
- Dr. Vivek Hegde was awarded the Best Poster Award for the research paper on 'Long term pollen storage studies in cassava and greater yam' in the 8th Indian Horticulture Congress held during 17-21 January 2019 at Indira Gandhi Krishi Viswavidyalaya, Raipur, Chhattisgarh.
- Dr. G. Suja received the Best Poster Award for the research paper titled 'Conservation agriculture-based sustainable intensification of elephant foot yam + banana system for resilience under climate change' (Authors: K. Remya and G. Suja) in the 'National Seminar on Abiotic Stress Management: Challenges and Opportunities' held during 25-26 October 2018 at Tamil Nadu Agricultural University, Coimbatore.
- Dr. K. Susan John won the Dr. R.L. Narasimha Swamy Memorial Award for the Best Research Paper on 'Nutrient partitioning in root wilt disease affected *vis a vis* healthy coconut palms grown in an Entisol of humid

tropics' (Authors: Jeena Mathew, A. Abdul Haris, Chinju M. Raj, V. Krishna Kumar, Ravi Bhat, K. Muralidharan and K. Susan John) in the PLACROSYM XXIII, held during 06-08 March 2019 at Central Coffee Research Institute, Chikkamagaluru, Karnataka.

- Dr. Sanket J. More received the Best Ph.D. Thesis Award from Gujarat Association for Agricultural Sciences, Ahmedabad, Gujarat for the academic year 2014-2015.
- Dr. S.S. Veena won the Best Oral Presentation Award for the research paper entitled 'Progress and prospects of leaf blight management in taro (*Colocasia esculenta* (L.) Schott)' (Authors: S.S. Veena, M.L. Jeeva, A. Asha Devi, J. Sreekumar and R.S Misra) in the 'National Symposium on Cutting Edge Approaches for Sustainable Plant Disease Management and Ensuring Farmers Profit' held during 21-23 December 2018 at ICAR-National Research Centre for Banana, Tiruchirappalli, Tamil Nadu.

Dr. S.S. Veena receiving the Best Oral Presentation Award

- Mrs. M.G. Sujina won the Best Oral Presentation Award for the research paper entitled 'Utilisation and characterization of a fungal endophyte *Nigrospora oryzae* against *Phytophthora colocasiae* causing taro leaf blight' (Authors: M.G. Sujina, M.L. Jeeva, G.L. Sreelatha, N. Shahana and S.S. Veena) in the 'National Symposium on Cutting Edge Approaches for Sustainable Plant Disease Management and Ensuring Farmers Profit' held during 21-23 December 2018 at ICAR-National Research Centre for Banana, Tiruchirappalli, Tamil Nadu.
- Ms. Sruthy G.S. won the Best Oral Presentation Award for the research paper entitled 'Cloning and expression of coat protein gene of *sweet potato leaf curl virus (SPLCV)*' (Authors: G.S. Sruthy and T. Makeshkumar) in the 'National Symposium on Cutting Edge Approaches for Sustainable Plant Disease Management and Ensuring Farmers Profit' held during 21-23 December 2018 at ICAR-National Research Centre for Banana, Tiruchirappalli, Tamil Nadu.
- Mrs. M.G. Sujina won the Best Oral Presentation Award for the research paper entitled 'Purification and characterization of antifungal compound from endophytic *Bacillus subtilis* isolated from *Vitex negundo*' (Authors: M.G. Sujina, M.L. Jeeva, G.L. Sreelatha, and P.R. Amrutha) in the 'National Conference on Novel Technologies for Sustainable Agriculture and Allied Industries (NMTSSI)', held during 28-29 January 2019 at Chidambaram, Tamil Nadu.
- Mr. P. Prakash received Dr. N.A. Mujumdar Prize Award for Best Oral Research Paper titled 'Does APMC market increase farmers income? Evidence from value chain analysis of sweet potato in Karnataka' (Authors: P. Prakash, D. Jaganathan, P.S. Sivakumar, Sheela Immanuel, Prabhat Kishore and Pramod Kumar) in the 78th Annual Conference of Indian Society of Agricultural Economics held during 01-03 November 2018, organized by the Institute of Economic Growth and International Food Policy Research Institute, New Delhi.
- Dr. H. Kesava Kumar was felicitated by Advocate Shri. V.S. Sunil Kumar, Honourable Minister for Agriculture and Farmers' Welfare, Kerala, for his contributions in the selection of State Agricultural Awards 2018 on the occasion of VAIGA and Krishi Unnati Mela 2018 at Thrissur on 30 December 2018.
- Dr. Sanket J. More bagged the third prize in the extempore speech (Hindi Speaking State category) during the Hindi competitions organized by the Town Official Language Implementation Committee, Thiruvananthapuram, in connection with the Joint Hindi Fortnight Celebrations 2018.
- ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, bagged the second

prize in the category of 'Best Exhibition Stall Award' in VAIGA & Krishi Unnati Mela - International Workshop and Exhibition on Agro-processing and Value Addition held during 27-30 December 2018 at Thekkinkadu Maidanam, Thrissur, Kerala.

ICAR-CTCRI bagged second prize in the category of 'Best Exhibition Stall Award' in VAIGA

- ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, bagged the first prize in the category of 'Best Exhibition Stall Award' in the National Horticultural Fair held during 23-25 January 2019 at ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru.
- ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, bagged the first prize in the category of 'Best Exhibition Stall Award' in Krishidham Expo held during 15-17 February 2019 at ICAR-Central Potato Research Institute, Regional Station, Modipuram, Meerut, Uttar Pradesh.

ICAR-CTCRI bagged first prize in the category of 'Best Exhibition Stall Award'

Award of Ph.D.

- Mrs. Chithra S. was awarded Ph.D. in Environmental Sciences from University of Kerala for the thesis entitled 'Cassava starch factory solid waste (Thippi): Prospects on utilization for nutrient recycling in cassava cultivation' under the guidance of Dr. K. Susan John.
- Mrs. Seena Radhakrishnan A.R. was awarded Ph.D. in Environmental Sciences from University of Kerala for the thesis entitled 'Evaluation of agronomic, nutritional and socio-economic impacts of organic production of cassava (*Manihot esculenta* Crantz)' under the guidance of Dr. G. Suja.
- Mrs. Pravi Vidyadharan was awarded Ph.D. in Biotechnology from University of Kerala, for the thesis entitled 'Molecular diagnosis and characterization of *Sclerotium rolfsii* causing collar rot disease in *Amorphophallus paeoniifolius'* under the guidance of Dr. M.L. Jeeva.
- Mrs. Archana P.V. was awarded Ph.D. in Biotechnology from University of Kerala, for the thesis entitled 'Molecular diagnosis and characterization of *Phytophthora colocasiae* causing leaf blight disease of taro' under the guidance of Dr. M.L. Jeeva.
- Mrs. Pooja N.S. was awarded Ph.D. in Biotechnology from University of Kerala, for the thesis entitled 'Utilization of agricultural residues from cassava for lignocellulosic ethanol production' under the guidance of Dr. M.L. Jeeva and co-guidance of Dr. G. Padmaja.

Award of M.Sc. Biotechnology/Biochemistry/ B.Sc.-M.Sc. (Integrated) Biotechnology

- Ms. Anjitha Nair U.M. was awarded B. Sc.-M. Sc. (Integrated) Biotechnology from College of Agriculture, Vellayani. The project work was done on the topic, 'Identification of molecular markers for resistance to taro leaf blight in *Colocasia esculenta* L. Schott.' at ICAR-CTCRI under the guidance of Dr. A. Asha Devi.
- Ms. Arya R.S. was awarded B. Sc.-M. Sc. (Integrated) Biotechnology from College of

Agriculture, Vellayani. The project work was done on the topic, 'Identification of molecular markers linked to anthracnose resistance in greater yam' at ICAR-CTCRI under the guidance of Dr. M.N. Sheela.

- Ms. Gargi Sadan was awarded B. Sc.-M. Sc. (Integrated) Biotechnology from College of Agriculture, Vellayani. The project work was done on the topic, 'Molecular marker analysis for cassava mosaic disease resistance' at ICAR-CTCRI under the guidance of Dr. M.N. Sheela.
- Mr. Bimal Thomas was awarded B. Sc.-M. Sc. (Integrated) Biotechnology from College of Agriculture, Vellayani. The project work was done on the topic, 'Characterization of selected *Curcuma* species germplasm using morphological and molecular markers' at ICAR-CTCRI under the guidance of Dr. K.I. Asha.
- Ms. Jijisree A. was awarded M.Sc. in Biotechnology from University of Kerala. The project work was done on the topic, 'Micropropagation and transformation of CMD resistant lines of cassava (*Manihot esculenta* Crantz)' at ICAR-CTCRI under the guidance of Dr. Krishna Radhika N.
- Mr. Vipinkumar S.L. was awarded M.Sc. in Biotechnology from University of Kerala. The project work was done on the topic, '*In vitro* conservation of selected CMD resistant cassava (*Manihot esculenta* Crantz) accessions' at ICAR-CTCRI under the guidance of Dr. Krishna Radhika N.
- Ms. Arya Ajay was awarded M.Sc. in Biotechnology from University of Kerala. The project work was done on the topic, 'Morphological and molecular characterisation of selected accessions of cassava (*Manihot esculenta* Crantz) germplasm' at ICAR-CTCRI under the guidance of Dr. K.I. Asha.
- Ms. Dolly Pradhan was awarded M.Sc. in Biotechnology from Utkal University, Bhubaneswar, Odisha. The project work was done on the topic, '*In vitro* screening for salt tolerance in taro (*Colocasia esculenta* L.)' at ICAR-CTCRI, Regional Centre, Bhubaneswar, under the guidance of Dr. V.B.S. Chauhan.
- Ms. Udiptanita Rath was awarded M.Sc. in Biotechnology from Utkal University, Bhubaneswar, Odisha. The project work was done on the topic, '*In vitro* screening for drought tolerance in taro (*Colocasia esculenta* L.)'at ICAR-CTCRI, Regional Centre, Bhubaneswar, under the guidance of Dr. V.B.S. Chauhan.
- Ms. Arpita Aradhana Das was awarded M.Sc. in Biotechnology from Rama Devi Women's University, Odisha. The project work was done on the topic, '*In vitro* screening for salt tolerance in cassava' at ICAR-CTCRI, Regional Centre, Bhubaneswar under the guidance of Dr. Kalidas Pati.
- Ms. Swapna Sagarika Gumansingh was awarded M.Sc. in Biotechnology from Rama Devi Women's University, Odisha. The project work was done on the topic, '*In vitro* screening for drought tolerance in cassava' at ICAR-CTCRI, Regional Centre, Bhubaneswar under the guidance of Dr. Kalidas Pati.
- Ms. Amina, A.T. was awarded M.Sc. in Biotechnology from University of Kerala. The project work was done on the topic, 'Genome analysis, identification and characterization of *MeGRAS* family gene in cassava (*Manihot esculenta* Crantz) at ICAR-CTCRI under the guidance of Dr. Senthilkumar K.M.
- Ms. Pushpitha P. was awarded M.Sc. in Biotechnology from University of Kerala. The project work was done on the topic, 'Genome wide analysis, identification and characterization of *MeHSP70* genes in cassava (*Manihot esculenta* Crantz) at ICAR-CTCRI under the guidance of Dr. Senthilkumar K.M.
- Ms. Shahina S. was awarded M.Sc. in Biotechnology from University of Kerala. The project work was done on the topic, 'Genome analysis, identification and characterization of *MeMADS*-box family genes in cassava (*Manihot esculenta* Crantz) at ICAR-CTCRI under the guidance of Dr. Senthilkumar K.M.
- Ms. Geethu Mohan was awarded M.Sc. in Biochemistry from University of Kerala. The project work was done on the topic, 'Biochemical, mineral and proximate composition of cassava varieties' at ICAR-CTCRI under the guidance of Dr. G. Byju.

- Mr. Muhammed Faiz M. was awarded M.Sc. in Biochemistry from University of Kerala. The project work was done on the topic, 'Nutrient enrichment of biochar and its effect on nutrient mobilization in an ultisol' at ICAR-CTCRI under the guidance of Dr. G. Byju.
- Mr. Altaf F.S. was awarded M.Sc. in Biochemistry from University of Kerala. The project work was done on the topic, 'Site specific nutrient management of elephant foot yam on soil biochemistry and soil quality' at ICAR-CTCRI under the guidance of Dr. G. Byju.
- Ms. Aswathy H.S. was awarded M.Sc. in Biochemistry from University of Kerala. The project work was done on the topic, 'Spatial variation in post-harvest soil and plant attributes under different tuber crops' at ICAR-CTCRI under the guidance of Dr. K. Susan John.
- Mr. Suvin Surendran was awarded M.Sc. in Biochemistry from University of Kerala. The project entitled 'Soil enzyme activity and tuber proximate analysis in cassava (*Manihot esculenta* Crantz) varieties under organic management was done at ICAR-CTCRI under the guidance of Dr. G. Suja.
- Ms. Shahana, N. was awarded B.Sc.-M.Sc. (Integrated) Biotechnology from Kerala Agricultural University. The thesis work was done on the topic, 'Identification and characterization of endophytes from tropical tuber crops against *Colletotrichum gloeosporioides* (Penz.) Sacc. causing anthracnose in greater yam (*Dioscorea alata* L.)" at ICAR-CTCRI under the guidance of Dr. M.L. Jeeva.
- Ms. Adithya V. was awarded B.Sc.-M.Sc. (Integrated) Biotechnology from Kerala Agricultural University. The thesis work was done on the topic, 'Molecular characterization of pathogens associated with post-harvest diseases in elephant foot yam'at ICAR-CTCRI under the guidance of Dr. S.S. Veena.
- Mr. Achuth P. Jayaraj was awarded M.Sc. (Integrated Biotechnology) from Kerala Agricultural University on the topic 'Physiological and molecular studies on cyanogenic potential in cassava (*Manihot esculenta* Crantz) in response to nitrogen nutrition, water stress and shade'. The work was done at ICAR-CTCRI under the guidance of Dr. Saravanan Raju.
- Ms. Reshma was awarded M. Sc. in Food Technology and Quality Assurance from Mahatma Gandhi University, Kottayam for the project work entitled 'Development of anti-oxidant and dietary fibre rich functional sago using beetroot powder' at ICAR-CTCRI under the guidance of Dr. T. Krishnakumar.
- Ms. Shafana. S. was awarded M.Sc. in Food Science and Technology from Kerala University of Fisheries and Ocean Studies (KUFOS) for the project work entitled 'Development of anti-oxidant and dietary fibre rich functional sago using sweet potato leaves powder''at ICAR-CTCRI under the guidance of Dr. T. Krishnakumar.
- Ms. Jyothi Raj was awarded M.Sc. in Food Technology and Quality Assurance from the Mahatma Gandhi University, Kottayam for the project work entitled 'Effects of power ultrasound treatment on physico-chemical and functional properties of tuber starches' at ICAR-CTCRI under the guidance of Dr. T. Krishnakumar.

Recognitions

Dr. Archana Mukherjee

- Chairperson, Asia Sweet potato Breeders and Seed Systems Meeting (ASPSSM-2018) held at ICAR–CTCRI, Thiruvananthapuram, during 28-31 May 2018.
- Chairperson, Session on Agribusiness Venture: Agriculture, Horticulture, Forestry and Food Processing at the National Agri-Business Entrepreneurship Conclave (NABEC-2019): Building Agri-Business Start-Up Ecosystem organized at Umiam, Meghalaya during 09-11 February 2019.
- Technical Adsvisor, FSN, MSSRF, Chennai.
- Member, State Level Project Screening Committee (SLPSC), RKVY, Govt. of Kerala.
- President, Indian Society for Root Crops.
- Delivered a lead lecture on 'Tropical tubers: Journey from Life saving food to Future smart crops' during 8th Horticultural Congress at

Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh during 17-21 January 2019.

- Panelist, Technical Assistance and Research for Indian Nutrition and Agriculture (TARINA) on 31 January 2019, New Delhi
- Delivered a lead lecture on 'Ascent to entrepreneurship development and commercialization with roots and tuber crops' at the National Agri-Business Entrepreneurship Conclave (NABEC-2019): Building Agri-Business Start-Up Ecosystem organized at Umiam, Meghalaya during 09-11 February 2019.
- Delivered a key note address 'Journey of tropical tuber crops from food, nutrition security to agripreneurship' in connection with K.V. George Memorial Lecture Series-X, at St. Thomas College, Kozhencherry, Kerala on 01 March 2019.
- Inaugurated the Workshop on 'Applied Statistics and Data Analysis for Science and Society' during 14-16 March 2019 organized by Department of Agricultural Statistics, College of Agriculture, Vellayani, Kerala Agricultural University and delivered the keynote address.
- Chief Guest of the valedictory function of the two months training programme on Agripreneurship sponsored by MANAGE, Government of India, at College of Agriculture Vellayani, Kerala Agricultural University on 28 March 2019.
- Reviewer, *Agricultural Research*.

Dr. James George

- Delivered an invited lecture in the 'National Congress on Intensification and Diversification in Agriculture for Livelihood and Rural Development' at Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, on 29 May 2018.

Division of Crop Improvement

Dr. M.N. Sheela

- Secretary, Indian Society for Root Crops.
- Member, Board of Studies, Faculty of Agriculture, Kerala Agricultural University.
- Chairperson, Departmental Promotion Committee (DPC) for the Technical Staff category-II (Field/Farm Technician) at ICAR-National Research Centre for Banana, Tiruchirappalli.
- Special Invitee, Symposium on Reshaping Agriculture for Better Nutrition-The Agriculture, Food, Nutrition, Health Nexus organized by ICRISAT during 06-07 September 2018 at ICRISAT, Hyderabad.
- Special Invitee, ISCB Symposium on Enhancing the Farm Income through Biotechnological Innovations and Socio-economic Research in India and presented a paper on 'Recent advances in cassava improvement in ISCB', during 03-04 December 2018 at New Delhi.
- External examiner for the evaluation of theses and conduct of final viva-voce examination of Ph.D. programme of two students, Kerala Agricultural University.
- Technical expert, Biodiversity Impact Assessment Consultative Meetings organised by the Kerala Biodiversity Board on 04 September 2018 and 17 January 2019 at Thiruvananthapuram.
- ICAR nominee, DPC Meeting for Career Assessment of Scientists of ICAR-Indian Institute of Spices Research on 26 March 2019, at ICAR-Indian Institute of Spices Research, Kozhikode.

Dr. K.I. Asha

- External expert, selection of Research Fellow for the project funded by DST-SERB at the Department of Botany, University of Kerala, Thiruvananthapuram, on 23 April 2018.
- As Chairman, Board of Adjudicators, conducted the Pre-submission viva-voce of the Ph.D. thesis of Smt. Remya Krishnan R.V. at the Department of Botany, University of Kerala, Kariavattom, Thiruvananthapuram, on 06 June 2018.
- External expert, assessment of Ms. Manjula K.K., Research Scholar, Department of Botany, University of Kerala, for up-gradation of CSIR-JRF to SRF, on 10 October 2018.
- Reviewer, *Journal of Root Crops*.

Dr. P. Murugesan

- Chairman, technical session on 'Horticultural technologies for climate resilience and

productivity' in the National Symposium on Horticulture in the Vanguard of Climate Change and Urban Environment organized during 07-08 February 2019 by the Department of Horticulture, Annamalai University, Chidambaram, Tamil Nadu.

- Member, Expert Panel for Technical Paper Evaluation Committee, 31st Kerala Science Congress (KSC) 2019.
- Delivered a lead lecture on 'Genetic resources of unexploited horticultural crops with special emphasis to spices and plantation crops' in the National Symposium on Horticulture in the Vanguard of Climate Change and Urban Environment organized during 07-08 February 2019 at the Department of Horticulture, Annamalai University, Chidambaram, Tamil Nadu.
- Delivered a lead lecture on 'Climate change mitigation through horticultural plant genetic resources' in the National Seminar on Climate Resilient Agriculture for Abiotic Stress organized during 12-13 March 2019 by the Department of Plant Breeding and Genetics, Annamalai University, Chidambaram, Tamil Nadu.
- Visiting Fellow under the SAP-UGC (Govt. of India) DRS Phase-II in the project entitled 'Abiotic stress tolerance in crop' and delivered an expert lecture and finalized programme in the theme 'Genetic resources of horticultural crops with emphasis to abiotic stress' at the Department of Plant Breeding and Genetics, Annamali University, Annamalai University, Chidamabaram, Tamil Nadu, India during 02-04 January 2019.
- Delivered an invited lecture on 'Hybrid seed production/seed quality in horticultural crops as per the qualification pack of ASCI' on 25 January 2019 in the one month certificate course on Nursery Worker of Agriculture Skill Council of India (ASCI), funded by Pradhan Mantri Kaushal Vikas Yojana (PMKY) organized during 15 January to 12 February 2019 at ICAR-Central Marine Fisheries Research Institute, Kochi.
- Reviewer, *Crop Science*, published by the Crop Science Society of America and reviewed a research paper entitled, 'Chemical characterization of the American oil palm from the Brazilian Amazon forest'. *Crop Sci*. 2018. **58**: 1982-1990 (España, M.D., S. Mendonça, P.A. Osorio Carmona, M. Borges Guimarães, R. Nonato Vieira da Cunhaand M. Teixeira Souza Junior.).

Dr. A. Asha Devi

- Expert, Expert Panel for Technical Evaluation Committee, 31st Kerala Science Congress.
- External evaluator of practical and *viva-voce* examination of M.Sc. Genetics and Plant Breeding students (second semester) of the Department of Botany, University of Kerala during 09-10 August 2018.
- External expert, Pre-submission seminar of Smt. Reshmi S., Department of Biotechnology and Ms. Ponni T.G, Department of Botany, University of Kerala, Kariavattom, Thiruvananthapuram on 05 November 2018 and 19 March 2019 respectively.
- External examiner for evaluation of thesis and conduct of final examination of the Ph.D. Programme of Ms. Smitha Bhasi, Departmentof Plant Biotechnology, College of Agriculture, Vellayani on 16 March 2019.
- Chairman, Open Defence Seminar, Smt. Vineetha Chandran, Kannur University on 22 March 2019 at the Department of Biotechnology and Microbiology, Thalassery Campus, Palayad.
- Reviewer, *Journal of Environmental Biology*, reviewed a research article on 'Marker assisted screening of breeding population of wheat segregating for stripe rust resistance using SSR markers'.
- Reviewer, *Journal of Agricultural Biotechnology and Sustainable Development*, reviewed a research article on 'Morpho-qualitative characterization and processability of ten local cassava accessions (*Manihot esculenta* Crantz) in Njombe, Cameroon'.

Dr. Shirly Raichal Anil

- Executive Committee Member, Indian Society for Root Crops.
- External examiner for two B.Sc.-M.Sc. (Integrated) Biotechnology students at College of Agriculture (KAU), Vellayani, Thiruvananthapuram.
- External expert, Pre-submission seminar, Mr. Aneeshkumar A.L., Research Scholar,

JNTBGRI, on 10 July 2018; Mr. Shamnad, J., Research Scholar, JNTBGRI on 22 October 2018 and Mr. Rakesh, K.V., Research Scholar, Department of Botany, Kariavattom on 30 March 2019.

- Invited talk on 'Role of polyploidy in the evolution of crops' during the National Workshop on Techniques for Chromosome Analysis at the Department of Botany, University of Kerala on 22 November 2018.

Dr. Kalidas Pati

- Resource person, Krushak Sachetanata Programme, Govt. of Odisha and delivered a presentation on the 'Importance of tuber crops' at IMAGE, Bhubaneswar on 20 June 2018.
- Resource person and delivered a lecture on 'Orange flesh sweet potato' at Balasore, Odisha under Odisha World Fish Project and USAID sponsored programme on 28 November 2018.

Dr. N. Krishna Radhika

- Editor, *Journal of Root Crops*.

Dr. C. Visalakshi Chandra

- Joint Secretary, Indian Society for Root Crops.
- Delivered a lead lecture on 'Varietal evaluation and characterisation for Postharvest Physiological deterioration (PPD) tolerance and enhanced shelf life in cassava (*Manihot esculenta* Crantz)' in the International Conference on Climate Change, Biodiversity and Sustainable Agriculture (ICCBSA-2018) held during 13-16 December 2018 at Assam Agricultural University (AAU), Jorhat, Assam.

Dr. V.B.S. Chauhan

- Expert for setting the question paper for final semester examination of B.Sc. (Horticulture), Central Agricultural University, Imphal, Manipur.
- Lead speaker in the Participatory Agriculture Development Programme on 'Farm Income through Technology Awareness, Access and Adoption' organized by Adventz, Cuttack on 23 August 2018.

Division of Crop Production

Dr. V. Ravi

- Chief Editor, Journal of Root Crops.
- External examiner for conducting qualifying viva voce for M.Sc. and Ph.D. students, College of Agriculture, Vellayani, Kerala Agricultural University.
- External examiner for conducting and evaluation of M.Sc. and Ph.D. thesis at Kerala Agricultural University.

Dr. G. Byju

- Project associate of a Research Project on 'Nutrient management of potato' at ICAR-CPRI, Shimla.
- External Examiner for 14 M.Sc. and 3 Ph.D. theses evaluation and conduct of viva-voce at Kerala Agricultural University.
- Reviewer, *Scientia Horticulturae*, *Agronomy*, *Communications in Soil Science* and *Plant Analysis* and *Journal of Environment Biology*.
- Judge, Agriculture Session, 34th Kerala Science Congress and evaluated the Young Scientist Award and Best Poster Award organized at Fatima Mata National College, Kollam during 02-03 February 2019.
- Team leader of Post-flood loss assessment and rehabilitation of tuber crops in Kerala after the deluge of August 2018. Prepared the report and presented before the Hon'ble Minister for Agriculture & Farmers' Welfare, Kerala and the ICAR Review Committee. About 188 soil samples were also collected and analyzed and a manuscript of a paper based on the results is in the final stage of preparation.

Dr. G. Suja

- Editor, *Journal of Root Crops*
- DG's Nominee Subject Expert, ARS Scientist Assessment Committee Meeting, ICAR-Central Plantation Crops Research Institute, Kasaragod on 19 December 2018.
- Member, Advisory Committee, Ph.D. Programme, Department of Agronomy, College of Horticulture, Vellanikkara, Thrissur, Kerala Agricultural University.
- External examiner for the evaluation of a Ph.D. thesis, Department of Agronomy, College

of Horticulture, Vellanikkara, Thrissur, Kerala Agricultural University.

- Subject Expert, Annual Action Plan Meeting of KVKs of Kerala and Lakshadweep at Karshaka Bhavanam, Kerala Agricultural University, Thrissur during 18-20 March 2019.
- External expert, evaluation of research papers in the 31st Kerala Science Congress organized at Fatima Mata National College, Kollam during 02-03 February 2019.
- Reviewer, *Journal of Root Crops*, *Indian Journal of Agronomy, Journal of Tropical Agriculture*.
- Invited resource person for Advance Training Course on 'Innovative Approaches and Strategies for Higher Profitability and Sustainability in Organic Production System' and delivered a lecture on 'How safe and sustainable is organic production? Evidences from tuber crops and Current status of organic farming in Kerala' organized by ICAR-Centre for Advance Faculty Training on Organic Farming (CAFT), MPUAT, Udaipur on 06 June 2018.
- Nominated to deliver lecture on 'Vertical farming in tropical tuber crops: Research needs and future prospects in the National Workshop on Vertical Farming at Horticultural Sciences Division, ICAR, New Delhi held on 18 October 2018.
- Invited lecture on 'Organic farming for safe and sustainable food production with special focus on tuberous vegetables' at the State Level Technical Workshop on Organic Farming and GAP for Quality Production organized by VFPCK, Thiruvananthapuram on 15 February 2019.

Dr. K. Susan John

- Reviewer, *Rubber Science*, *Agricultural Research*, *Journal of Plantation Crops* and *Journal of Root Crops*.
- Reviewer, project proposal under SARD (Selective Augmentation of Research and Development), KSCSTE.
- Expert, recruitment of Sales Officers, FACT, Aluva.
- Invited lecture on 'Customized fertilizer formulations for tropical tuber crops: Development and experience in Kerala' in the National Crop Nutrition Summit 2018 held at New Delhi on 20 April 2018.
- Invited talk on 'Is customized fertilizers a suitable option to manage the soil fertility issues of Kerala?: Experience with tropical tuber crops under intercropping in coconut gardens' at Fertilizer Policy and Soil Health Governance organized by Fertilizer Association of India (FAI), Southern Region at Thiruvananthapuram on 24 July 2018.
- Chief Guest, inauguration of the Department of Botany, Mar Ivanios College, Thiruvananthapuram for the year 2018-19 and delivered a talk on 'Tropical tuber crops for food and nutritional security under global climate change' on 09 August 2018.
- Invited lecture on 'Development protocol and scope of customized fertilizer formulations in soil health management and crop productivity' at the Model Training Course on Recent Advances in Nutrient *vis-a-vis* Soil Health Management for Major Oil Seed Cropping Systems of India at ICAR-IIOR on 11 September 2018.
- Invited lecture on 'Significance of soil testing in soil health management and crop productivity' on 'World Soil Day 2018' celebration at the Department of Environmental Sciences, University of Kerala, Thiruvananthapuram on 04 December 2018.
- Resource person for the one year Diploma course in Agricultural Extension Services for Input Dealers Programme at ICAR-CPCRI and delivered lecture on 'Importance of soil testing, method of soil sampling, interpretation and farm advisory based on soil test results and integrated nutrient management' on 04 January 2019.
- Resource person for the *Kisan Kalyan Karyasalai Programme* at Kazhakootam block, interface of Kollam district and interface of Ernakulam district and delivered lectures on 'Soil health management' on 02 May 2018, 15 February 2019 and 01 March 2019 respectively.
- Resource person in the 'Agricultural Skill Development Programme' organized by ICAR-IISR-KVK and delivered a lecture on 'Soil fertility and nutrient management of tropical tuber crops' on 19 February 2019.

Dr. V. Ramesh

- IMC member, ICAR-Sugarcane Breeding Institute, Coimbatore.
- Treasurer, Indian Society for Root Crops.

Dr. R. Muthuraj

- As an associate, instrumental in the development of a new potato variety 'Kufri Sahyadri' (Medium maturing, high yielding, resistant to potato cyst nematode and late blight disease) released during 2018-19 by ICAR-CPRI, Shimla.
- Resource person for the workshop held at KVK, Thirupathisaram on 12 June 2018 and delivered talk on improved cultivation practices and calendar of operations for cassava.
- Resource person for the 'Field day-cum-Entrepreneur Workshop Meet on Chinese Potato' at Tirunelveli, Tamil Nadu on 11 January 2019.
- Resource person for the Training on 'Stakeholder Meet and Entrepreneurship Development Programme on Utilizing Tuber Crops based Sustainable Development' held at SMELC building, West Garo Hills, Tura, Meghalaya on 01 December 2018.
- Resource person for the 'Stakeholders Workshop and Entrepreneurship Development Programme on Tuber Crop Technologies' held at ICAR-KVK, Namsai, Arunachal Pradesh on 05 December 2018.

Dr. Sanket J. More

- Expert, comprehensive viva voce examination of Mr. Sigikumar, KTU-QIP scholar at KTM College of Engineering, Kollam on 05 March 2019.
- Editor, *Journal of Root Crops*.

Division of Crop Protection

Dr. C.A. Jayaprakas

- Joint Secretary, Association of Advancement of Entomology.
- Lead talk in the National Symposium on Coastal Agriculture: Boosting Production Potential under Stressed Environment held during 28 September-01 October 2018 at KKV, Dapoli.

Dr. M.L. Jeeva

- Lead talk on 'Yam diseases: present status and management' in the National Symposium on Cutting Edge Approaches for Sustainable Plant Disease Management and Ensuring Farmer's Profit', held at ICAR-National Research Centre for Banana, Tiruchirappalli, Tamil Nadu.
- Question paper setter for M. Sc. Plant Pathology, Faculty of Agriculture, Annamalai University.
- External examiner of Ph.D. thesis, Bharathiar University, Kerala Agicultural University, and Kannur University.
- Reviewer, *Sugartech*, *Archives of Phytopathology and Plant Protection*, *Journal of Root Crops*.

Dr. S.S. Veena

- Member, DPC, ICAR-Sugarcane Breeding Institute, Coimbatore.

Dr. T. Makeshkumar

- Lead talk on 'CRISPR/Cas9-A powerful genome engineering tool for plants to combat resistance against plant viruses'in the National Symposium on Cutting Edge Approaches for Sustainable Plant Disease Management and Ensuring Farmer's Profit, held at ICAR-National Research Centre for Banana, Tiruchirappalli, Tamil Nadu.
- DBT Nominee, Institute Bio-safety Committee, ICAR-IISR, Kozhikode (2016-2019).
- Member, Institute Bio-safety Committee, Kerala Agricultural University (2016-2019).
- Member, Institute Management Committee, ICAR-CPCRI, Kasaragod (2018-2020).
- External member, Selection Committee, ICAR-IISR, Kozhikode.
- Expert, Project evaluation, Kerala Biotechnology Commission, KSCSTE.
- External examiner for evaluation of Ph.D. thesis and viva-voce, TNAU, Coimbatore, Bharathiar University, Coimbatore, Jawaharlal Nehru Technological University Hyderabad and Madurai Kamaraj University, Madurai.

Dr. E.R. Harish

- Member, Executive Committee, *Entomon*.

Dr. H. Kesava Kumar

- Expert, Scientific Advisory Committee Meeting, ICAR-Krishi Vigyan Kendra, Thirupathisaram, Kanyakumari on 08 March 2019.
- Member, State Agricultural Awards Selection Committee 2018.

Division of Crop Utilization

Dr. M.S. Sajeev

- Delivered an invited lecture on 'Value addition in tuber crops' in the Seminar on Hand holding support to Farmers organized by Department of Agriculture, Government of Kerala on 27 October 2018 at Kattappana, Idukki.
- Delivered an invited lecture on 'Value addition in tuber crops' in Technology Clinic on Fruits and Vegetable Processing on 30 November 2018 at District Industries Centre, Kasaragod.
- Delivered an invited lecture on 'Value addition in tuber crops' in Technology Clinic on Fruits and Vegetable Processing and Value Added Products on 20 December 2018 at District Industries Centre, Ernakulam.
- Delivered an invited lecture on 'Value addition in tuber crops' in Agri based Food Processing Technology Clinic on 29 December 2018 at District Industries Centre, Idukki.
- Delivered an invited lecture on 'Value added products and entrepreneurial opportunities in tuber crops' in Technology Machinery Demonstration cum Kisan Mela on 15 February 2019 at Nayarambalam, Ernakulam.
- Member, Advisory Committee, M.Sc. Processing Technologies, KAU, College of Agriculture, Vellayani, Thiruvananthapuram.
- Curriculam Committee Member, B.Tech. Food Technology, Kerala Technological University, Thiruvananthapuram.
- FRC Member, B. Tech. Food Engineering, Kerala Agricultural University, Thrissur.
- Expert, Interview Board, Selection of SRFs at NIIST, Thiruvananthapuram.

Dr. A.N. Jyothi

- Member, Technical Committee, State Pesticide Testing Laboratory, Department of Agriculture, Govt. of Kerala.
- Member, Advisory Committee, Ph.D. programme, College of Agriculture, Vellayani, Thiruvananthapuram.

Dr. T. Krishnakumar

- Technical Committee Member, Equipments Purchase Committee for establishing NABL lab in SAGOSERVE, Salem, Tamil Nadu.
- Invited resource person in the seminar on tuber crops and delivered a talk on 'Postharvest processing and value addition in tuber crops' organized by Deputy Director of Horticulture, Department of Horticulture and Plantation Crops on 13 February 2019, at Salem, Tamil Nadu.
- Question paper setter for the courses on Food Process Engineering and Process Engineering of Spices and Plantation Crops for Agricultural Engineering College and Research Institute, TNAU, Coimbatore.
- Resource person for the 'Stakeholder Meet and Entrepreneurship Development Programme on Utilizing Tuber Crops based Sustainable Development' held at SMELC building, West Garo Hills, Tura, Meghalaya on 01 December 2018.
- Resource person for the 'Stakeholders Workshop and Entrepreneurship Development Programme on Tuber Crop Technologies' held at ICAR-KVK, Namsai, Arunachal Pradesh on 05 December 2018.

Mr. V.V. Bansode

- Lead speaker in the Participatory Agriculture Development Programme on 'Farm Income through Technology Awareness, Access and Adoption'organised by Adventz at R.I.T.E, Dhenknal, Odisha on 23 August 2018.

Section of Extension & Social Sciences

Dr. Sheela Immanuel

- Invited resource person for Prathibha Scholars, 15 and 22 April 2018 organised by Neyyatinkara Board of Education, Thiruvananthapuram.
- Invited resource person for PGDAEM-MANAGE correspondence courses on 26 and 29 June 2018 at SAMETI, Anayara, Thiruvananthapuram.
- Invited resource person for Officers' training programme and delivered lectures on Public

and private sector schemes for promoting agricultural entrepreneurship in Kerala and Manpower planning for agricultural business ventures for the Agriclinic and Agribusiness Center scheme (AC & ABC) trainees on 27 February 2019 at College of Agriculture, Vellayani, Thiruvananthapuram.

- Reviewer of research papers for Marine Biological Association of India.
- Reviewer, *Fishery Technology*.
- Member, DPC for ARS scientists, ICAR-IISR, Kozhikode.

Dr. J. Sreekumar

- Guide four M.Sc. (Integrated) Biotechnology students of Kerala Agricultural University.
- Guide two students of M.Phil. in Bioinformatics, University of Kerala.
- External examiner, M.Sc. (Ag.) thesis of Smt. Muhsina, A., Dept. of Agricultural Statistics, College of Agriculture, Vellayani.
- Conducted two sessions on Data analysis using SAS in the Workshop on 'Applied Statistics and Data Analysis for Science and Society' during 14-16 March 2019 organized by Department of Agricultural Statistics, College of Agriculture, Vellayani, Thiruvananthapuram
- Member, Editorial Board, *Journal of Tropical Agriculture* (JTA), Kerala Agricultural University.

Dr. P.S. Sivakumar

- Member, National Level Committee MANAGE Core Committee for Curriculum Revision in Extension Education.
- Expert for evaluating agri-business proposals for funding from Kerala Startup Mission, Kerala.
- Commercial expert, AGRINNOVATE, New Delhi.
- External examiner of two M.Sc. (Ag.) (Agricultural Extension) theses, Kerala Agricultural University and Anna University.
- Invited talk on 'Developing agricultural entrepreneurs in Kerala: Problems and prospects' in the training programme organised by the Association of Agricultural Officers, Kerala, on 08 September 2018.
- Invited talk on 'Participatory planning methodology with reference to extension plan preparation' at the MANAGE training programme on Innovative Extension Methodologies (IEM) for Participatory Action Learning (PAL) held during 16-25 July 2018.

Dr. D. Jaganathan

- Resource person for PGDAEM-MANAGE correspondence course on 27 June 2018 at SAMETI, Anayara, Thiruvananthapuram.
- Resource person for the 'Stakeholder Meet and Entrepreneurship Development Programme on Utilizing Tuber Crops based Sustainable Development' held at SMELC building, West Garo Hills, Tura, Meghalaya on 01 December 2018.
- Convenor for the session on Climate change and livelihood vulnerability: Role of ICT in climate smart IFS in the 'National Seminar on Integrated farming system for Enhancing Farmers' Income and Nutritional Security' on 06 December 2018 at West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal.
- Invited as resource person for the training programme of farmers and horticultural officers and delivered lecture on 'Arecanut based tuber crops cropping system' during 18-19 December 2018 at ICAR-KVK, MYRADA, Erode, Tamil Nadu.
- Resource person for Officers' training programme and delivered a lecture on 'Data collection methods in social research' for the Agriclinic and Agribusiness Center scheme (AC & ABC) trainees on 28 February 2019 at College of Agriculture, Vellayani, Thiruvananthapuram.
- Editor, *Journal of Root Crops*.
- Reviewer, *Journal of Plantation Crops*.

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 viz., Indo-Swiss Project on cassava mosaic disease funded by Swiss Agency for Development & Co- operation, Bern and Department of Biotechnology, Govt. of India, New Delhi. The national and state funding agencies are: ICAR, National Agricultural Innovation Fund (NAIF), Govt. of India, Protection of Plant Varieties & 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 National Institute of Agricultural Extension Management (MANAGE), Hyderabad, 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-National Rice Research Institute, Cuttack, Odisha, ICAR-Central Institute of Fisheries Technology, Kochi, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, ICAR-Central Marine Fisheries Research Institute, Kochi, ICAR-Central Plantation Crops Research Institute, Kasargod, ICAR Research Complex for NEH Region, Barapani, ICAR-National Academy of Agricultural Research 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 Agricultural & Technology, Bhubaneswar and Tamil Nadu Agricultural University, Coimbatore In addition, collaboration also exists with Dept. of Horticulture, Dept. of Agriculture, Govt. of Odisha, Dept. of Agriculture, Govt. of Kerala, Govt. of Tamil Nadu and North Eastern states.

ICAR-CTCRI with its Intellectual Property and Technology Management Unit & Professional Services Cell (IPTMU&PSC) has developed collaboration with MANAGE, Hyderabad and Centre for Research on Innovation and Science Policy (CRISP), Hyderabad and conducted a training programme on Social Science Research Methodology. Collaborations were also developed with public sector agencies like Kerala State Industrial Development Corporation (KSIDC), Kerala Start-up Mission, Department of Agriculture, Government of Kerala; ICAR Research Complex for North Eastern Hills, Umiam, Meghalaya; North Eastern Hill University, Tura Campus, KVK, Tura, Horticulture Department, West Garo Hills and Meghalaya Basin Development Agency; Krishi Vigyan Kendra, Namsai, Arunachal Pradesh and Madurai Agribusiness Incubation Forum of NABARD, Madurai 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 has been signed with Odisha University of Agriculture and Technology, Bhubaneswar, Odisha and Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh for PG and Ph.D. Programme. MoU had been signed with Indian Institute of Crop Processing Technology, Thanjavur for mutual utilization of research facilities. A MoU exists with Coconut Development Board for the validation and popularization of organic farming and customized fertilizers developed based on site specific nutrient management technologies in tropical tuber crops intercropped in coconut gardens. Moreover, AICRP on Tuber Crops at ICAR-CTCRI headquarters has collaboration with 21 centres spread over 18 states and one Union Territory.

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 BCKV, Kalyani, West Bengal and RAU, Dholi, Bihar. In the ICAR-All India-Network Programme on Organic Farming the institute has collaboration with ICAR-Indian Institute of Farming Systems Research, Modipuram. The institute is also associating with ICAR-Indian Institute of Water Management (IIWM), Bhubaneswar, Odisha for the preparation of soil fertility maps for various agro-ecosystems.

ICAR-ALL INDIA CO-ORDINATED RESEARCH PROJECT ON TUBER CROPS

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

All India Co-ordinated Research Project on Tuber Crops (AICRP-TC) is the largest national network of tropical root and tuber crops covering 18 states and one union territory in the north-eastern, eastern, western and southern parts of India. Presently the AICRP (TC) is having 21 centres, located in 12 State Agricultural Universities, three ICAR Institutions and two Central Agricultural Universities.

Achievements of ICAR-AICRP on Tuber Crops during 2018-2019

Genetic resources of tuber crops maintained at ICAR-CTCRI and AICRP centres

A total of 118 new germplasm collections were made by different centres during 2018-19. Altogether 4386 different accessions of root and tuber crops were maintained as gene bank for improvement of major crops, including cassava, sweet potato, aroids and yams and also in minor tuber crops at 21 centres. A total of 5579 accessions of different tuber crops were maintained in the National Repository for Tuber Crops at ICAR-CTCRI. Regional Centre of ICAR-CTCRI, Bhubaneswar maintained a total of 1242 accessions of tuber crops. Among the AICRP centres, maximum accessions of 12 tuber crops (1338) were maintained at RPCAU, Dholi. IC numbers were obtained for a total of 2020 germplasm collections at different centres.

Varietal development

Pooled analysis of data on tuber yield in IET on cassava mosaic resistant lines indicated that the entry TCa 16-4 performed best at Yethapur (44.58 t ha^{-1}), TCa 16-5 at Peddapuram (53.37 t ha^{-1}) and TCa 16-2 at Jagdalpur (32.38 t ha^{-1}), with no incidence of cassava mosaic disease. First year MLT on K-efficient cassava lines indicated the superiority of TCa 14-6 at Yethapur and Sree Athulya at Peddapuram. Among the five entries under MLT on cassava for culinary uses, TCa 13-4 yielded maximum in Chhattisgarh and TCa 13-7 in Manipur.

Under the new IET on orange-fleshed sweet potato, TSp 16-2 produced maximum marketable tuber yield at Ranchi, TSp 16-5 at Kalyani, TSp 16-9 at Peddapuram, TSp 16-7 at Jagdalpur, Navsari and Rajendranagar. Under MLT on sweet potato weevil resistance, TSp 12-6 performed well coupled with less weevil infestation in Bihar, TSp 12-4 in West Bengal and in Telangana, with more total and marketable tuber yield. Under MLT on sweet potato, maximum marketable tuber yield was recorded from Sree Bhadra in West Bengal and TSp 12-12 in Meghalaya based on the pooled data analysis.

Among the 14 entries evaluated under IET on taro, yield performance varied at different centres. TTr 17-4 produced the highest cormel yield at Kalyani, Rajendranagar and Coimbatore, TTr17-1 at Barapani and Kovvur, TTr 17-7 at Jorhat, TTr 17-12 at Dapoli, Tripura and Dholi, TTr 17-5 at Jagdalpur, TTr 17-8 at Imphal and Coimbatore, TTr 17-9 at Ranchi. In the first year of MLT on taro, TTr 12-4 was superior in yield at West Bengal and Tamil Nadu. The entry TTr 12-8 yielded maximum in Jharkhand, Bihar and Andaman & Nicobar islands. The evaluation of taro entries against *Phytophthora* leaf blight in MLT indicated that TCbl 12-3 and TCbl 12-4 were field resistant to leaf blight and yielded highest in West Bengal, TCbl 12-4 in Bihar, whereas TCbl 12-5 was superior in Maharashtra and Telangana.

Under IET on bunda, pooled analysis of yield data showed that TBd 17-1 was superior at Jagdalpur, TBd 17-2 at Barapani, TBd 17-3 at Kalyani, TBd 17-4 at Dholi and Ranchi. Under URT on swamp taro, the highest stolon yield was recorded in BCST-3 (24.19 t ha^{-1}) at Kalyani, AAUST-2 at Jorhat and BCST-1 at Imphal. Under URT on tannia, among the six entries, TTn 14-6 performed well and produced maximum tuber yield at Rajendranagar and Jagdalpur and TTn 14-1 at Kalyani. Under IET on elephant foot yam, based on two years pooled data, TEy 17-1 produced significantly higher corm yield (32.3 t ha^{-1}) at Dholi, TEy 17-5 at Kovvur, and the national check Gajendra yielded maximum at the other centres.

Under the IET on greater yam, TGy 17-6 produced the highest tuber yield at Kalyani (30.97 t ha^{-1}), national check Sree Karthika at Dapoli, local variety at Kovvur, TGy 17-3 at Jagdalpur (52.41 t ha^{-1}), Jorhat and Udaipur based on pooled means. Under URT on greater yam, TGy 14-7 produced maximum yield at Dapoli (25.43 t ha^{-1}), TGy 14-11 at Udaipur, Imphal and Kovvur (46.07 t ha^{-1}), TGy 14-3 at Jagdalpur, TGy 14-9 at Jorhat. Under MLT on greater yam, TGy12-3 produced maximum tuber yield at Bhubaneswar and Kovvur, TGy 12-1 at Jagdalpur (27.02 t ha^{-1}) and local variety at Udaipur. Highest organoleptic score was recorded in Sree Karthika (7.8) followed by TGy 12-3 (7.7) at Bhubaneswar, TGy 12-3 at Jagdalpur and Kovvur. Maximum bulbil yield and total yield was recorded in TDb 13-6 at Jagdalpur, TDb 13-5 at Ranchi , TDb 13-1 at Dapoli under MLT on aerial yam based on pooled data analysis.

Under first year MLT on yam bean, highest tuber yield was recorded in TYb 14-5 (17.37 t ha^{-1}) at Bhubaneswar, TYb14-9 at Dholi and TYb 14-8 at Kalyani. Arrowroot tuber yield varied widely among the centres in the new IET initiated with 15 entries. TAr 18-3 produced maximum yield at Kalyani, TAr 18-8 at Coimbatore, TAr 18-14 at Jagdalpur, Ranchi and Thiruvananthapuram and TAr 18-13 at Imphal.

Agro-techniques

The farming system studies involving tuber crops introduced in Narangi (village), Gajapati (District), Odisha state generated a gross income of ₹ 1,87,025 ha^{-1} with B:C ratio of 3.16 and employment generation of 365 man-days ha^{-1} in the place of the gross income of ₹ 49,125 ha^{-1} with B:C ratio of 1.93 and employment generation of 235 man-days ha^{-1} before intervention. The gross income and net income increased in Semra village of Ranchi district of Jharkhand after interventions of different components under tuber crops based farming system. Average B: C ratio of the famers increased from 1.36 to 2.3. The model created an additional employment of 73 man-days. Farming system introduced in Jorhat district of Assam increased the B:C ratio from 1.05 to 3.26. The employability also increased from 212 days to 660 days per ha. Tuber crops based farming system was established at Khweng and Mawbri village of Ribhoi district, Meghalaya. After intervention, the total area under farming at Khweng was 796 m^2 with a gross income of ₹ 23963 and net income of ₹ 14219 thereby resulting in B:C ratio of 1.45. Similarly at Mawbri, the total area under farming increased to 852 m^2 with gross income of ₹ 32747 and net income of ₹ 22390 resulting in a B:C ratio of 1.38.

Validation of organic farming technologies in elephant foot yam indicated positive response of organic farming over conventional methods, however highest B:C ratio was recorded in the conventional method at Dholi, Dapoli and Kalyani. Organic farming practices produced maximum corm yield at Navsari, Ranchi and Kovvur. In greater yam, organic package recorded the highest tuber yield and net income in all the centres, except Jorhat and Coimbatore, where conventional package resulted in highest yield. Organic farming resulted in superior performance of taro in most of the centres. At Rajendranagar, conventional method of cultivation resulted in more cormel yield.

Studies on integrated weed management in elephant foot yam revealed that weed control ground cover was the most effective for weed management with maximum growth and corm yield at Coimbatore (42.98 t ha^{-1}), Kovvur (41.44 t ha^{-1}), Kalyani (46.98 t ha^{-1}), Port Blair (23.50 t ha^{-1}) and Navsari. Hand weeding thrice, 30, 60 and 90 DAP was effective at Tripura and Ranchi.

Pests and disease management

Under the new trial on 'Management of sucking pests in taro', there was a significant reduction in aphid population in all the insecticidal treatments, whereas botanical insecticides were less effective

in reducing the population as compared to chemical insecticidal treatments.

For anthracnose management in greater yam, soil application and tuber treatment with *Trichoderma* followed by Carbendazim spray seven times showed minimum disease intensity and maximum tuber yield at Jagdalpur, Rajendranagar and Udaipur. The *Trichoderma* treatment along with Carbendazim spray thrice resulted in maximum tuber yield at Jagdalpur.

Seed corm treatment with Fungicide I (Carbendazim 25% + Mancozeb 50%) before storing the corms, corm treatment in cow dung slurry + *Trichoderma* @ 5g kg^{-1} corm 3 days before planting followed by drenching twice with 0.2% Carbendazim 25% + Mancozeb 50% gave very good control of collar rot of elephant foot yam in most of the centres. Chemical control gave best results at Ranchi and Fungicide II, 0.1% (Mancozeb 63% + Carbendazim 12%) was effective at Coimbatore. Both the chemicals were effective at Palampur and Lembucherra centres.

Planting material production

Planting material of improved varieties of tuber crops were multiplied and distributed to farmers by all the centres. The centres produced a total of 1,46,441 stems of cassava, 95,72,730 vine cuttings of sweet potato, 36.40 tons of elephant foot yam, 8.62 tons of taro, 2.16 tons of bunda, 30.20 tons of greater yam, 0.96 tons of lesser yam, 9 tons of Tikhur, and 166 kg of yam bean as part of planting material production programme.

Research-extension-farmers linkage

MPUAT, Udaipur organised two farmers training programme under Scheduled Caste Sub-Plan (SCSP) on 14 and 18 March, 2019. The Regional Centre of ICAR-CTCRI organized 'Tuber Day' on 9 January 2019 at Chandragiri (Village), Mohana (Block), Gajapati (District), Odisha. About 500 tribal farmers and farm women from 30 villages attended the programme. A field day on 'Tuber Crops: Future Smart Crops' was conducted on 04 October 2018 at ICAR Research Complex for NEH Region, Umiam. Value added tuber products were displayed in Kisan Mela held at Zeeradai and Motihari, including pickles, kheer and chips (elephant foot yam), sewai (elephant foot yam), chips and namkeen (sweet potato) and other recipes such as pickles of different tuber crops etc. were prepared and demonstrated among farmers by Navsari centre.

18th Annual Group Meeting of the AICRP on Tuber Crops

Functioning since 1968, AICRP on Tuber Crops has successfully completed 50 years of its efforts on R and D activities of tropical tuber crops, across the country, during 2018. The Golden Jubilee celebrations and 18th Annual group Meeting for the year 2017-18 was held at ICAR-CTCRI, Thiruvananthapuram during 26-28 April 2018. Dr. T. Janakiram, Assistant Director General (Hort. Science), ICAR, formally inaugurated the event, and former Project Co-ordinators were felicitated during the occasion. Agro-advisory system for cassava (AASC) developed by Dr V.S. Santhosh Mithra, ICAR-CTCRI, based on the information generated from the phenology studies conducted by AICRP centres across the country was launched during the inauguration. In connection with the golden jubilee year, many publications were released in vernacular languages by centres including the three technical bulletins viz., 'A compendium of tuber crops technologies 1968-2018 by AICRP on tuber crops', 'Tuber crops varieties released/ recommended for release by AICRP on tuber crops over five decades', and 'Tuber crops based integrated farming systems'. The Best Centre Award during 2017-18 was presented to Tamil Nadu Agricultural University, Tamil Nadu (which is having two AICRP centres, at Coimbatore and Yethapur) by Dr. T. Janakiram, Assistant Director General (Hort. Sci.).

Inauguration of Golden Jubilee Celebrations and 18th AGM of AICRP on Tuber Crops

PUBLICATIONS

Papers in Research Journals

Akshara George, Jeeva, M.L., Nath, V.S., Sreelatha, G.L., Sujina, M.G. and Makeshkumar, T. 2017. Morphological and molecular characterization of *Phytophthora colocasiae* obtained from fine spatial scale. *J. Root Crops,* **43**(2): 33-40. (*NAAS rating: 3.86*).

Anil, S.R., Siril, E.A. and Suhara Beevy, S. 2018. Genetic diversity and structure in *Amorphophallus* spp. Blume ex Decne. using morphological and ISSR markers. *Int. J. Veg. Sci*., DOI: 10.1080/19315260.2018.1530325.

Anju, P.S., Susan John, K., Bhadraray, S., Suja, G., Jeena Mathew, Nair, K.M., Sunitha, S. and Veena, S.S. 2018. Development and evaluation of customized fertilizer formulations for tuber crops grown as intercrops in coconut gardens. *Indian J. Fert.,* **14**(10): 50-54. (*NAAS rating: 2.80*).

Bansode, V.V, Smurti, S., Chauhan, V.B.S., Mahanand, S. and Mukherjee, A. 2018. Effect of initial pH, chemical preservatives and storage temperature on the shelf life of beta-carotene rich sweet potato *dahi*. *Int. J. Curr. Microbiol. App. Sci.,* **7**(8): 960-968. (*NAAS rating: 5.38*).

Biswas, K.K., Palchoudhury, S., Shukla, P., Godara, S., Balram, N., Bhattacharya, U.K. and Makeshkumar, T. 2018. DNA-A sequences of whitefly transmitted begomovirus infecting okra (*Abelmoschus esculenta*) in India are extensively diverse. *Indian Phytopathol.,* **71**(2): 249-256. (*NAAS rating: 5.90*).

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ONGOING PROJECTS

Institute Projects

Sl. No.	Project code	Project title	PI	Co-PIs
1.	HORTICARCTCRI SIL2015 001 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, 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, M. Nedunchezhiyan, 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, K.M. Senthilkumar, A.V.V. Koundinya, V. Ravi, P. Murugesan, R. Muthuraj, E.R. Harish, P. Prakash
3.	HORTICARCTCRI SIL2015 003 01459	Integrated crop, water and nutrient management for improving productivity of tropical tuber crops	G. Byju	V. Ravi, James George, R. Muthuraj, G. Suja, M. Nedunchezhiyan, S. Sunitha, K. Laxminarayana, V. Ramesh, T. Makeshkumar, M.N. Sheela, Archana Mukherjee, A. Asha Devi, K. Susan John, Saravanan Raju, S.S. Veena, J. Sreekumar, A.N. Jyothi, V.S. Santhosh Mithra, P. Prakash, Sanket J. More, Visalakshi Chandra C., J. Suresh Kumar, V.K. Dua (ICAR-CPRI, Shimla), Madhumita Das (ICAR-IIWM)

Sl. No.	Project code	Project title	PI	Co-PIs
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, G. Byju, V. S. Santhosh Mithra, M.N. Sheela, G. Suja, V. Ramesh, Sanket J. More, J. Suresh Kumar, K.L. Laxminarayana, Prince Kumar RS, ICAR-CPRI), V.K. Dua (ICAR-CPRI),
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, 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, K.I. Asha, V.S. Santhosh Mithra, T. Makeshkumar, Arutselvan R., T. Sirisha
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, Senthilkumar K.M., Arutselvan R., Koundinya A.V.V.
8.	HORTICARCTCRI SIL2013012 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, S.S. Veena, K.I. Asha, T. Krishnakumar, Saravanan Raju, G. Suja, V. Ramesh, G. Byju
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, K. Susan John, M. Nedunchezhiyan, T. Krishnakumar, P.S. Sivakumar
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, C.A. Jayaprakas,V. Ravi, M.N. Sheela, P. Murugesan, K. Venkatesan (NAARM, Hyderabad)

Externally Aided Projects

Sl. No.	Title	PI	Co-PIs	Funding agency
1.	Adapting clonally propagated crops to climatic and commercial changes	Archana Mukherjee J. Sreekumar	-	European Union
2.	Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro	Archana Mukherjee	Kalidas Pati J. Tarafdar (BCKV, Kalyani)	PPV & FRA, New Delhi
3.	Establishment of varietal gene bank and development of standards of DUS testing in yam bean (*Pachyrhizus erosus*) and greater yam (*Dioscorea alata*)	Archana Mukherjee	M.N. Sheela Kalidas Pati Vivek Hegde M. Nedunchezhiyan P.P. Singh (RAU, Dholi)	PPV & FRA, New Delhi
4.	DUS centre for cassava and sweet potato	M.N. Sheela	Archana Mukherjee Kalidas Pati Asha K.I. Krishna Radhika N. Shirly Raichal Anil Asha Devi A.	PPV & FRA, New Delhi
5.	ICAR-CIP collaborative work plan activity on crop improvement and varietal selection of sweet potato	Shirly Raichal Anil	Visalakshi Chandra C.	CIP, New Delhi
6.	Gene expression profiling of taro (*Colocasia esculenta* L. Schott) and role of transcriptional activators of epicuticular wax in host resistance against *Phytophthora* leaf blight disease	Vivek Hegde	P. Sethuraman Sivakumar	DBT, New Delhi
7.	Applied mutagenesis in cassava for improved agronomic, disease resistance and post-harvest traits	A.V.V. Koundinya	-	Department of Atomic Energy, Govt. of India
8.	All India-Network Programme on Organic Farming (AI-NPOF)	G. Suja	G. Byju S. Sunitha S.S. Veena A.N. Jyothi M.N. Sheela	ICAR – Indian Institute of Farming Systems Research, Modipuram
9.	Enhancing the economic viability of coconut based cropping systems for land use planning in Kerala	K. Susan John	S. Sunitha S.S. Veena	Kerala State Planning Board
10.	Response of cassava (*Manihot esculenta* Crantz) to polysulphate under ultisols (Laterites) and entisols (Sandy soils) of Kerala	K. Susan John	Jeena Mathew (ICAR-CPCRI)	International Potash Institute (India Region)

Sl. No.	Title	PI	Co-PIs	Funding agency
11.	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
12.	Climate smart natural resource management of cassava (*Manihot esculenta* Crantz) using geoinformatics tools	G. Byju	-	KSCSTE, Govt. of Kerala
13.	Potential impact of climate change on tropical tuber crops yield in major growing areas of India	G. Byju (Scientist Mentor)	Raji P. (Woman Scientist)	DST-WOS-A, Govt. of India
14.	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
15.	Popularization of climate resilient improved varieties of tuber crops for food, nutrition and doubling income with emphasis on wellness of tribal and marginal farmers in Kerala	V. Ravi Archana Mukherjee G. Byju J. Sreekumar	M.N. Sheela C.A. Jayaprakas Sheela Immanuel G. Suja K. Susan John V. Ramesh R. Muthuraj Saravanan Raju Sanket J. More D. Jaganathan	RKVY, Govt. of Kerala
16.	Popularization of climate resilient and nutritionally rich varieties of tuber crops for economic development and nutritional security of farmers of Odisha	R. Korada & Archana Mukherjee (2017-18) M. Nedunchezhiyan (2018-19)	K. Laxminarayana Kalidas Pati V.B.S. Chauhan K. Hanume Gowda V.V. Bansode Sheela Immanuel G. Byju P.S. Sivakumar D. Jaganathan Bharat Kumar Sahoo Bibhudi Das	RKVY, Govt. of Odisha
17.	ICAR-CTCRI -Tribal Sub Plan 'Livelihood improvement of tribal farmers through tuber crops technologies'	Sheela Immanuel (Nodal Officer) M. Nedunchezhiyan (PI)	Archana Mukherjee K. Laxminarayana Kalidas Pati V.B.S. Chauhan K. Hanume Gowda V.V. Bansode	ICAR, New Delhi

Sl. No.	Title	PI	Co-PIs	Funding agency
18.	Indo – Swiss Cassava Network	T. Makeshkumar M.N. Sheela	E.R. Harish B.G. Sangeetha Visalakshi Chandra C.	Indo Swiss collaboration on Biotechnology (ISCB)-DBT, Govt. of India
19.	Development and application of diagnostics to viruses infecting tuber crops (EFY, cassava, sweet potato and yam)	T. Makeshkumar	M.L. Jeeva R. Arutselvan R. Muthuraj	ICAR-CRP on Vaccines and Diagnostics
20.	On-farm trials of cassava bio-pesticides against borer pests of banana in Kerala	C.A. Jayaprakas	E.R. Harish B.G. Sangeetha	Department of Agriculture and Farmers' Welfare, Govt. of Kerala
21.	Augmentation of biopesticides production from cassava leaves using fully automated manufacturing facilities	C.A. Jayaprakas	E.R. Harish B.G. Sangeetha	RKVY, Govt. of Kerala
22.	High value compounds/ Phytochemicals	A.N. Jyothi	J. Sreekumar Shirly Raichal Anil	ICAR (Network Project)
23.	Techno-Incubation Centre	M.S. Sajeev	T. Krishnakumar	Small Farmers Agribusiness Consortium, Govt. of Kerala
24.	Techno-Incubation Centre at ICAR–CTCRI, Regional Centre, Bhubaneswar	M. Nedunchezhiyan	M.S. Sajeev V.V. Bansode	RKVY, Govt. of Odisha
25.	All India Co-ordinated Research Project on Post Harvest Engineering & Technology	M.S. Sajeev	T. Krishnakumar	CIPHET, Ludhiana (ICAR, New Delhi)
26	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
27.	XIIth Plan IP & TM Scheme: National Agricultural Innovation Foundation (NAIF)	P. Sethuraman Sivakumar	R. Muthuraj Vivek Hegde H. Kesava Kumar T. Krishnakumar D. Jaganathan R. Bharathan	ICAR – NAIF, New Delhi

PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA etc. IN INDIA

Programme	Particulars of the programme	Name of the participants
44th Annual Institute Research Council Meeting	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 03-05 April 2018	All Scientists
Meeting of Kerala State Industrial Development Corporation	Kerala State Industrial Development Corporation, Thiruvananthapuram 06 April 2018	Dr. Sheela Immanuel
Consultative Meeting of KSBB-FAO, TCP Project	Government Guest House, Thycaud, Thiruvananthapuram, 10 April 2018	Dr. K.I. Asha
National Crop Nutrition Summit	New Delhi, 20 April 2018	Dr. K. Susan John
Stakeholders Interface Meeting in connection with Krishi Unnati Mela and VAIGA – 2018	ICAR-Central Plantation Crops Research Institute, Kasaragod, 21 April 2018	Dr. D. Jaganathan
18th Annual Group Meeting of AICRP on Tuber Crops	ICAR–Central Tuber Crops Research Institute, Thiruvananthapuram 26-28 April 2018	Dr. Archana Mukherjee Dr. James George Dr. S. Sunitha Dr. G. Suja Dr. R. Muthuraj Dr. J. Suresh Kumar Dr. D. Jaganathan
Workshop on Agritech Matters: Feed Billions by Harvesting Technology	Jointly organized by Villgro Innovations Foundation and ICAR – Central Tuber Crops Research Institute, Thiruvananthapuram 30 April 2018	Dr. Archana Mukherjee Dr. P.S. Sivakumar Dr. R. Muthuraj Dr. D. Jaganathan Dr. H. Kesava Kumar
Review Meeting on Project Expenditure of State Department Projects	Legislative Assembly, Thiruvananthapuram, 04 May 2018	Dr. Sheela Immanuel Dr. S. Sunitha
Workshop on Believe in Leadership from Below	Pankajakasturi Knowledge Park, Kandala, Thiruvananthapuram 05 May 2018	Dr. Sheela Immanuel Dr. P.S. Sivakumar Dr. D. Jaganathan
National Symposium on Scouting, Documentation and Dissemination of Grassroot Innovations and Traditional Knowledge	Mar Dioscorus College of Pharmacy, Alathara, Thiruvananthapuram 07 May 2018	Dr. N. Krishna Radhika Dr. C. Visalakshi Chandra
RKVY-State Level Sanctioning Committee Meeting	Department of Agriculture and Farmers Empowerment, Odisha, 18 May 2018	Dr. Kalidas Pati
9th H.H. Sree Visakham Thirunal Endowment Lecture-2018	ICAR-Central Tuber Crops research Institute, Thiruvananthapuram 19 May 2018	All Scientists

Programme	Particulars of the programme	Name of the participants
Meeting on Aspirational Districts Outreach Programme	ICAR-National Rice Research Institute, Cuttack, 24 May 2018	Dr. Kalidas Pati
Annual Group Meeting of AICRP on Palms	ICAR-Indian Institute of Oil Palm Research, Pedavegi, West Godavari, Andhra Pradesh, 24-25 May 2018	Dr. James George
National Seminar on Innovative Mechanization for Small and Marginal Farmers under Rainfed Areas	The Institution of Engineers, Thiruvananthapuram, 25–26 May 2018	Dr. M. S. Sajeev, Dr. T. Krishnakumar
National Conference on Intensification and Diversification in Agriculture for livelihood & Rural Development	Rajendra Prasad Central Agricultural University, Pusa, Bihar 28–31 May 2018	Dr. James George Dr. R. Muthuraj Dr. P.S. Sivakumar
Asia Sweet Potato Breeders and Seed Systems Meeting (ASPSSM-2018)	ICAR–Central Tuber Crops Research Institute, Thiruvananthapuram 28-31 May 2018	Dr. Archana Mukherjee Dr. G. Byju Dr. Sheela Immanuel Dr. M.N. Sheela Dr. Shirly Raichal Anil Dr. C. Mohan Dr. P. Murugesan Dr. K.I. Asha Dr. A. Asha Devi Dr. N. Krishna Radhika Dr. C. Visalakshi Chandra Dr. K.M. Senthilkumar Dr. A.V.V. Koundinya Dr. Vivek Hegde
Interface Meeting with Smt. Krishna Raj, Union Minister of State for Agriculture & Farmers' Welfare	ICAR-Central Marine Fisheries Research Institute, Vizhinjam, Thiruvananthapuram 29 May 2018	Dr. Archana Mukherjee Dr. Sheela Immanuel
Interaction Session of Scientists of ICAR-CTCRI with Sweet potato Breeders from Asian countries	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 30 May 2018	All Scientists
National Dialogue on AI and IoT Applications in Agriculture	ICAR-National Academy of Agricultural Research Management, Hyderabad 31 May–02 June 2018	Dr. J. Sreekumar Dr. V.S. Santhosh Mithra
Meeting on Research Activities of different ICAR Institutes situated at Cuttack and Bhubaneswar	ICAR-Central Institute of Fisheries Education, Bhubaneswar, 02 June 2018	Dr. Kalidas Pati
State Level Mango Mela 2018	Central Horticultural Experiment Station, ICAR-Indian Institute of Horticultural Research, Bhubaneswar 03-04 June 2018	Dr. Kalidas Pati
Seminar on Improved Technologies of Tuber Crops with Special Reference to Mealybug Management in Cassava	Krishi Vigyan Kendra, Tirupathisaram, Kanyakumari, 12 June 2018	Dr. R. Muthuraj Dr. D. Jaganathan

Programme	Particulars of the programme	Name of the participants
Technology Sourcing Fest for MSME-Science, Technology Interface Programme	CSIR–National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram 12 June 2018	Dr. M.S. Sajeev
Discussion on Collaborative Research on Root and Tuber Crops with Bioversity International	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 18 June 2018	All Scientists
International Yoga Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 21 June 2018	All Scientists
Farmer–Researcher Interactive Meeting	Krishi Bhavan, Mudakkal, Attingal, Thiruvananthapuram, 03 July 2018	Dr. S.S. Veena
Review Meeting of Vayalum Veedum of AIR	AIR, Milco unit, Kadakkavur, Thiruvananthapuram, 11 July 2018	Dr. D. Jaganathan
Meeting on Past for a Positive Future	Kerala Council for Historical Research, Mascot Hotel, Thiruvananthapuram 12 July 2018	Dr. Sheela Immanuel Dr. D. Jaganathan
National Workshop on Fertilizer Policy and Soil Health Governance	Fertilizer Association of India, Thiruvananthapuram, 24 July 2018	Dr. K. Susan John
Awareness Programme on Technological Empowerment of Women for Entrepreneurship Development in Tuber Crops based Value Added Products	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 26 July 2018	All Scientists
National Workshop on Artificial Intelligence (AI) in Agriculture: Status and Challenges	New Delhi, 30–31 July 2018	Dr. V.S. Santhosh Mithra
Meeting of Kerala State Industrial Development Corporation	Kerala State Industrial Development Corporation, Thiruvananthapuram 03 August 2018	Dr. Sheela Immanuel
32nd Annual National Level Convention	Odisha Assembly of Small and Medium Enterprises, 13 August 2018	Shri. Venkatraman V. Bansode
Meeting of Indian Postal Service	Thiruvananthapuram 01 September 2018	Dr. Archana Mukherjee Dr. Sheela Immanuel
Workshop on Biodiversity Rapid Assessment	Biodiversity Board, Thiruvananthapuram 04 September 2018	Dr. M.N. Sheela Dr. Sheela Immanuel
Entrepreneurship Development Programme on Tuber Crops Technologies	Alvan Thulukapatti, Mukoodal, Tirunelveli, 07 September 2018	Dr. R. Muthuraj Dr. P.S. Sivakumar Dr. D. Jaganathan
National Workshop on Statistical Methods for Data Analysis using R (SMDA-2018)	Department of Statistics, University of Kerala, Thiruvananthapuram 10-15 September 2018	Dr. J. Sreekumar
Meeting on Government Connect	State Bank of India, Thiruvananthapuram 13 September 2018	Dr. Archana Mukherjee Dr. Sheela Immanuel

Programme	Particulars of the programme	Name of the participants
Hindi Fortnight Celebrations	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 14-28 September 2018	All Scientists
Interactive Meeting on Academia-Vegetable Seed Industry Workshop for Developing Solutions to the Plant Virus Problems	ICAR-Indian Institute of Horticultural Research, Bengaluru 15 September 2018	Dr. T. Makeshkumar
National Workshop on Introductory Course on Next Generation Sequencing (NGS) Data Analysis	Uni Biosys Biotech Research Labs, Kochi, Kerala, 20-21 September 2018	Dr. N. Krishna Radhika
RKVY – Technical Expert Committee Meeting to Finalise Tissue Culture Lab Expansion of BFMC	Vikas Bhavan, Thiruvananthapuram 26 September 2018	Dr. Shirly Raichal Anil
Workshop on Artificial Intelligence for Plantation Crops	ICAR–Central Plantation Crops Research Institute, Kasaragod 28-29 September 2018	Dr. V. S. Santhosh Mithra
National Symposium on Coastal Agriculture: Boosting Production Potential under Stressed Environment	Dr. Babasaheb Sawant Konkan Krishi Vidyapith, Dapoli 28 September–01 October 2018	Dr. C.A. Jayaprakas Dr. E.R. Harish
ICAR-Indian Institute of Spice Research Biosafety Committee Meeting	ICAR-Indian Institute of Spice Research, Kozhikode, 29 September 2018	Dr. T. Makeshkumar
RKVY-State Level Project Screening Committee (SLPSC)	Agriculture and Farmers Empowerment Department, Government of Odisha 10 October 2018	Dr. V.B.S. Chauhan
National Workshop on Vertical Farming	NASC Complex, New Delhi 18 October 2018	Dr. G. Suja
National Symposium on Doubling Farmers' Income through Agronomic Interventions under Changing Scenario	Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, 24-26 October 2018	Dr. G. Suja
World Congress on Computers in Agriculture	Indian Institute of Technology, Mumbai 24-26 October 2018	Dr. V.S. Santhosh Mithra
Seminar on Hand Holding Support to Farmers	Department of Agriculture, Government of Kerala, Kattappana, Idukki 27 October 2018	Dr. M.S. Sajeev
37th Research and Extension Council Workshop	Regional Agricultural Research Station, Kumarakom, Kottayam 30 October 2018	Dr. V. Ramesh Dr. D. Jaganathan
Annual Review Meeting of CRP on Vaccines and Diagnostics	ICAR-Central Institute of Brackishwater Aquaculture, Chennai 30-31 October 2018	Dr. T. Makeshkumar

Programme	Particulars of the programme	Name of the participants
Meeting in connection with Vigilance Awareness Week	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 03 November 2018	All Scientists
26th Meeting of the Central Sub-Committee on Crop Standards, Notification and Release of Crop Varieties for Horticultural Crops	Krishi Bhavan, New Delhi 05 November 2018	Dr. M.N. Sheela
Swadeshi Science Congress	CSIR–National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram 07-09 November 2018	Dr. S.S. Veena
27th International Conference on Virology: Global Viral Epidemics: A Challenging Threat	Post Graduate Institute of Medical Education & Research, Chandigarh 10–14 November 2018	Dr. T. Makeshkumar
Stakeholders Interface Meeting in Connection with Krishi Unnati Mela and VAIGA 2018	ICAR-Central Institute of Fisheries Technology, Kochi, 16 November 2018	Dr. D. Jaganathan
Research Advisory Committee Meeting	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 16-17 November 2018	All Scientists
ISWS Golden Jubilee International Conference	ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh 21-24 November 2018	Dr. J. Suresh Kumar
National Workshop on Frontier Areas of Plant Biotechnology	College of Horticulture, Kerala Agricultural University, Vellanikkara 21-30 November 2018	Dr. N. Krishna Radhika
International Workshop on Scientific Writing	CSIR-Indian Institute of Chemical Technology, Hyderabad 22 November 2018	Dr. Senthilkumar K.M.
Tuber Crops Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 22-23 November 2018	All Scientists
8th International Conference (ICON-SWM 2018)	Acharya Nagarjuna University, Guntur, Andhra Pradesh 22-24 November 2018	Dr. V. Ramesh
National Conference on Revisiting Agricultural Research and Monitoring System for Developing Innovations: To Meet the Newer Challenges	Jointly organized by Agricultural Research Service Scientists Forum and ICAR-Central Institute of Women in Agriculture, Bhubaneswar 24–25 November 2018	Shri. Venkatraman V. Bansode Dr. Kalidas Pati
XIII Annual Group Meeting of the All India Network Programme on Organic Farming (AI-NPOF)	Tamil Nadu Agricultural University, Coimbatore, 27-29 November 2018	Dr. G. Suja
Fruits and Vegetable Processing Technology Clinic	District Industries Centre, Kasaragod 30 November 2018	Dr. M. S. Sajeev

Programme	Particulars of the programme	Name of the participants
Stakeholder Meet and Entrepreneurship Development Programme on Utilizing Tuber Crops based Sustainable Development	SMELC Building, Dakopgre, West Garo Hills, Tura, Meghalaya 01 December 2018	Dr. P.S. Sivakumar Dr. R. Muthuraj Dr. T. Krishnakumar Dr. D. Jaganathan
Entrepreneurship Development Programme on Tuber Crop Technologies	Krishi Vigyan Kendra, Namsai, Arunachal Pradesh, 05 December 2018	Dr. P.S. Sivakumar Dr. R. Muthuraj Dr. T. Krishnakumar
World Soil Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 05 December2018	All Scientists
National Seminar on Integrated Farming System for Enhancing Farmers' Income and Nutritional Security	West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal 05-07 December 2018	Dr. D. Jaganathan
Vegetables for Livelihood and Nutritional Security Under Changing Climate Scenario	Bidhan Chandra Krishi Vishwavidyalaya, Kalyani, West Bengal 06-07 December 2018	Dr. J. Suresh Kumar
National Symposium on Entomology 2018: Advances and Challenges	Professor Jayashankar Telangana State Agricultural University, Hyderabad 10-12 December, 2018	Dr. E.R. Harish
International Food Convention: Holistic Approaches for Start-Ups, Human Resource Training for Agriculture and Food Industry Gemmation	CSIR-Central Food Technological Research Institute, Mysore 12-15 December 2018	Dr. M.S. Sajeev Dr. T. Krishnakumar
Hindi Workshop	ICAR–Central Tuber Crops Research Institute, Thiruvananthapuram 15 December 2018	All Scientists
Meeting on Fruits and Vegetable Processing and Value Added Products	Technology Clinic, District Industries Centre, Ernakulam, 20 December 2018	Dr. M.S. Sajeev
Conference on National Top Expo and Summit – 2018	Hotel Swosti Premium, Bhubaneswar, Odisha, 20-21 December 2018	Dr. Kalidas Pati
National Symposium on Cutting Edge Approaches for Sustainable Plant Disease Management and Ensuring Farmers' Profit	ICAR-National Research Centre on Banana, Tiruchirappalli, Tamil Nadu 21-23 December 2018	Dr. M.L. Jeeva Dr. S.S.Veena Dr. T. Makeshkumar
Krishi Unnati Mela - International Workshop and Exhibition on Agro Processing and Value Addition (VAIGA – 2018)	Thekkinkadu Maidanam, Thrissur, Kerala, 27-30 December 2018	Dr. Archana Mukherjee Dr. Sheela Immanuel Dr. G. Byju Dr. D. Jaganathan
Agri Based Food Processing Technology Clinic	District Industries Centre, Idukki 29 December 2018	Dr. M.S. Sajeev

Programme	Particulars of the programme	Name of the participants
Krishi Unnati Mela - International Workshop and Exhibition on Agro Processing and Value Addition (VAIGA – 2018)	Thekkinkadu Maidanam, Thrissur, Kerala, 29-30 December 2018	Dr. M.S. Sajeev
QRT Meeting of All India Network Programme on Organic Farming (AI-NPOF)	Hotel Horizon, Thiruvananthapuram 10-11 January 2019	Dr. G. Suja
Field Day Cum Entrepreneur Meet on Chinese Potato	AlvanThulukapatti, Tirunelveli 11 January 2019	Dr. V. Ravi Dr. Sheela Immanuel Dr. R. Muthuraj Dr. P.S. Sivakumar Dr. D. Jaganathan
8th Indian Horticulture Congress: Shaping Future of Indian Horticulture	Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh 17-21 January 2019	Dr. Archana Mukherjee Dr. R. Muthuraj Dr. A.V.V. Koundinya Dr. P. Murugesan Dr. Vivek Hegde
Institute Biosafety Committee Meeting of Kerala Agricultural University	College of Agriculture, Vellayani, Thiruvananthapuram, 21 January 2019	Dr. T. Makeshkumar
RKVY-State Level Project Screening Committee (SLPSC)	Agriculture and Farmers Empowerment Department, Govt. of Odisha 22 January 2019	Dr. V.B.S. Chauhan
Udyam Samaagam (A conclave of Agripreneurship): Farm to Market - Challenges and Opportunities	Organized by Ministry of Micro, Small & Medium Enterprises Institute, Government of India, Thrissur, Kerala 24–25 January 2019	Dr. M.S. Sajeev
Seminar on State Credit	National Bank for Agriculture and Rural Development, Regional Office, Thiruvananthapuram, 29 January 2019	Dr. Sheela Immanuel
National Seminar on Strengthening of Seed Systems in the North Eastern and Unreached Regions – Problems, Prospects and Policies	ICAR-Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal, 03-05 February 2019	Dr. P. Murugesan
National Seminar on Advances and Applications in Plant Science	Department of Botany, University of Kerala, Thiruvananthapuram 06-08 February 2019	Dr. Shirly Raichal Anil Dr. Sanket J. More
National Conference on Farmers First for Conserving Soil and Water Resources in Eastern Region (FFCSWR-2019)	ICAR-Indian Institute of Soil and Water Conservation, Sunabeda, Koraput, Odisha, 06-08 February 2019	Dr. Kalidas Pati
National Symposium on Horticulture in the Vanguard of Climate Change and Urban Environment	Department of Horticulture, Annamalai University, Chidambaram, Tamil Nadu 07-08 February 2019	Dr. P. Murugesan
Workshop on Agro-Entrepreneurship Development	P.N. Paniker Foundation, Thiruvananthapuram, 08 February 2019	Dr. M.S. Sajeev

Programme	Particulars of the programme	Name of the participants
National Conference on Emerging Food Processing Technologies for Safe Food	Thangal Kunju Musaliar Institute of Technology, Kollam, 09 February 2019	Dr. M.S. Sajeev
National Agri-Business Entrepreneurship Conclave (NABEC-2019): Building Agri-Business Start-Up Ecosystem	Umiam, Meghalaya 09-11 February 2019	Dr. Archana Mukherjee Dr. P.S. Sivakumar
International Conference on Agricultural Extension and Advisory Services: Innovation to Impact	National Institute of Agricultural Extension Management (MANAGE), Hyderabad, 12-14 February 2019	Dr. P.S. Sivakumar
National Productivity Week Celebrations	ICAR–Central Tuber Crops Research Institute, Thiruvananthapuram 12-18 February 2019	All Scientists
State Level Technical Workshop on Organic Farming & GAP for Quality Production	Institute of Management in Government, Thiruvananthapuram 15 February 2019	Dr. G. Suja
Technology-Machinery Demonstration cum Kisan Mela	Nayarambalam, Ernakulam 15 February 2019	Dr. M.S. Sajeev
National Science Day	ICAR-Central Tuber Crops research Institute, Thiruvananthapuram 19-22 February 2019	All Staff Members
Prime Minister's Kisan Samman Nidhi Yojana (PM-KISAN) cum Live Web Telecast	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 24 February 2019	All Staff Members
National Symposium on Recent Challenges and Opportunities in Sustainable Plant Health Management	Banaras Hindu University, Varanasi 26-28 February 2019	Dr. T. Makeshkumar
Hindi Workshop	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 28 February 2019	All Scientists
Meeting in Connection with K.V. George Memorial Lecture Series-X	St. Thomas College, Kozhencherry, Pathanamthitta, 01 March 2019	Dr. Archana Mukherjee Dr. Sheela Immanuel
23rd Plantation Crops Symposium (PLACROSYM XXIII)	Chikkamagaluru, Karnataka 06-08 March 2019	Dr. P. Murugesan
Special Meeting in Connection with the Harvest of Organic Yams and Establishment of Tuber Crop Museum	Open Jail & Correctional Home, Nettukaltheri, Thiruvananthapuram 07 March 2019	Dr. Archana Mukherjee Dr. G. Byju Dr. G. Suja
International Women's Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 08 March 2019	All Scientists
Kerala Agro Food Pro - 2018	Department of Industries, Thrissur, 12 March 2019	Dr. M.S. Sajeev

Programme	Particulars of the programme	Name of the participants
National Seminar on Climate Resilient Agriculture for Abiotic Stress	Department of Plant Breeding and Genetics, Annamalai University, Chidamabaram, Tamil Nadu 12-13 March 2019	Dr. P. Murugesan
National Seminar on Viral Genomics: Its Implications in Viral Diagnosis and Disease Control	Inter University Centre for Genomics & Gene Technology, University of Kerala, Karyavattom, Thiruvananthapuram 14 March 2019	Dr. T. Makeshkumar Dr. E.R. Harish Dr. H. Kesava Kumar Dr. Sangeetha, B.G.
Workshop on Applied Statistics and Data Analysis for Science and Society	Department of Agricultural Statistics, College of Agriculture, Vellayani, Kerala Agricultural University, 14 March 2019	Dr. Archana Mukherjee
National Conference on Agri-Nutrition	Ministry of Women and Child Development, Govt. of India, The Ashok Hotel, New Delhi 15 March 2019	Dr. A. N. Jyothi
Annual Action Plan Meeting of KVKs of Kerala & Lakshadweep	Karshaka Bhavanam, Kerala Agricultural University, Thrissur, 18-20 March 2019	Dr. G. Suja
Young Innovators Meet	Kerala Development and Innovation Strategic Council, Thiruvananthapuram 20 March 2019	Dr. Archana Mukherjee Dr. Sheela Immanuel
Workshop on Intellectual Property Valuation of Agricultural Technologies	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 22 March 2019	Dr. Archana Mukherjee Dr. Sheela Immanuel Dr. P.S. Sivakumar Dr. R. Muthuraj Dr. D. Jaganathan Dr. H. Kesava Kumar
61st Meeting of Board of Studies of College of Agriculture	College of Agriculture, Vellayani, Thiruvananthapuram 28 March 2019	Dr. M.N. Sheela

VISITS ABROAD

Name of the scientist	Period	Place of visit	Purpose
Dr. M.N. Sheela	17-21 September 2018	Phnom Penh, Cambodia	As Invited speaker presented a paper titled 'Control of cassava mosaic disease in India' at Regional CMD Control Plan Meeting organized by Global Cassava Partnership for the 21st Century
Dr. C. A. Jayaprakas	04-28 June 2018	Hainan Province, China	Attended training course on 'Integrated pest management of tropical crops for developing countries'
	07-11 October 2018	Berlin, Germany	Participated in the 12th International Working Conference on Stored Product Protection (IWCSPP) and presented a poster on 'Management of major coleopteran pests of stored-products using the insecticidal principles isolated from cassava, *Manihot esculenta* Crantz'
	11-14 November 2018	Vancouver British Columbia, Canada	Participated in the Entomological Society of America (ESA) Joint Annual Meeting 2018 at the Vancouver Convention and presented the paper entitled 'Cassava, *Manihot esculenta* Crantz, a befitting source for the isolation of green molecules against red palm weevil'
Dr. K. Susan John	05-07 September 2018	KU Leuven, Belgium	Attended the 5th International Zinc Symposium at Irish College and presented an oral research paper titled 'Recent advances in the zinc nutrition of tropical tuber crops in different soil types of Kerala, India'
Dr. T. Makeshkumar	17-21 September 2018	Phnom Penh city, Cambodia	Participated in the Regional CMD Control Plan Meeting and presented 'Status report of cassava mosaic disease in India'
	06-16 December 2018	Braunschweig, Germany	Undertaken short-term research visit at DSMZ Plant Virus Department
Mr. P. Prakash	28 July-02 August 2018	Vancouver, Canada	30th International Conference of Agricultural Economists

Dr. M.N. Sheela and Dr. T. Makeshkumar along with the delegates of the Regional CMD Control Plan Meeting in Cambodia

Dr. C.A. Jayaprakas in China

Dr. T. Makeshkumar in Cambodia

Dr. K. Susan John with the delegates of the 5th International Zinc Symposium at KU Leuven, Belgium

Short-term research visit by Dr. T. Makeshkumar at DSMZ Plant Virus Department

Mr. P. Prakash in the 30th International Conference of Agricultural Economists, Canada

DISTINGUISHED VISITORS

- Shri. Alphons Kannanthanam, Hon'ble Minister of State for Tourism (Independent Charge), New Delhi.
- Dr. Abhilaksh Likhi, Joint Secretary (Cooperation), Ministry of Agriculture and Farmers Welfare, Govt. of India.
- Dr. G. Kalloo, Former DDG (Hort. Sci.), ICAR, New Delhi.
- Dr. N.K. Krishnakumar, Regional Representative in South & Central Asia, Bioversity International & Former DDG (Hort. Sci.), ICAR, New Delhi.
- Shri. Devendra Kumar Singh IAS, Agricultural Production Commissioner, Govt. of Kerala.
- Dr. P.K. Jayasree, Director, Department of Agriculture & Farmers' Welfare, Govt. of Kerala.
- Smt. Shardha Sampath, Chief Post Master General, Kerala Circle, Thiruvananthapuram.
- Dr. Purnachandra Rao, Director, National Centre for Earth Science Studies, Thiruvananthapuram.
- Shri. S. Harikishore IAS, Executive Director, Kudumbasree Mission, Govt. of Kerala.
- Shri. A. Somadethan, Assistant Director (Retd.), Income Tax Office, Thiruvananthapuram.
- Dr. T.N. Seema, Vice Chairperson, Haritha Keralam Mission, Government of Kerala.
- Dr. Simon Heck, CIP Program leader, Uganda.
- Dr. Maria Andrade, World Food Prize Laureate 2016, CIP, Mozambique.
- Dr. T. Janakiram, ADG (Hort. Sci.), ICAR, New Delhi.
- Dr. C. Devakumar, Former ADG (EP&D), ICAR, New Delhi.
- Dr. M. Anandaraj, Former Director, ICAR-Indian Institute of Spices Research, Kozhikode.
- Dr. S.K. Nanda, Former Project Coordinator, AICRP on PHT, ICAR-Central Institute of Post-Harvest Engineering and Technology, Ludhiana.
- Dr. S. Arulraj, Former Director, ICAR-Indian Institute of Oil Palm Research, Pedavegi, Andhra Pradesh.
- Dr. P. Kalia, Emeritus Scientist & Former Head, Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, Pusa, New Delhi.
- Prof Dr. P.M. Rajan Gurukkal, Vice Chairman, Kerala State Higher Education Council, Thiruvananthapuram.
- Prof. (Dr.) V.K. Ramachandran, Vice Chairman, Kerala State Planning Board, Thiruvananthapuram.
- Advocate Smt. Rakhi Ravikumar, Deputy Mayor, Thiruvananthapuram Corporation, Thiruvananthapuram.

- Dr. S.P. Verma, Former Project Coordinator, AICRP (TC), ICAR-CTCRI, Thiruvananthapuram.
- Dr. M.S. Palaniswami, Former Project Coordinator, AICRP (TC), ICAR-CTCRI, Thiruvananthapuram.
- Dr. Saji Gopinath, Chief Executive Officer, Kerala Startup Mission, Thiruvananthapuram.
- Shri. Alathara Anil Kumar, Ward Councillor, Thiruvananthapuram Corporation, Thiruvananthapuram.

Distinguished RAC experts on the occasion of the First Meeting of RAC VIII

CTCRI STAFF MEMBERS

Managerial Personnel

Dr. Archana Mukherjee	:	Director
Dr. James George	:	Project Coordinator (up to 31.01.2019)
Dr. V. Ravi	:	Head, Crop Production
Dr. C.A. Jayaprakas	:	Head (Acting), Crop Protection & Central Public Information Officer
Dr. M.N. Sheela	:	Head (i/c), Crop Improvement
Dr. Sheela Immanuel	:	Head (i/c), Extension and Social Sciences
Dr. M. Nedunchezhiyan	:	Head (i/c), Regional Centre, Bhubaneswar
Dr. M.S. Sajeev	:	Head (i/c), Crop Utilisation
Shri. Abhishek Rana	:	Senior Administrative Officer
Shri. P. Krishnakumaran	:	Finance and Accounts Officer

Personnel

HEADQUARTERS, Thiruvananthapuram	
Director	**Dr. Archana Mukherjee**
AICRP on Tuber Crops	
Dr. James George (Rtd. on 31.01.2019)	Principal Scientist & Project Coordinator
Dr. S. Sunitha	Principal Scientist
Dr. 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 (up to 08.05.2018)	Scientist
Dr. A.V.V. Koundinya	Scientist

HEADQUARTERS, Thiruvananthapuram	
Dr. Senthilkumar K.M.	Scientist
Division of Crop Production	
Dr. V. Ravi	Principal Scientist & Head
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

HEADQUARTERS, Thiruvananthapuram	
Shri. A. Madhu	Assistant Chief Technical Officer
Shri. I. Puviyarasan	Assistant Chief Technical Officer
Shri. M. Kuriakose	Assistant Chief Technical Officer
Shri. C.S. Salimon	Assistant Chief 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. L. Luke Armstrong	Technical Assistant
Dr. S. Karthikeyan	Technical Assistant
Smt. Pallavi Nair K.	Technical Assistant
Shri. K. Sunil	Technical Assistant
Shri. T. Raghavan	Technical Assistant
Shri. B. Satheesan	Senior Technician
Shri. D.T. Rejin	Senior Technician
Shri. Shinil T.M.	Senior Technician
Shri. C. Krishnamoorthy	Technician
Shri. K. Velayudhan	Technician
Shri. T. Manikantan Nair	Technician
Administration and Accounts	
Shri. Abhishek Rana (w.e.f. 02.04.2018)	Senior Administrative Officer
Smt. P. Krishnakumaran	Finance and Accounts Officer
Shri. P.C. Noble	Assistant Administrative Officer
Shri. T. Vijayakumara Kurup	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

HEADQUARTERS, Thiruvananthapuram	
Shri. S. Hareendrakumar	Assistant
Shri. Arjun Murali	Assistant
Shri. S. Sreekumar (w.e.f. 24.04.2018)	Assistant
Smt. V. Sathyabhama	U. D. C.
Shri. O.C. Ayyappan	U. D. C.
Shri. R.S. Adarsh	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 (Rtd. on 31.03.2019)	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
Smt. 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. Vidhya P.	Skilled Support Staff
Shri. Arunraj D.	Skilled Support Staff
Shri. SreenathVijay	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. (up to 25.06.2018)	Skilled Support Staff
Smt. Remya V.S.	Skilled Support Staff

REGIONAL CENTRE, Bhubaneswar	
Scientists	
Dr. M. Nedunchezhiyan	Principal Scientist & Head (i/c)
Dr. K. Laxminarayana	Principal Scientist
Dr. Kalidas Pati	Scientist
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 (Rtd. on 30.04.2018)	Technical Officer
Shri. Pramod Kumar Mati	Technical Officer
Shri. Bibhuti Bhusan Das	Technical Officer
Shri. Bharat Kumar Sahoo	Senior Technical Assistant
Shri. Sushanta Kumar Jata	Senior Technical Assistant
Shri. Raja K. (w.e.f. 06.08.2018)	Technical Assistant
Shri. Keshab Paikaray	Senior Technician
Administration and Accounts	
Shri. P.K. Acharya	Private Secretary
Shri. A. Lakshmana Rao	Assistant
Skilled Support Staff	
Shri. Ramachandra Das (Rtd. on 31.05.2018)	Skilled Support Staff
Shri. Bijoykumar Nayak	Skilled Support Staff
Shri. Akshayakumar Nayak (Rtd. on 28.02.2019)	Skilled Support Staff
Shri. Purna Samal	Skilled Support Staff
Shri. Bhajaman Malik	Skilled Support Staff
Shri. Sauri Pradhan	Skilled Support Staff
Shri. Ramesh Nayak (Rtd. on 31.03.2019)	Skilled Support Staff
Shri. Babuli Sethi	Skilled Support Staff
Shri. Fakir Charan Bhoi	Skilled Support Staff
Shri. Samsuddin Khan	Skilled Support Staff

OTHER INFORMATION

44th Meeting of Annual Institute Research Council

The 44th meeting of the Annual Institute Research Council of ICAR-CTCRI was held during 03-05 April 2018 under the chairmanship of Dr. Archana Mukherjee, Director. The 10 ongoing Institute projects with 56 research activities were presented by the Principal Investigators. The projects were thoroughly discussed and the suggestions were recorded and documented. The meeting concluded on the third day with the plenary session. Dr. Archana Mukherjee in her concluding remarks expressed happiness about the successful conduct of the 44th IRC and thanked all the external experts namely, Dr. S.G. Nair, Former Head, Division of Crop Improvement, ICAR-CTCRI, Shri. M. Unnikrishnan, Former Principal Scientist, Division of Crop Improvement, ICAR-CTCRI, Dr. Ashalatha S. Nair, Professor and Former Head, Department of Botany, Kerala University, Kariavattom, Dr. C.S. Ravindran, Former Head, Division of Crop Production, ICAR–CTCRI, Thiruvananthapuram, Dr. K. Ushakumari, Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram, Dr. M.S. Palaniswami, Former Project Coordinator, AICRP (TC), ICAR–CTCRI, Thiruvananthapuram, Dr. K. Umamaheswaran, Professor and Head, Department of Plant Pathology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram, Dr. G. Padmaja, Former Director (Acting), ICAR–CTCRI, Thiruvananthapuram, Dr. S.N. Moorthy, Former Head, Division of Crop Utilization, ICAR–CTCRI, Thiruvananthapuram, ICAR–CTCRI, Dr. M. Anantharaman, Former Head, Section of Extension and Social Sciences, ICAR–CTCRI, Thiruvananthapuram and Dr. N. Kishore Kumar, Professor, Department of Agricultural Extension, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram for providing valuable inputs for improving the research projects. The IRC meeting was coordinated by Dr. Saravanan Raju, IRC Secretary.

18th Annual Group Meeting and Golden Jubilee Celebrations of the All India Coordinated Research Project on Tuber Crops at ICAR-CTCRI

The 18th Annual Group Meeting of the All India Coordinated Research Project on Tuber Crops (AICRP-TC) was held at ICAR-CTCRI, Thiruvananthapuram, during 26-28 April 2018. The programme was inaugurated by Dr. T. Janakiram ADG (Hort. Sci.), ICAR, New Delhi. Dr. James George, Project Coordinator welcomed the participants and narrated the journey of AICRP-TC from 1968 to 2018, in the Golden Jubilee year. Dr. Archana Mukherjee, Director, ICAR-CTCRI delivered the presidential address. Dr. S.P. Verma and Dr. M.S. Palanisami, Former Project Coordinators were honoured during the function. The Best Centre Award for 2017-18 was presented to Tamil Nadu Agricultural University, with two AICRP centres, at Coimbatore and Yethapur. The award was received by Dr. M. Vel Murugan, PI, Yethapur and Dr. Kamalkumaran, PI, Coimbatore. An agro-advisory system for cassava developed by Dr. V.S. Santhosh Mithra, Principal Scientist, ICAR-CTCRI, based on the information generated from the phenology studies conducted by AICRP centres across the country was launched. Publications prepared in connection with the Golden Jubilee year, which included technical bulletins on “Compendium of tuber crops technologies-1968 to 2018 by AICRP on tuber crops”, “Tuber crops varieties released/recommended for release by AICRP on tuber crops over five decades”, “Tuber

crops based integrated farming systems" and few folders in vernacular languages by various centres were released during the occasion. Dr. S. Sunitha, Principal Scientist, PC Cell, proposed the vote of thanks.

Release of publications

Participants of the 18th Annual Group Meeting of AICRP

H.H. Sree Visakham Thirunal Endowment Lecture-2018

The Indian Society for Root Crops (ISRC) in collaboration with the ICAR-CTCRI organized the 9th H.H. Sree Visakham Thirunal Endowment Lecture on 19 May 2018. The programme started with a floral tribute to H.H. Sree Visakham Thirunal by the dignitaries. Dr. C.A. Jayaprakas, President, ISRC welcomed the gathering. The function was presided over by Dr. Archana Mukherjee, Director, ICAR-CTCRI. The program was inaugurated by Prof. Dr. P.M. Rajan Gurukkal, Vice Chairman, Kerala State Higher Education Council, Thiruvananthapuram. He highlighted the importance of traditional agriculture and the need for integrating the traditional knowledge with modern science. Prof. (Dr.) V.K. Ramachandran, Vice Chairman, Kerala State Planning Board, Thiruvananthapuram delivered the endowment lecture. He discussed about the strengths and challenges in agriculture, changes in the land reforms and the opportunities existing in the internal markets. Dr. V.S. Santhosh Mithra, Secretary, ISRC, proposed the vote of thanks. About 200 delegates attended the function.

H.H. Sree Visakham Thirunal Endowment Lecture

Asia Sweet potato Breeders and Seed System Meeting 2018

The third Asia Sweet potato Breeders and Seed System Meeting 2018 was held at ICAR-CTCRI, Thiruvananthapuram, during 28-31 May 2018. Twenty four delegates from various Asian countries and CIP centres, including India, attended the meeting. The meeting was inaugurated by

Participants of the 3rd Asia Sweet potato Breeders and Seed System Meeting 2018 at ICAR-CTCRI (top) and field visit to sweet potato fields (bottom)

Dr. Simon Heck, CIP Program leader, Uganda. Dr. Sreekanth Attaluri, Program Manager, CIP, India gave the welcome address and Dr. Archana Mukherjee, Director, ICAR-CTCRI delivered the opening remarks. Dr. Maria Andrade, World Food Prize Laureate 2016 was one among the key speakers. All the country leaders presented their respective achievements and the meeting was successfully concluded on 31 May 2018. The meeting was coordinated by Dr. Sheela Immanuel and Dr. G. Byju, Principal Scientists, ICAR-CTCRI.

Seminar on Improved Technologies of Tuber Crops

Seminar on 'Improved technologies of tuber crops with special reference to mealybug management in cassava' was organized on 12 June 2018 at Krishi Vigyan Kendra, Tirupathisaram, Kanyakumari. Lecture-cum-discussions were delivered by Dr. R. Muthuraj and Dr. D. Jaganathan. More than 100 farmers and other stakeholders from Kanyakumari district attended the seminar. Exhibition on technologies of tuber crops was also organized.

Distribution of planting materials of cassava

Inaugural address by DDH, Kanyakumari

Entrepreneurship Development Programme on Chinese potato

Entrepreneurship Development Programme on tuber crops with special reference to Chinese Potato at Mukoodal, Tirunelveli district was organized on 07 September 2018. Sirukizhangu (*Plectranthus rotundifolius*) is cultivated in about 500 hectares in Kadayam, Ambasamudram and Pappakudi blocks, catering to requirements of neighbouring Kerala state. Considering the need to maximise productivity of Sirukizangu, ICAR-CTCRI has launched a programme in collaboration with Horticultural department and other local agencies.

Distribution of planting materials of Chinese potato

Dr. P. Sethuraman Sivakumar, Dr. R. Muthuraj and Dr. D. Jaganathan participated in the Scientist-Farmer interaction sessions. Smt. S. Subavasugi, Assistant Director (Horticulture), stressed the need to work collaboratively with all stakeholders. A highlight of the event was the address by Dr. Archana Mukherjee, Director, ICAR-CTCRI, who interacted with farmers through teleconferencing and assured necessary technical help for Sirukizhangu farmers. Various technologies developed at ICAR-CTCRI, like biopesticides and alcohol from cassava, functional food products like pasta, noodles and breakfast bars from cassava along with medicinal tuber varieties of sweet potato were exhibited to farmers. About 100 farmers and farm women took part in the programme.

One-day Awareness Programme on Women Entrepreneurship

A one-day awareness programme on 'Technological Empowerment of Women for Entrepreneurship Development in Tuber Crops based Value Added

Products' sponsored by the Women Scientist Division, KSCSTE was organized on 26 July 2018 at ICAR-CTCRI, Thiruvananthapuram. The programme was inaugurated by Shri. S. Harikishore IAS, Executive Director, Kudumbasree Mission, Government of Kerala. Dr. V. Ravi, Director i/c presided over and Dr. Sajeev, M.S., Programme Co-ordinator welcomed the gathering. Dr. A.N. Jyothi, Principal Scientist, proposed the vote of thanks.

National Workshop on e-Crop: an IoT Solution in Agriculture

A three days National Workshop on 'e-Crop: an IoT solution in Agriculture' was held at ICAR-CTCRI, Thiruvananthapuram during 05-07 September 2018. The workshop was inaugurated on 05 September, 2018 by Shri. Devendra Kumar Singh IAS, Agricultural Production Commissioner, Government of Kerala. Dr. Archana Mukherjee, Director, ICAR-CTCRI presided over the function. Dr. Sheela Immanuel, Head, Section of Extension and Social Sciences welcomed the gathering and

Inauguration of the Workshop on e-crop by Shri Devendra Kumar Singh, IAS

Participants of the Workshop on e-crop

briefed about the utility of ICT tools in agriculture. Dr. Mithra proposed the vote of thanks. A total of 17 participants including Scientists from ICAR institutes, SAUs and Private organizations attended the workshop.

Post-flood Loss Assessment and Rehabilitation of Tuber Crops in Kerala

The ICAR-CTCRI conducted a survey and analysis of the deluge on the extent of damage to tuber crops owing to flood in the state. A team led by Dr. G. Byju and consisting of Dr. S. Sunitha, Dr. M.S. Sajeev, Dr. V. Ravi, Dr. A. Asha Devi, Dr. Shirly Raichal Anil, Dr. M.N. Sheela, Dr. J. Sreekumar, Dr. T. Makeshkumar, Dr. C.A. Jayaprakas, Dr. A.N. Jyothi, Dr. M.L. Jeeva, Dr. G. Suja, Dr. P. Murugesan, Dr. Saravanan Raju, Dr. S.S. Veena, Dr. C. Mohan, Dr. H. Kesava Kumar, Dr. K.I. Asha, Dr. V.S. Santhosh Mithra, Dr. Vivek Hegde, Dr. V. Ramesh, Dr. E.R. Harish, Dr. A.V.V. Koundinya, Dr. R. Muthuraj, Dr. D. Jaganathan, Mr. V.R. Sasankan, Mr. D.T. Rejin and Mrs. R. Shiny made a detailed survey and data collection from all the 14 districts of the states during 07-12 September 2018.

The members of the study team visited the respective offices of Principal Agricultural Officer and had detailed discussions about the flood damaged areas and a map was prepared to randomly survey the tuber crop growing regions. With the active support of ADAs and Agricultural Officers of Krishi Bhavans, surveys were conducted and data collection of tuber crops as well as documentation of the loss was made. Wherever needed, Krishi Vigyan Kendras (KVK) as well as other local bodies, such as Village Office, Panchayat Office were contacted.

The results of the study showed that the state lost tuber crops in an area of 7679.30 ha with a total economic loss of ₹ 288.04 crores. This loss comes

to 8.65% of the total area under tuber crops, which is 88803 ha. Studies using ecological niche and crop models predicted a total yield reduction of tuber crops to the extent of 15% during 2018 due to flood and its aftermath. Among the districts, Alappuzha, Thrissur, Ernakulam, Malappuram, Pathanamthitta and Wayanad were the worst hit, where 78.50% of the total loss of area under tuber crops occurred. The state lost 5838.71 ha of cassava, which caused ₹ 204.35 crores loss to the farmers. Alappuzha, Malappuram, Ernakulam, Thrissur and Pathanamthitta were worst affected districts with 76.46% loss in area under cultivation. Elephant foot yam, another important tuber crop, is cultivated in an area of 7143 ha and the study showed that 943.60 ha were damaged by flood, which is 13.21% of the total area under cultivation. Alappuzha, Pathanamthitta, Kollam and Thrissur suffered very serious damage to the crop. The crop loss caused ₹ 56.62 crores of economic loss to the farmers. Taro, which is cultivated in an area of 8085 ha, is another important tuber crop of Kerala and the flood damaged 355 ha, with an economic loss of ₹ 14.20 crores. Yams are grown in an area of 1874 ha and the state lost 11.70% of the area (219 ha), which caused a loss of ₹ 4.38 crores to the yam farmers, who are mostly concentrated in the districts of Pathanamthitta, Alappuzha, Idukki and Kollam. The Chinese potato is cultivated in Thrissur district. An area of 78.5 ha of the crop was destroyed by flood, which caused economic loss of ₹ 2.36 crores. Besides these, the state also suffered loss of sweet potato in an area of 5.5 ha in Kasaragod and Kannur districts, with a monetary loss of ₹ 1.65 crores.

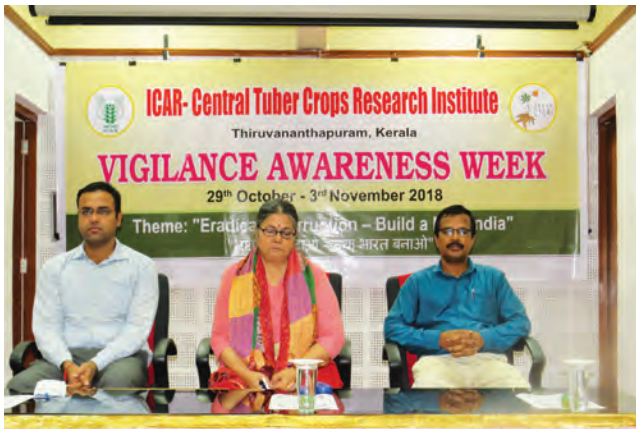
ICAR-CTCRI has made a 10-point recommendation package, which includes application of lime/ dolomite to improve the soil structure and ameliorate soil acidity, soil testing and site specific nutrient management (SSNM) recommendations, use of quality planting material (QPM) of tuber crops, adoption of good agricultural practices (GAP) developed by ICAR-CTCRI, application of farmyard manure, compost, green manure cowpea, green leaf manures, coir pith compost and biofertilizers and control of soil borne diseases.

Entrepreneurship Orientation Programme for Agricultural Students

The ICAR-CTCRI, IPTMU & PSC and Section of Extension and Social Sciences organised an 'Entrepreneurship Orientation Programme for Agricultural Students' in collaboration with College of Agriculture, Vellayani, Kerala Agricultural University during 24-26 September, 2018. This EDP was inaugurated by Dr. Saji Gopinath, CEO, Kerala Startup Mission along with Dr. Archana Mukherjee, Director, ICAR-CTCRI and Dr. Sheela Immanuel, Head, Social Sciences, ICAR-CTCRI. The event was the fourth edition of the ICAR-CTCRI & KAU Collaborative EDP, and about 110 B.Sc. (Ag.) students of College of Agriculture, Vellayani participated in the programme.

Vigilance Awareness Week 2018

The Institute observed Vigilance Awareness Week on the theme 'Eradicate Corruption-Build a New India' during 29 October-03 November 2018 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. The week started with the vigilance pledge taken by the employees of ICAR–CTCRI, Thiruvananthapuram, administered by Dr. Archana Mukherjee, Director. Staff and students participated in creative activities like poster making competition, elocution competition etc. to create awareness amongst all sections of employees. A special talk was presented by Shri. Abhishek Rana, Senior Administrative Officer, ICAR-CTCRI on Preventive Vigilance and conduct rules on 3 November 2018. The winners of various competitions were felicitated. The meeting concluded with the vote of



Vigilance Awareness Week 2018

Distribution of certificate by Dr. S. Arulraj, Chief Guest

thanks by Dr. Saravanan Raju, Vigilance Officer, ICAR-CTCRI.

National Workshop on Advances in Social and Behavioural Science Research

The third edition of ICAR-CTCRI-AESA-CRISP-MANAGE-NAARM collaborative National Workshop 'Advances in Social and Behavioural Science Research' was organised during 12–17 November 2018. The participants were imparted basic and advanced skills in conducting social science research. Eminent resource persons, Dr. Rasheed Sulaiman, Chair, Global Forum for Rural Advisory Services (GFRAS, Switzerland), Dr. Sivaramane N., Principal Scientist, NAARM along with Institute faculty handled the classes. Dr. S. Arulraj, Former Director, Indian Institue of Oil Palm Research, Pedavegi, Andhra Pradesh was the Chief Guest for the Valedictory session. A total of 36 participants attended the six-days programme.

Participants of the National Workshop

First meeting of the Research Advisory Committee VIII of ICAR-CTCRI

The first meeting of RAC VIII of ICAR-CTCRI was held during 16-17 November 2018 at ICAR-CTCRI, Thiruvananthapuram. The meeting was chaired by Dr. G. Kalloo, Former DDG (Hort. Sci.), ICAR. Dr. Archana Mukherjee, Director, ICAR-CTCRI, welcomed the Chairman and members of RAC. She made a presentation on Institute profile and significant research achievements. Dr. James George, Project Coordinator, AICRP on Tuber Crops briefed about the achievements of AICRP on tuber crops. The constitution of RAC VIII is given below:

RAC VIII meeting

RAC VIII of ICAR-CTCRI

1.	Dr. G. Kaloo, Former DDG (Horti.Sci), ICAR, New Delhi	Chairman
2.	Dr. M. Anandaraj, Former Director, ICAR- IISR, Kozhikode	Member
3.	Dr. S. K. Nanda, Former Project Coordinator, AICRP (PHT), CIPHET, Ludhiana	Member
4.	Dr. S. Arulraj, Former Director, ICAR- IIOPR, Pedavegi, West Godavari	Member
5.	Dr. P. Kalia, Former Head, Division of Vegetable Science, ICAR- IARI, New Delhi	Member
6.	Dr. C. Devakumar, Former ADG (EP & D), ICAR, New Delhi	Member
7.	Dr. T. Janakiram, ADG (Hort. Sci. I), ICAR, New Delhi	Member
8.	Dr. Archana Mukherjee, Director, ICAR-CTCRI, Thiruvananthapuram	Member
9.	Dr. G. Suja, Principal Scientist, ICAR- CTCRI, Thiruvananthapuram	Member Secretary

The action taken report of the third meeting of RAC VII was presented and approved. The project leaders presented the salient achievements of 10 ongoing Institute projects and 27 externally funded projects and the targets for 2018-19. Based on the presentations, suggestions were given by the honorable members for implementation. The chairman and members emphasized the research focus on doubling farmers' income, strategic, anticipatory and adaptive research along with smart tools in the context of climate change, digital farming, bio-fortification, and aligning the research activities as per vision 2050. The team also visited the Institute farms, museum and Techno-Incubation Centre. The meeting was coordinated by Dr. Suja G., Principal Scientist & Member Secretary, RAC VIII of ICAR-CTCRI.

Tuber Crops Day and Farmers Fair Celebrations

Tuber Crops Day was celebrated during 22-23 November 2018 at ICAR-CTCRI, Thiruvananthapuram. The celebration was inaugurated by Dr. P.K. Jayasree, Director, Department of Agriculture & Farmers' Welfare, Government of Kerala. In her inaugural speech, she highlighted the importance of improved varieties/ technologies for enhancing productivity of tuber crops in the context of climate change. The meeting was presided over by Dr. Archana Mukherjee, Director, ICAR-CTCRI. Dr. Sheela Immanuel, Head, Extension and Social Sciences welcomed the gathering. Dr. M.N. Sheela, Head, Crop Improvement proposed the vote of thanks. The inaugural function was followed by Scientist-Farmer interface. About 200 farmers attended the function.

Tuber Crops Day and Farmers' Fair

Stakeholders Meet and Tuber Crops Entrepreneurship Development Programme at Tura, Meghalaya

The ICAR-CTCRI in collaboration with North Eastern Hill University, Tura Campus, KVK, Tura, Horticulture Department, West Garo Hills and Meghalaya Basin Development Agency organised a Stakeholder Meet and Entrepreneurship Development Programme on Tuber Crops Technologies on 01 December 2018.

Shri. Ram Singh IAS, Deputy Commissioner, West Garo Hills addressing the gathering

Participants of the Stakeholders Meet and Tuber Crops EDP at Tura

A Tuber Crops exhibition-cum-ethnic food festival, inaugurated by Shri. Ram Singh IAS, Deputy Commissioner, West Garo Hills District & Chairman, Meghalaya Basin Development Agency (MBDA) was organised along with the EDP, where various food products developed by ICAR-CTCRI were demonstrated to the participants. The Stakeholder meeting was inaugurated by Prof. G. Singaiah, Pro-Vice Chancellor of NEHU, Tura campus in the presence of Shri A.S. Singh, Programme Coordinator, KVK, West Garo Hills; Mr. M. Sangma, District Horticulture Officer; Dr. P. Sethuraman Sivakumar, Dr. R. Muthuraj, Dr. D. Jaganathan and Dr. T. Krishnakumar, ICAR-CTCRI. About 100 farmers from various parts of West Garo Hills participated in the programme.

Stakeholders Meet and Tuber Crops Entrepreneurship Development Programme at Namsai, Arunachal Pradesh

The ICAR-CTCRI, Thiruvananthapuram in collaboration with Krishi Vigyan Kendra, Namsai (ICAR Research Complex for North Eastern Hills, AP Centre, Basar, Arunachal Pradesh) organised Tuber Crops Ethnic Food Festival and Stakeholder Meet at KVK Campus on the occasion of World Soil Health Day on 05 December 2018. This mega event was inaugurated by Shri. Chow Tewa Mein, Hon'ble MLA, Chongkham. He called for a collaborative approach to develop small scale industries for processing tuber crops. Dr. P. Sethuraman Sivakumar, Principal Scientist, ICAR-CTCRI indicated that tuber crops products like chips, namkeen, pasta and noodles have high potential for developing farmer-oriented village level processing units. Shri. B.R. Dey, Assistant Director, Industries, Namsai, Dr. Manish Kanwat, Senior Scientist & Head, KVK, Namsai and Mr. S.K. Jawal, Assistant Director, Fisheries participated in the meeting. Dr. R. Muthuraj and Dr. T. Krishnakumar conducted the technical sessions. A total of 13 SHGs and progressive farmers from Namsai district showcased their local recipes. In addition, Scientists from ICAR-CTCRI, Thiruvananthapuram, demonstrated the tuber crops based products. A total of 120 farmers, members of self-help groups and Farmers Producers Organizations participated in the event.

Tuber Crops Ethnic Food Festival at KVK, Namsai

Participants of the Tuber Crops Ethnic Food Festival

World Soil Day 2018

The World Soil Day 2018 was celebrated at ICAR-CTCRI on 05 December 2018. The function was presided by Dr. Archana Mukherjee, Director, ICAR-CTCRI and she administered the pledge for the World Soil Day. Advocate Smt. Rakhi Ravikumar, Deputy Mayor, Thiruvananthapuram Corporation was the Chief Guest. Shri. Alathara Anil Kumar, Ward Councillor, Thiruvananthapuram Corporation delivered the keynote address. Dr. Thomas George, Professor (Agricultural Chemicals), Kerala Agricultural University delivered the Guest Lecture on the theme 'Be the solution to soil pollution'. Soil health card was distributed by Dr. Archana Mukherjee. Dr. James George, Project Coordinator, AICRP (TC) and Dr. V. Ravi, Principal Scientist & Head, Division of Crop Production gave special remarks. Dr. K. Susan John, Principal Scientist and Nodal Officer of the Soil Health Card Programme proposed the vote of thanks.

World Soil Day celebrations

VAIGA (Value Addition for Income Generation in Agriculture) and Krishi Unnati Mela

The VAIGA and Krishi Unnati Mela was inaugurated on 27 December 2018 by Shri. P. Sathasivam, Honourable Governor of Kerala at Thrissur, Kerala. President of the function, Shri. V.S. Sunil Kumar, Honourable Minister for Agriculture, Kerala stated that the State Government will give thrust to production, processing, value addition and marketing so as to sustain agriculture based livelihood and attract new entrepreneurs to the farm sector. He also pointed out that VAIGA will serve as a platform to introduce innovative technologies and possibilities in the field of agro-processing and value addition of farm produce and their marketing. Over 350 stalls showcased the technologies relating to agro-processing and value addition in diverse fields. Officials from various agencies including ICAR Institutes, SAUs, Department of Agriculture, KVKs and NGOs participated in the event. ICAR-CTCRI, Sreekariyam, Thiruvananthapuram was one of the organizers of this mega event and participated in seminars and exhibition for showcasing improved

technologies of tuber crops for the benefit of farming community. ICAR-CTCRI team consisting of Dr. Archana Mukherjee, Director, ICAR-CTCRI and other scientists/staff members viz., Dr. G. Byju, Dr. Sheela Immanuel, Dr. M.S. Sajeev, Dr. J. Sreekumar,

Inaugural address by Shri. P. Sathasivam, Honourable Governor of Kerala at VAIGA event

Inauguration of ICAR-CTCRI stall by Shri. P. Sathasivam, Honourable Governor of Kerala

Dr. D. Jaganathan, Dr. S. Shanavas, Dr.B.S. Prakash Krishnan, Mr. B. Satheesan, Mr. K. Sunil, Mr. Aswin Raj P. and Mr. Arun Raj D. participated in the VAIGA and Krishi Unnati Mela during 27-30 December 2018 at Thrissur, Kerala.

Field day-cum-Agripreneur Meet on Chinese Potato at Tirunelveli

The ICAR-CTCRI in collaboration with Madurai Agri-Business Incubation Forum of NABARD, Madurai, organised a 'Field day-cum-Agripreneur Meet on Chinese Potato' at Alvan Thulukapatti, Ambasamudram, Tirunelveli district, Tamil Nadu on 11 January 2019. Dr. V. Ravi, Head, Division of Crop Production presided over the event in the presence of Dr. Sheela Immanuel, Head, Extension and Social Sciences, Dr. R. Muthuraj and Dr. P. Sethuraman Sivakumar, Principal Scientists, Dr. D. Jaganathan, Scientist and Smt. S. Subavasugi, Assistant Director (Horticulture), Pappakudi. During the meeting, the farmers were imparted training on scientific cultivation and quality seed production of Chinese

Field day on Chinese potato at Alvan Thulukapatti

potato. The farmers were also taken to the sites of Frontline Demonstrations of Sree Dhara and were explained about the superiority of Sree Dhara over local varieties. About 100 farmers and entrepreneurs from various villages of Ambasamudram participated in the event.

National Science Day Celebrations (NSD-2019) with Students

The National Science Day (NSD) Celebrations 2019 was organized by ICAR-CTCRI during 19-22 February 2019. The programme was co-sponsored by Kerala State Council for Science, Technology and Environment and supported by Department of Science & Technology, Government of India. Dr. Shirly Raichal Anil, Principal Scientist, was the

Dr. Archana Mukherjee inaugurating NSD-2019 by watering a sweet potato plant

Programme Co-ordinator and Dr. V. Ramesh, Principal Scientist, was the General Convenor of the NSD-2019 Celebrations at ICAR-CTCRI. 'Communicating Science for All' was the theme for the National Science Day. The National Science Day celebration was inaugurated on 19 February 2019. Sixty students from two schools in Thiruvananthapuram namely, The School of the Good Shepherd and the Loyola School were present. Two students from each of these schools delivered talk on the theme.

Dr. Purnachandra Rao, Director, NCESS addressing the gathering of NSD-2019

In the Inter-collegiate Quiz Competition conducted as a part of the National Science Day, students from eight colleges from Thiruvananthapuram participated. Valedictory function of the National Science Day was held on 22 February 2019. Dr. Purnachandra Rao, Director, National Centre for Earth Science Studies (NCESS) was the Guest of Honour. In his address, he encouraged the staff and students to get involved in their duty with a sense of joy and interest.

Hon'ble Prime Minister's interaction with Kerala Farmers during the PM-KISAN Launch through Video Conference at ICAR-CTCRI, Thiruvananthapuram

The ICAR-CTCRI, Thiruvananthapuram hosted the Hon'ble Prime Minister Shri. Narendra Modi Ji's interactions with Kerala farmers through video conferencing on the occasion of ***"Pradhan Mantri Kisan SAmman Nidhi" (PM-KISAN)*** scheme launching at Gorakhpur, Uttar Pradesh on 24 February 2019. The ICAR-CTCRI was one of the five Institutes chosen by the Ministry of Agriculture and Farmers' Welfare, Government of India, wherein the farmers could interact with the Hon'ble Prime Minister regarding PM-KISAN Scheme. Shri. Alphons Kannanthanam, Hon'ble Minister of State for Tourism (Independent Charge) graced the occasion and shared about the agricultural policy and various schemes designed for the "farmers welfare" in the country. Dr. Abhilaksh Likhi, Joint Secretary (Cooperation), Ministry of Agriculture and Farmers' Welfare, Government of India

PM-KISAN launch through video conference at ICAR-CTCRI

provided an overview of PM-KISAN scheme and stated that PM-KISAN is a revolutionary scheme for providing income support for farming and other needs. Dr. Archana Mukherjee, Director, ICAR-CTCRI welcomed the dignitaries, farmers and other invited guests and media. Dr. Mukherjee explained the benefits of PM-KISAN scheme for small and marginal farmers. The farmer's conversation with our Hon'ble Prime Minister in local language was translated to Hindi by Dr. A. Asha Devi, Principal Scientist. Dr. J. Sreekumar, Principal Scientist proposed the vote of thanks. About 500 participants including farmers, Government officials, and the staff members of the Institute were present at this event. All the technicalities for the Video Conference was arranged and coordinated by Shri. A. Madhu, Assistant Chief Technical Officer, ICAR-CTCRI.

Reaching the Unreached: ICAR-CTCRI Join Hands with Jail Department, Kerala

The ICAR-CTCRI, Thiruvananthapuram, has initiated a joint programme with Jail Department, Government of Kerala and established a 'Tuber Crops Museum' at Open Jail and Correctional Home located at Nettukaltheri, Thiruvananthapuram, Kerala.

The programme started during March 2018 by providing planting material, technical support and establishing an organic yam garden. The harvest of the organic yam crop as well as establishment of a Tuber Crops Museum was inaugurated on 07 March 2019 by Mrs. R. Sreelekha I.P.S., Director General of Prisons, Kerala. Dr. Archana Mukherjee, Director, ICAR-CTCRI graced the occasion and delivered the keynote speech.

The ICAR-CTCRI has provided organic inputs as well as quality planting material of 23 different varieties of tropical tuber crops for the establishment of the Tuber Crops Museum. This include cassava mosaic disease resistant varieties such as Sree Reksha, Sree Sakthi and Sree Suvarna; β carotene rich sweet potato variety, Bhu Sona; anthocyanin rich sweet potato variety, Bhu Krishna; dwarf white yam variety, Sree Swetha; elephant foot yam varieties, Gajendra, Sree Padma and Sree Athira.

The ICAR-CTCRI has taken up this programme in collaboration with Coconut Development Board (CDB), Government of India under a project, 'Higher productivity and profitability from coconut gardens through soil health management in tuber crops'. Dr. G. Byju and Dr. G. Suja, Principal Scientists and PIs of the CDB funded project co-ordinated the programme.

Launching of Tuber Crops Museum at Open Jail & Correctional Home, Nettukaltheri, Thiruvananthapuram by Mrs. Sreelekha I.P.S

International Women's Day Celebrations

The International Women's Day was celebrated at the Institute in a befitting manner by organising various events to the women staff of the Institute on 8 March 2019. A meeting on the Theme 'Balance for better' was organised. The day started off with the live webcast of Hon'ble PM's address. This was followed by the screening of a video as a tribute to honour the accomplishments and contributions of illustrious 'women achievers' who have excelled in different spheres of life. Dr. M.N. Sheela, Head, Division of Crop Improvement and Chairperson, Women Cell, ICAR-CTCRI welcomed the gathering. The programme was presided by Dr. Archana Mukherjee, Director, ICAR-CTCRI. In her presidential address, the Director congratulated all the lady staff members for their valuable contributions towards the development of the Institute. She also briefed about the achievements of ICAR-CTCRI over the last 56 years. The Chief Guest of the programme was Smt. Sharda Sampath, Chief Post Master General, Kerala Circle. She stated that women empowerment should be made evident in all spheres of life. Two senior lady staff

members of the Institute, who were due to retire were honoured during the occasion for their meritorious service to the Institute. Various competitions were also conducted and the prizes for the winners were given away by the Chief Guest. Dr. B.G. Sangeetha, Scientist proposed the vote of thanks.

International Women's Day celebrations

Institute Management Committee (IMC) Meeting

The XV Institute Management Committee Meeting of ICAR-CTCRI, Thiruvananthapuram was held on 18 March 2019 under the Chairmanship of Dr. Archana Mukherjee, Director, ICAR-CTCRI, Thiruvananthapuram in the Golden Jubilee Hall and the following Members/Dignitaries/Officers attended the meeting.

1.	Dr. Archana Mukherjee, Director, ICAR-CTCRI, Thiruvananthapuram	Chairperson
2.	Dr. H.P. Maheswarappa, Project Co-ordinator (AICRP on Palms), ICAR-CPCRI, Kasaragod	Member
3.	Dr. C. Palaniswami, Principal Scientist & Head (Crop Production), ICAR-SBI, Coimbatore	Member
4.	Dr. M. Pitchaimuthu, Principal Scientist, Division of Vegetable Crops, ICAR-IIHR, Bengaluru	Member
5.	Dr. V. Ravi, Principal Scientist & Head, Division of Crop Production, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
6.	Dr. C.A. Jayaprakas, Head (Acting), Division of Crop Protection, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
7.	Dr. M. Nedunchezhiyan, Principal Scientist & Head (i/c), ICAR-CTCRI, Regional Centre, Bhubaneswar	Special Invitee
8.	Dr. P. Murugesan, Principal Scientist, Division of Crop Improvement, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
9.	Dr. M.S. Sajeev, Principal Scientist & Head (i/c), Division of Crop Utilization, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
10.	Dr. Sheela Immanuel, Principal Scientist & Head (i/c), Section of Extension & Social Sciences, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
11.	Dr. G. Byju, Principal Scientist, & SIC (PME Cell), ICAR-CTCRI, Thiruvananthapuram	Special Invitee
12.	Dr. J. Sreekumar, Principal Scientist & SIC (Farm), ICAR-CTCRI, Thiruvananthapuram	Special Invitee
13.	Shri. P Krishnakumaran, Finance & Accounts Officer, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
14.	Smt. Jessymol Antony, Asst. Finance & Accounts Officer, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
15.	Shri. P.C. Noble, Assistant Administrative Officer, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
16.	Shri. T. Vijayakumara Kurup, Assistant Administrative Officer, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
17.	Shri. Abhishek Rana, Senior Administrative Officer, ICAR-CTCRI, Thiruvananthapuram	Member Secretary

Chairperson of IMC was Director, ICAR-CTCRI. A brief research achievement of the Institute was presented by the Director. The Heads/Principal Scientists from various divisions presented the research highlights/achievements discipline-wise. This was followed by a brief presentation of minutes of the previous meeting by the Member Secretary and thereafter the review of the action taken on each item. The same was approved by the house. The Finance & Accounts Officer presented the progressive expenditure up to 16 March 2019.

Workshop on Intellectual Property Valuation of Agricultural Technologies

The ICAR-CTCRI organised one day workshop on 'Intellectual Property Valuation of Agricultural Technologies' for the IP professionals, scholars and students, who are engaged in IP portfolio management and commercialisation on 22 March 2019. Four experts from technology IP management and commercialisation, including Dr. Manoj Samuel, Principal Scientist, ICAR-CIFT, Kochi handled the sessions. The participants were imparted knowledge and critical skills in various aspects of technology/IP valuation including value estimation methods, pragmatic pricing, technology licensing process, and valuation of Geographical Indications. About 100 IP professionals, entrepreneurs, AC&ABC trainees, scholars and students took part in the workshop.

Inaugural address by Director, ICAR-CTCRI

Participants of the workshop

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. **Maintenance:** The library contains more than 18300 documents including books, bound back volumes of journals, which are being maintained.
2. **Circulation of books**: A total of 211 books were issued to the users on loan.
3. **CeRA:** About 20 Document Delivery Request (DDR) of various state agricultural universities and ICAR institutes of CeRA were satisfied by sending soft copy/hard copy of library materials.
4. **Ready-reference service**: Provided ready assistance and solutions to the user's various queries. These include enquiries in person

or over the phone regarding any matter 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 1500 users availed the facility of reference services from the library.

5. **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 B.Sc., M.Sc. project works, Ph.D. and PDF works under the guidance of the Institute Scientists. They were given necessary guidance in the use of reference resources and also photocopying facility.
6. **Photocopying:** Library continued to provide photocopying service to the Institute staff and other library users on official/payment basis.
7. **New additions:** Ten new scientific books, eight Ph.D. and 13 B.Sc.-M.Sc. (Integrated Biotechnology) theses were added during this year. Six journals, two in Hindi and four in English, five news papers, three in English and two in Malayalam were subscribed.

Hindi Corner

Three Hindi Workshops were held during this year on 29 June 2018; 15 December 2018 and 28 February 2019 by the Official Language Implementation Committee (OLIC). In the first two workshops, classes were taken by Shri. A. Somadethan, Assistant Director (Retd.), Income Tax Office, Thiruvananthapuram on the topic, 'Noting, Drafting/Official Language Awareness Programme' and 'Official Language Policy/Official Language Awareness Programme', respectively. The third workshop was conducted by Smt. P.A. Usha, Asst. Director (OL), All India Radio, Thiruvananthapuram on the topic, 'Noting and drafting'.

Four OLIC meetings were also conducted during this period on 29 June, 29 September, 31 December 2018 and 26 March 2019. Various issues related to Official Language Implementation were discussed during these meetings.

The Hindi Fortnight 2018 was celebrated during 14-28 September 2018, where, various competitions were held for the staff and children. Thirty three participants actively participated and bagged various prizes, which were distributed during the valedictory function on 15 December 2018. Dr. Archana Mukherjee, Director and Chairperson (OL), ICAR-CTCRI presided over the function and distributed prizes to the winners/ participants and exhorted the staff to boost Hindi implementation work. Shri. A. Somadethan, Retd. Assistant Director (OL), Income Tax Office, Thiruvananthapuram was the Chief Guest.

During this period, six staff members viz., Dr. H. Kesava Kumar, Dr. D. Jaganathan, Dr. T. Krishnakumar, Dr. K.M. Senthilkumar, Shri. S. Radhakrishnan Nair and Shri. K. Sarathchandra Kumar were awarded certificates for completing Hindi correspondence course 'Prabodh' conducted by the Central Hindi Training Institute, New Delhi. Nine staff members have enrolled for 2018-19 course in Prabodh/Praveen.

In the joint Hindi Fortnight celebrations of TOLIC, Dr. Sanket J. More and Dr. H. Kesava Kumar, Scientists participated in the competitions and Dr. Sanket J. More won third prize for Extempore Speech (Hindi Speaking State).

Hindi Fortnight celebrations

State of art of *Mera Gaon Mera Gaurav*

ICAR-CTCRI, Thiruvananthapuram and its Regional Centre implemented the MGMG programme in collaboration with other stakeholders viz., Department of Agriculture, Krishi Vigyan Kendra, grama panchayat, input dealers, progressive farmers, SHGs etc. During 2018-19, interface meetings, training programmes, demonstration of improved practices, farm advisory visits, mobile advisory services were organized in the selected villages for the benefit of farming community. A total of 46 scientists adopted 51 villages for the overall development of the villages through various programme as given below.

Activities undertaken

S. No.	Name of the activity	No. of activities conducted	No. of farmers participated & benefitted
1	Visit to village by teams	75	274
2	Interface meeting/ *Goshthis*	61	949
3	Trainings organized	25	405
4	Demonstrations conducted	32	133
5	Mobile-based advisories	135	212
6	Literature support provided	119	588
7	Awareness created	51	1662
	Total	**498**	**4223**

Mobile-based advisories, numbering 135, 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 (119) were also supplied to farmers. Bio-pesticides were distributed to 65 farmers. Planting materials of cassava, sweet potato, greater yam, elephant foot yam and arrowroot were given to 15 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 advised to farmers.

General awareness created among the farmers in the MGMG villages were, use of fungicides for elephant foot yam disease, use of *Menma*, *Nanma* and *Shreya* for the control of 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 in aroids, especially elephant foot yam, collar rot management in elephant foot yam, tuber crops processing and value addition, integrated pests and disease management in tropical tuber crops, SSNM of cassava, information regarding the methods and dosage of fertilizers and herbicide application, knowledge on new varieties of tuber crops and advances in nutrient management and selection of pest and disease free planting material.

The major problems identified in the MGMG villages were, labour shortage, price fluctuations, climate change, 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 and nutritional deficiencies.

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, Department of Fisheries and Panchayat Vikasana Samithi.

Distribution of planting material of tuber crops under MGMG programme

Swaccha Bharat Abhiyan

ICAR-CTCRI is dedicatedly involved in various activities related to "Swachha Bharat Mission", 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 were being implemented such as:

- Swaccha Bharat Abhiyan was conducted weekly on every last day of the week for half an hour and all the staff members were instructed to clean their respective labs and sitting areas.
- On the last working day of the month, Swaccha 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 prepared to maintain records of presence of members.
- Many dust bins, hand gloves and brooms for cleaning were purchased and Swaccha Bharat Abhiyan logo and tag line were used in the Institute.
- All members participated in cleaning activities.

Swachhata Hi Seva–2018

The Swachhata Hi Seva-2018 fortnight was observed at ICAR-CTCRI Headquarters (HQ) and at Regional Centre (RC), Bhubaneswar from 15 September to 02 October 2018. It was inaugurated with the administration of the 'Swachhata Shapath' by Dr. Archana Mukherjee, Director. To uphold and disseminate the message of swachhata campaign, awareness programs were organised at schools in Thiruvananthapuram and Bhubaneswar and at tourist places. A Swachhata awareness lecture highlighting the importance of Swachhata, pollution free environment and conservation of the nature was conducted at ICAR-CTCRI, Thiruvananthapuram. Dr. T.N. Seema, Vice Chairperson, Haritha Keralam Mission, Government of Kerala delivered the lecture and Dr. Archana Mukherjee presided over the function. All the staff and students of ICAR-CTCRI and Students Police Cadets from Government High School, Chavadimukku attended the lecture. To emphasise the significance of solid waste management and conserving nature, compost pit was constructed to compost the waste generated on site. The valedictory function was conducted on 02 October 2018. Dr. Archana Mukherjee, Director, ICAR-CTCRI and Dr. M. Nedunchezhiyan, Head (i/c), presided over the programmes at HQ and RC, respectively.



Dr. T.N. Seema delivering the awareness lecture on Swachhata (left); Swachhata Hi Seva campaign by staff members of ICAR-CTCRI (middle and right)

Flagging off for Swachhata Campaign by the Director


Swachhata Hi Seva Campaign in flood affected areas of Chengannur, Kerala

Swachhata Hi Seva campaign by staff members of ICAR-CTCRI, RC Bhubaneswar

150th Birth Anniversary of Mahatma Gandhiji, Father of Nation

A floral tribute to the Father of Nation, Mahatma Gandhiji was offered to celebrate his 150th Birth Anniversary. Prizes were distributed to the winners

Floral tribute to the Father of Nation

of several competitions held in connection with Swachhata Hi Seva-2018. Director and all staff members participated in cleaning the main campus to pay homage to Mahatma Gandhiji.

Swachhata Pakhwada-2018

The Swachhata Pakhwada-2018 was observed at ICAR-CTCRI, Thiruvananthapuram during 16-31 December 2018. Swachhata Pakhwada 2018 was inaugurated with the administration of 'Swachhata Pledge' by Dr. Archana Mukherjee, Director, ICAR-CTCRI. The Swachhata awareness banner was displayed at prominent places for awareness of public. All the staff members of ICAR-CTCRI along with the Director, Dr. Archana Mukherjee were involved in cleaning activities to create awareness to the general public regarding the importance of maintaining cleanliness. Planting of trees was done by the Director and staff of ICAR-CTCRI. Swachha Bharat awareness placards were installed around the campus for preventing the general public from throwing wastes on streets. Under 'Swachhata Pakhwada', cleaning activities in Cheruvikkal Government Primary School, Thiruvananthapuram premises was done to create awareness among the school children. As a concluding event, a special programme on the theme "Wealth from Waste" was conducted in the Bio-pesticide laboratory, where cassava leaves were utilised as a source of biogas. Shri. M. Unnikrishnan, Principal Scientist (Retd.), ICAR-CTCRI and Shri. Suresh Muthukulam, Principal Information Officer (Rtd.), Farm Information Bureau graced the occasion. Swachhata Pakhwada was observed at ICAR-CTCRI, RC, Bhubaneswar during 16-31 December 2018 including Kisan Diwas on 23 December 2018.

Swachhata campaign by staff members of ICAR-CTCRI

Field Level Demonstrations/OFTs Conducted

Demonstrations on improved varieties of cassava, sweet potato, taro and Chinese potato; Integrated management of pseudostem weevil of banana and mealybug in cassava using cassava based bio-formulations were established in Tamil Nadu, Kerala, Meghalaya and Arunachal Pradesh with 35 farmers for proving the technical feasibility and economic viability of the improved technologies. Farmers were trained to adopt scientific crop management practices. Pests and diseases viz., mealybug, spiraling white fly and cassava mosaic disease in cassava; sweet potato weevil and leaf eating insects in sweet potato and sucking insects and nematode in Chinese potato were managed with integrated pest, disease and nematode management practices.

Farm Advisory Visits

- Scientific team consisting of Dr. E.R. Harish, Dr. D. Jaganathan, Dr. R. Muthuraj, and Dr. H. Kesava Kumar visited farmers' cassava fields during May–June 2018 at Nagercoil, Kanyakumari district to assess the incidence of mealybug in cassava. Integrated pest management practices for managing mealybug in cassava were discussed with farmers.
- Farm advisory visits among elephant foot yam growers were conducted by Dr. D. Jaganathan and Dr. A.V.V. Koundinya in East Godavari and West Godavari districts of Andhra Pradesh during August 2018 and February 2019. Farm advisory visits were conducted by Dr. D. Jaganathan among elephant foot yam growers in Erode district of Tamil Nadu during December 2018.
- A team consisting of Dr. P.S. Sivakumar, Dr. R. Muthuraj, Dr. D. Jaganathan and Dr. T. Krishnakumar conducted farm advisory visits among tuber crops growers of Arunachal Pradesh during December 2018.
- A team consisting of Dr. V. Ravi, Dr. Sheela Immanuel, Dr. R. Muthuraj, Dr. P.S. Sivakumar


Farm advisory visit in Kanyakumari

Farm advisory visit in West Godavari

Farm advisory visit in East Godavari

Farm advisory visit in Erode

Farm advisory visit in Tirunelveli

Farm advisory visits in Arunachal Pradesh

and Dr. D. Jaganathan conducted farm advisory visits among farmers of Chinese potato in Tirunelveli district of Tamil Nadu during January 2019.

- Dr. C.A. Jayaprakas and Dr. E.R. Harish conducted farm advisory visits in Kalliyoor Thondiyoor and Vellanad of Thiruvananthapuram district during August and September 2018 and Ambalavayal of Wayanad district during March 2019 for diagnosis of pests and diseases and to provide suitable recommendations.

Recreation Club Corner

The Independence Day function was organized on 15 August 2018 by the recreation club of ICAR-CTCRI. Staff members donated generously for the flood victims of Kerala during difficult times during August–September 2018. The New Year was welcomed with a get-together of all club members. Republic day function on 26 January 2019 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. Staff members who retired from ICAR-CTCRI service were also felicitated by the Recreation Club of ICAR-CTCRI.

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.

- Green Fest 2018 (Agri Fest and Kappa Maholsav) during 28 March-08 April 2018 at Kanakakunnu Palace, Thiruvananthapuram, Kerala.
- All India Seminar on Innovative Mechanization for Small and Marginal Farmers under Rainfed Agriculture during 25-26 May 2018, Institution of Engineers (I), Thiruvananthapuram.
- Exhibition on 12 June 2018 in connection with the Seminar on Improved Technologies of Tuber Crops with special reference to mealybug management in cassava at Krishi Vigyan Kendra, Tirupathisaram, Kanyakumari.
- Technology Sourcing Fest for MSMEs, MSME-Science, Technology Interface Programme on 12 June 2018 at CSIR-NIIST, Thiruvananthapuram.
- Exhibition on 05 September 2018 in connection with SAARC Regional Expert Consultation on 'Women's Empowerment for Agriculture Development in South Asia: Enabling Policy' at ICAR-CIWA, Bhubaneswar.
- Exhibition on 07 September 2018 in connection with EDP programme on tuber crops at Mukkoodal, Tirunelveli.
- Exhibition during 06-08 September 2018 in connection with Science Show at Kaliyakavilai, Kanyakumari.
- Science Exhibition during 22-23 September 2018 at Institute of Life Science, Bhubaneswar.
- Exhibition on 28 September 2018 at Krishi Jagarana Samiti, Guapur, Balipatna, Khurdha district.
- Exhibition on 01 November 2018 at Kunnathukal, Kudumbasree Mission, Govt. of Kerala
- Exhibition on 02 November 2018 at Pedikulam, Kudumbasree Mission, Govt. of Kerala.
- Exhibition on 03 November 2018 at Vamanapuram, Kudumbasree Mission, Govt. of Kerala.
- Exhibition on 07 November 2018 at Parassala, Kudumbasree Mission, Govt. of Kerala.
- Exhibition on 08 November 2018 at Poovachal Kudumbasree Mission, Govt. of Kerala.
- Exhibition on 09 November 2018 at Nemom, Kudumbasree Mission, Govt. of Kerala.
- Exhibition in connection with Tuber Crops Day and Farmers' Fair during 22-23 November 2018 at ICAR-CTCRI, Thiruvananthapuram.
- A Stakeholder Meet and Entrepreneurship Development Programme on Tuber Crop Technologies on 01 December 2018 at SMELC Building, Dakopgre, Tura, Meghalaya.
- A Stakeholder Meet and Entrepreneurship Development Programme on Tuber Crop Technologies on 05 December 2018 at Krishi Vigyan Kendra, Namsai.
- VAIGA & Krishi Unnati Mela-International Workshop and Exhibition on Agro-processing and Value Addition during 27-30 December 2018 at Thekkinkadu Maidanam, Thrissur, Kerala.

VAIGA & Krishi Unnati Mela at Thrissur

National Horticultural Fair at Bengaluru

Tuber crops food festival at Namsai

Krishidham Expo at Meerut

- Karshika Mela during 31 December 2018 to 06 January 2019 at New Man College Ground, Thodupuzha, Idukki, Kerala.
- Krushi Odisha organized by the Department of Agriculture & Farmers Empowerment, Government of Odisha during 15-19 January 2019 at Biju Patnaik Play Ground, Bhubaneswar, Odisha.
- World Conference on Brackishwater Aquaculture (BRAQCON-2019) during 22-25 January 2019 at ICAR-Central Institute of Brackishwater Aquaculture, Chennai, Tamil Nadu.
- National Horticultural Fair during 23-25 January 2019 at ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru.
- Exhibition in connection with Krishi Mela on 02 February 2019 at Berhampur, Chatrapur, Ganjam district, Odisha.
- National Conference on Farmers First for Conserving Soil and Water Resources in Eastern Region (FFCSWR-2019) during 06-08 February 2019 at Koraput, Odisha.
- Technology and Machinery Demonstration Mela 2019 during 15-16 February 2019 at Njarakkal, Kochi.
- Krishidham Expo during 15-17 February 2019 at ICAR-Central Potato Research Institute, Regional Station, Modipuram, Meerut, Uttar Pradesh.
- Exhibition in connection with Tribal Sub Plan Programme during 18-19 February 2019 at ICAR-CIFA, Bhubaneswar.
- Agriculture Exhibition on 26 February 2019 at ICAR-NRRI, Cuttack, Odisha.

वर्ष 2018–2019 के दौरान इस संस्थान में किये गए राजभाषा कार्यान्वयन से सम्बन्धित कार्यक्रम

राजभाषा कार्यान्वयन समिति की बैठक का आयोजन

इस संस्थान की निदेशक महोदया, डॉ० अर्चना मुखर्जी की अध्यक्षता में, ता. 29.06.2018, 29.09.2018, 31.12.2018 और 26.03.2019 को राजभाषा कार्यान्वयन समिति की बैठकों का आयोजन किया गया था। इस अवसर पर राजभाषा कार्यान्वयन से संबंधित विभिन्न मुद्दों पर विचार – विमर्श किया गया। उसके आधार पर उक्त मुद्दों का अनुपालन किया जा रहा है।

हिन्दी कार्यशाला का आयोजन

क) केंद्र सरकार की राजभाषा नीति के अनुसार इस संस्थान के सभी कर्मचारियों के लिए ता. 29.06.2018 को एक–दिवसीय हिन्दी कार्यशाला 'टिप्पण, आलेखन/राजभाषा जागरूकता कार्यक्रम' का आयोजन किया गया। डॉ. अर्चना मुखर्जी, निदेशक और अध्यक्षा (राजभाषा), भा.कृ.अनु.प–केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनन्तपुरम ने उपस्थित सभी कर्मचारियों को सम्बोधित किया। उन्होंने हिन्दी के महत्व पर प्रकाश डालते हुए समारोह का उद्घाटन किया। डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभी का स्वागत किया। श्री. ए. सोमदत्तन, सेवानिवृत सहायक निदेशक (राजभाषा) ने 'टिप्पण, आलेखन/राजभाषा जागरूकता कार्यक्रम' पर व्याख्यान दिया। कुल 33 प्रतिभागियों ने कार्यशाला में भाग लिया। श्रीमती. टी. के सुधालता, सहायक मुख्य तकनीकी अधिकारी (हिंदी) ने धन्यवाद प्रस्ताव पेश किया।

ख) ता. 15.12.2018 को "राजभाषा नीति/राजभाषा जागरूकता कार्यक्रम" पर एक दिन की हिन्दी कार्यशाला आयोजित किया गया। डॉ. अर्चना मुखर्जी, निदेशक और अध्यक्ष (राजभाषा), भा.कृ.अनु.प–केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनन्तपुरम ने उपस्थित सभी कर्मचारियों को सम्बोधित किया। डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभा का स्वागत किया। श्री. ए. सोमदत्तन, सेवानिवृत सहायक निदेशक (राजभाषा) तिरुवनंतपुरम कार्यशाला में व्याख्यान दिया। कुल 33 प्रतिभागियों ने कार्यशाला में भाग लिया। श्रीमती. टी. के सुधालता, सहायक मुख्य तकनीकी अधिकारी (हिंदी) ने धन्यवाद प्रस्ताव पेश किया।

ग) ता. 28.02.2019 को "टिप्पण/आलेखन" पर एक दिन की हिन्दी कार्यशाला आयोजित की गई। डॉ. अर्चना मुखर्जी, निदेशक और अध्यक्ष (राजभाषा), भा.कृ.अनु.प–केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनन्तपुरम ने उपस्थित सभी कर्मचारियों को सम्बोधित किया और डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभी का स्वागत किया। श्रीमती. पी. ए. उषा, सहायक निदेशक (राजभाषा), आकाशवाणी, तिरुवनंतपुरम "टिप्पण/आलेखन" पर व्याख्यान दिया। कुल 31 प्रतिभागियों कार्यशाला में भाग लिया।

हिन्दी पखवाड़ा समारोह का आयोजन

ता. 14–28 सितम्बर 2018 को हिन्दी पखवाड़ा मनाया गया। इस संस्थान के कर्मचारी गण और बच्चों के लिए निम्नलिखित 5 श्रेणियों में 1. निबंध लेखन 2. अनुवाद 3. भाषण 4. कविता पाठ 5. सुलेख 6. खुला मंच 7. अन्ताक्षरी 8. सिर्फ एक मिनट आदि हिंदी प्रतियोगिताओं का आयोजन किया गया। वैज्ञानिक, तकनीकी/प्रशासनिक, कुशल सहायक कर्मचारी, अस्थायी कर्मचारी एवं बच्चों समेत कुल 33 प्रतिभागियों ने भाग लिया।

हिन्दी पखवाड़ा का समापन समारोह एवं पुरस्कार वितरण ता. 15.12.2018 को आयोजित किया गया। डॉ० अर्चना मुखर्जी, निदेशक और अध्यक्ष (राजभाषा) बैठक की अध्यक्षता की और हिंदी समारोह के संबंध में आयोजित विभिन्न प्रतियोगिताओं के विजेताओं को पुरस्कार वितरण किया। मुख्य अतिथि श्री ए. सोमदत्तन, सेवानिवृत्त सहायक निदेशक (राजभाषा), आयकर कार्यालय, तिरुवनंतपुरम द्वारा प्रमाण पत्र वितरित किए गए।

नगर राजभाषा कार्यान्वयन समिति में आयोजित कार्य

इसके अलावा तिरुवनंतपुरम नगर राजभाषा कार्यान्वयन समिति द्वारा आयोजित हिंदी प्रतियोगिताओं में डॉ. संकेत जि. मोरे और डॉ. ह. केसव कुमार ने सहभाग लिया। डॉ. संकेत जि. मोरे को हिन्दी आशु–भाषण प्रतियोगिता में (हिंदी भाषी राज्य) तीसरा पुरस्कार प्राप्त हुआ।

तिरुवनंतपुरम नगर राजभाषा कार्यान्वयन समिति के बैठकें

इस संस्थान के निदेशक और अध्यक्ष (राजभाषा) डॉ. अर्चना मुखर्जी, डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) और श्रीमती. टी. के सुधालता, सहायक मुख्य तकनीकी अधिकारी (हिंदी) इस बैठक में भाग लिया।

प्रोत्साहन योजना

हिन्दी में काम करनेवाले कर्मचारियों को प्रोत्साहन योजना में नकद पुरस्कार दिये गये। इस वर्ष दो प्रतिभागियों को पुरस्कार दिये गये।

अन्य सार्वजनिक कार्यकलापें

इस संस्थान की सभी रबड़ की मोहरें, नाम पट्ट,साइन बोर्ड, फॉर्म, पत्र शीर्ष आदि द्विभाषी रूप में बनाये गए हैं। हिंदी में प्राप्त पत्रों के उत्तर भी हिंदी में दिए गए हैं। धारा 3(3) के तहत सभी परिपत्र, कागजात, द्विभाषी रूप में किये गए हैं। वार्षिक कार्यक्रम के निर्धारित लक्ष्यानुसार अधिक से अधिक पत्राचार हिंदी में किये जा रहे हैं। प्रबोध/प्रवीण पत्राचार पाठ्यक्रमों के तहत नामंकन किए गए। 9 कर्मचारियों ने मई–2019 के दौरान आयोजित हिन्दी परीक्षा में भाग लिया।

IMPORTANT EVENTS AND ACHIEVEMENTS

Events

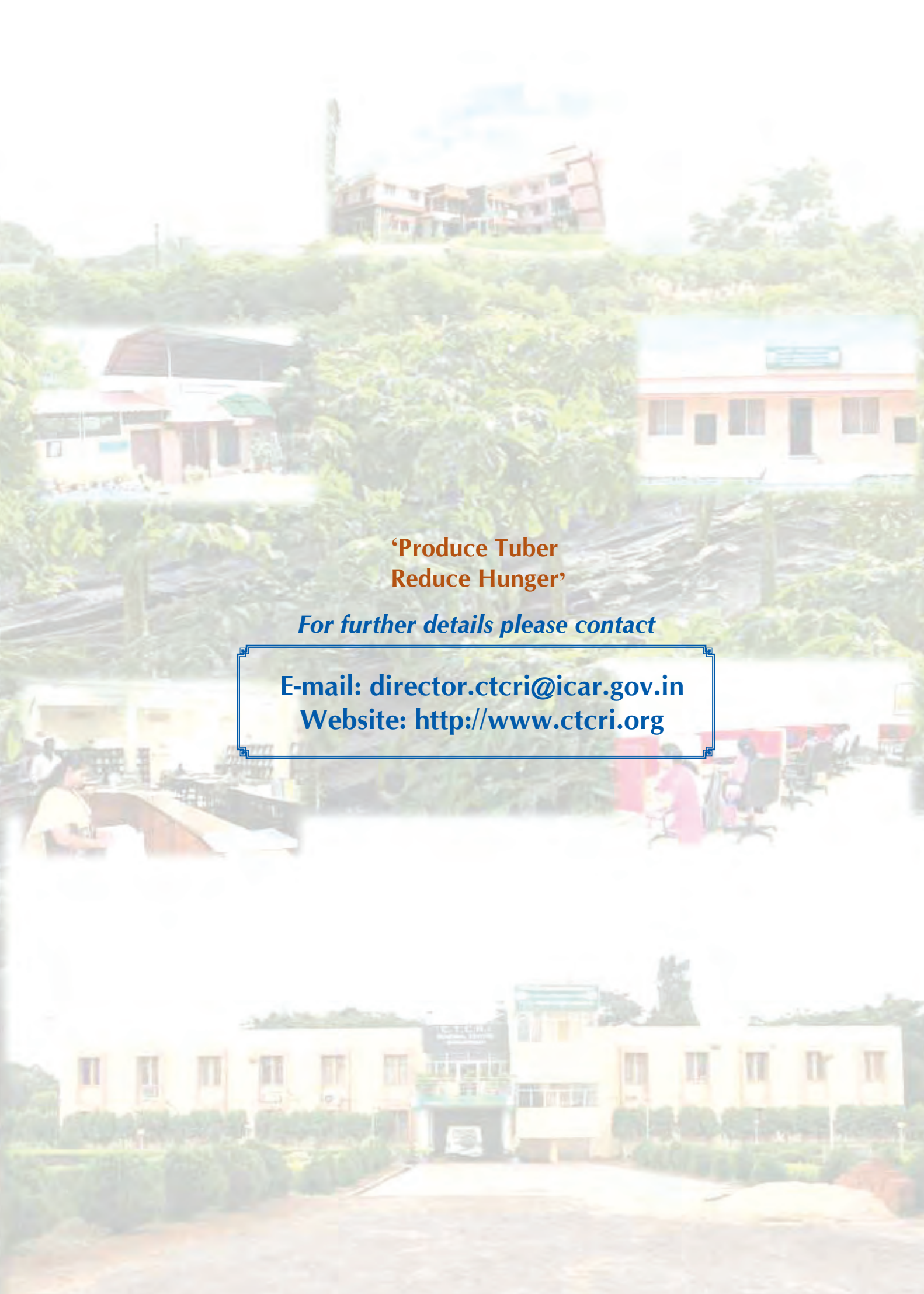
Name of the Event	Date
44th Annual Institute Research Council Meeting	03-05 April 2018
18th Annual Group Meeting and Golden Jubilee Celebrations of the All India Coordinated Research Project on Tuber Crops	26-28 April 2018
H.H. Sree Visakham Thirunal Endowment Lecture	19 May 2018
Annual Asia Sweet potato Breeders and Seed System Meeting 2018	28-31 May 2018
International Yoga Day	21 June 2018
National Workshop on e-Crop : an IoT Solution in Agriculture	05-07 September 2018
Hindi Fortnight Celebrations	14-28 September 2018
Entrepreneurship Orientation Programme for Agricultural Students	24-26 September 2018
Swachhata Hi Seva	15 September-02 October 2018
150th Birth Anniversary of Mahatma Gandhi	02 October 2018
Vigilance Awareness Week	29 October-03 November 2018
National Workshop on Advances in Social and Behavioural Science Research	12–17 November 2018
Research Advisory Committee Meeting	16-17 November 2018
Tuber Crops Day and Farmers Fair celebrations	22-23 November 2018
Stakeholders Meet and Tuber Crops Entrepreneurship Development Programme at Tura, Meghalaya	01 December 2018
Stakeholders Meet and Tuber Crops Entrepreneurship Development Programme at Namsai, Arunachal Pradesh	05 December 2018
World Soil Day 2018	05 December 2018
Farmers Day (Kisan Diwas) Celebrations	23 December 2018
Swachhata Pakhwada 2018	16-31 December 2018
Value Addition for Income Generation in Agriculture (VAIGA) and Krishi Unnati Mela	27-30 December 2018
Refresher Training on 'Improved technologies of tuber crops' for Technical personnel of ICAR-CTCRI	08 to 10 January 2019
Field Day-cum-Agripreneur Meet on Chinese potato at Tirunelveli	11 January 2019
Release of video entitled 'Produce tuber Reduce hunger' at New Delhi	31 January 2019
Enhancing Personal Efficiency in Job Performance for Skilled Support Staff of ICAR-CTCRI	04-06 February 2019
National Productivity Week Celebrations at ICAR-CTCRI, Thiruvananthapuram	12-18 February 2019
National Science Day Celebrations	19-22 February 2019
Pradhan Mantri Kisan SAmman Nidhi (PM-KISAN)-cum-Live Web Telecast	24 February 2019
Stakeholders Interface in connection with International Women's day	08 March 2019
Institute Management Committee Meeting	18 March 2019
Workshop on Intellectual Property Valuation of Agricultural Technologies	22 March 2019

Achievements

Particulars	Nos.
Institute projects	8
Flagship projects	2
External aided projects	27
Tuber crops germplasm maintained in the field gene bank	5579
Tuber crops varieties released	2
Technologies commercialized	8
ICT Apps developed	3
External fund mobilised (₹ lakhs)	2359.73
Revenue generated (₹ lakhs)	130.69
B. Sc. students guided	196
M. Sc. students guided	56
Ph. D. scholars guided	30
Ph. D. awarded	5
PDF guided	3
Farmers visited the Institute	1223
Students visited the Institute	1464
Officers visited the Institute	100
Trainings conducted	80
Institute staff members trained	83
Awards received	19
Publications in peer reviewed journals	70
Papers presented in conferences / seminars / symposia / workshops etc.	84
Books	4
Book chapters	13
Technical bulletins	3
Popular articles	56
Folders, leaflets	14
e-Publication	1
Radio talks	8
TV programme	5
Scientists visited abroad	5
Dignitaries visited the Institute	21
Exhibitions organized	29
FLDs conducted	35

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. Unnikrishan 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. Unnikrishan 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 100 g^{-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 100 g^{-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%)



'Produce Tuber
Reduce Hunger'

For further details please contact

E-mail: director.ctcri@icar.gov.in
Website: http://www.ctcri.org

भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch