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वार्षिक प्रतिवेदन
ANNUAL REPORT
2020

भा कृअनु प - केन्द्रीय कंद फसल अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद्)
श्रीकार्यम तिरुवनन्तपुरम 695 017 केरल भारत
ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
Sreekariyam Thiruvananthapuram 695 017 Kerala India

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PREFACE

The ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), in its 57th year of service, is spearheading with great momentum and leaving its mark on the agricultural sector around the world with the introduction of 68 improved varieties in total, besides development of farmer-friendly production, protection and value addition technologies in tropical tuber crops. Tuber crops, an important group of climate-resilient crops can sustain food, nutritional, health and livelihood security as these crops are rich in dietary fibre, minerals, vitamins and many bio-active phytochemicals. In this background, I'm privileged to present the research accomplishments, technological advancements and development activities of the Institute in the year 2020, documented as 'Annual Report of ICAR-CTCRI'.

The field gene bank constituting 5,713 accessions is continued to be enriched and conserved. A high yielding hybrid greater yam variety, TGy12-1 was recommended for state release in Kerala with the name 'Sree Hima'. A yellow-fleshed cassava genotype, 17S-325 with high β-carotene and calcium content has been identified. Nutritional rich lines of taro with high contents of antioxidants, phenolics, starch and minerals were also identified. *In vitro* plant regeneration protocols were developed for purple (Bhu Krishna), orange (Bhu Sona) and white (Kishan) fleshed sweet potato varieties, cassava (Sree Jaya), taro (Muktakeshi) and yam (Orissa Elite).

The sustainable resource management technologies such as feasible cropping systems involving tuber crops, SSNM recommendations and customized fertilizer formulations, INM in greater yam and arrowroot, nutrient use efficient cassava genotypes and soil carbon sequestration packages for hill cassava production system were developed. Research on climate smart agricultural practices for cassava with reduced carbon emission, weed management and water scheduling for taro, diagnosis and correction of emerging soil-plant nutritional disorders, quality planting material production and physiological studies related to climate change were also conducted.

Development of biorational control measures to manage sweet potato weevil, identification of genes related to sweet potato weevil infestation, management of a new emerging pest called sweet potato Leaf miner, isolation of a new strain of plant associated nematode *Panagrolaimus* sp. from the stems of cassava, designing of indigenous soilless growth pouches for maintaining axenic culture of root knot nematode in Chinese potato, isolation of pathogens associated with leaf rot and pseudostem rot in elephant foot yam, management of postharvest rot in elephant foot yam, greater yam anthracnose and taro leaf blight diseases, preparation of small RNA sequence libraries using next-generation sequencing and editing of cassava mosaic virus genome for developing CMD resistance were some of the major research highlights.

The notable value addition technologies/products/machineries developed are particle boards from cassava stem-sugarcane bagasse, thermoplastic starch sheets from cassava starch-fibre composites, food grade cassava starch phosphate, rice analogue from cassava, anthocyanin and β-carotene rich nutri-jellies from sweet potato, ready-to-eat extruded puffed snacks, low cost cassava peeling machine and prototype continuous steaming machine for sago wafer production.

Self learning cassava model to add learning capability to eCrop, computational model for prediction of plant-pathogen interaction, interactive web application for the prediction of protein-protein interaction in plants, Biofortification Priority Index (BPI) and online marketing platforms were also developed. Several field level demonstrations of tuber crops technologies and varieties as well as farm advisory visits were conducted in different parts of the country. Technologies of tropical tuber crops were disseminated through frontline extension activities under SCSP and NEH programmes. For the livelihood improvement of tribal farmers through tuber crops technologies, various activities were taken up under the Tribal Sub Plan.

The techno-incubation centre is extending hand holding support to young entrepreneurs. Three technologies on 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 Bharat Mission*'. The quality research publications including those in high impact national and international journals have improved the scientific credibility.

For strengthening the R&D activities of the Institute, QRT, RAC and IMC meetings were convened. Besides, ICAR-CTCRI participated in 7 exhibitions and organized 45 trainings with the mission to reach the unreached. The Institute also observed National Science Day, Constitution Day, World Environment Day, International Yoga Day, Tuber Crops Day and World Soil Day.

Like other crops, cultivation and marketing of root and tuber crops were also adversely affected by the lockdown imposed due to Covid-19 pandemic. Even in the amidst of the adverse conditions, ICAR-CTCRI could manifest the potential of tuber crops as a food security crop through supply of tubers to 'Community Kitchens' run by different agencies in Thiruvananthapuram and Bhubaneswar. A massive and ambitious programme called '*Subhiksha Keralam'* was initiated by the Government of Kerala to boost farming of tuber crops among agricultural clubs and farming groups and ICAR-CTCRI supplied planting materials worth ₹2.7 lakhs under this programme.

I express my deep sense of gratitude to Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his valuable guidance and support. I sincerely acknowledge the timely guidance and support provided by Dr. Anand Kumar Singh, DDG (Horticulture Science), Dr. T. Janakiram, former ADG (HS-I) and Dr.Vikramaditya Pandey, ADG (HS-1) (Acting).

The support extended by PPV&FRA, 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 highly commendable despite the predicaments of Covid-19 pandemic situation. I also appreciate and congratulate the editorial team for bringing out this publication on time.

20-04-2021

V. Ravi
Director

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EXECUTIVE SUMMARY

Research Achievements

The major research achievements which involve collection and conservation of newer germplasm accessions, varietal improvements, development of processes, protocols, methods, technologies, products and machineries under different Institute projects and externally funded projects during the year 2020 are given below:

Crop Improvement

- A total of 5,713 accessions, comprising 1,217 cassava, 1,129 sweet potato, 1,121 yams, 701 edible aroids, 297 minor tuber crops and 1,248 collections from Regional Station are maintained and conserved in the field gene bank.
- One hundred and fifty five new collections of tuber crops; cassava (29), sweet potato (32), yams (33), edible aroids (50) and minor tuber crops (11) were added to the germplasm.
- In cassava, 454 accessions were subjected to preliminary characterization for six juvenile plant characters viz., plant colour, young stem colour, apical leaf colour, young leaf colour, young petiole colour and cassava mosaic disease incidence at 4 months after planting. There is wide variability in the colour of whole plant, young stem, apical leaf, young leaf and petiole. Cassava mosaic disease incidence in the early growth stage was low in 39 accessions, medium in 123, high in 93 and very high in 62 accessions, while 137 accessions were free without showing any mosaic disease symptoms.
- In cassava, a clone, 17S-325 with high yield (57.7 t ha^{-1}) and good culinary quality was developed through the crossing of yellow fleshed genotype with cassava mosaic resistant varieties. It has higher carotene content (6.01mg 100 g^{-1}) than all the released varieties of cassava in India. The tubers also have high starch (27.6%), sugar (0.59%), protein (3.9%), potassium (0.46%), calcium (1840 ppm), Fe (80.60 ppm) and Zn (23 ppm) contents.
- Among the CMD resistant cassava varieties evaluated for dry matter content, 15S-156 had the highest dry matter (47.5%), followed by D-143 (44.2%). In the replicated yield trial of CMD resistant varieties for culinary purpose, 15S-59 yielded the highest (95.05 t ha^{-1}), followed by 15S-184 (90.11 t ha^{-1}) and 15S-433 (85.18 t ha^{-1}). The CMD resistant varieties are significantly high yielding as compared to the check variety, M-4 (37.04 t ha^{-1}).
- Molecular characterization of 41 sweet potato accessions along with six wild accessions was done using 11 ISSR primers. The 47 accessions were grouped into two principal clusters on the basis of Jaccard's similarity at 0.58 on similarity index scale.
- Sweet potato genotypes, SB-5/61, Megh-2, BP-2, Dhenkanal Local-2 and RS-III-3 were identified as drought tolerant lines.These genotypes exhibited maximum shoot length, root length, number of leaves, number of roots and fresh plant weight at concentration of 15 g l^{-1} of PEG in MS medium under *in vitro* conditions.
- Among 158 white yam accessions evaluated, 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 found to be high yielding (>5 kg plant^{-1}). The accession, Dr-59 produced high yield coupled with compact tuber shape, while Dr-80, Dr-57 and Dr-113 showed excellent cooking quality. The tuber yield per plant ranged from 1.0 kg (CTDE-81) to 4.3 kg (CTDE-145) among the 220 accessions of lesser yam. Higher number of tubers/plant (>50) was recorded in accessions viz., CTDE-39, De-49 and CTDE-53. High tuber yield (>4.0 kg plant^{-1}) was recorded in De-62, De-103 and De-145.

- A high yielding (57.87 t ha^{-1}) greater yam hybrid, TGy12-1 was recommended for state release in Kerala with the name 'Sree Hima'. This variety has high dry matter (30.19%), starch (26.3%), crude protein (5.28%) and excellent culinary quality with high organoleptic score (7.97).
- In the advanced yield trial of greater yam hybrids, DaH-10-1-2 yielded the highest (55.95 t ha^{-1}) followed by DaH-66 (48.31 t ha^{-1}).
- Among the new bushy white yam genotypes evaluated, the hybrid, Drd-9495 produced the highest yield (36.41 t ha^{-1}) followed by Drd-835 (30.25 t ha^{-1}) as compared to the check variety, Sree Dhanya (25.55 t ha^{-1}). In the on farm trials, the non-trailing white yam, SD-15 produced significantly higher yield (41.72 t ha^{-1}).
- The *in vitro* pollen germination medium was optimized for greater yam to test the pollen viability of male parents. Maximum pollen germination (41.67%) of the variety Sree Karthika was recorded in modified Brewbaker and Kwack medium containing 100 mg l^{-1} boric acid, 300 mg l^{-1} calcium nitrate, 200 mg l^{-1} magnesium sulphate, 100 mg l^{-1} potassium nitrate and 15.0% sucrose.
- An efficient transformation protocol was optimized for taro (*Colocasia esculenta* L. Schott) variety Muktakeshi using *Agrobacterium* strain LBA4404 carrying β-glucoronidase (GUS) reporter gene on vector PBI 121. A total of 42.86% of transformed explants regenerated on regeneration medium supplemented with 4.0 mg l^{-1} BAP along with 1.0 mg l^{-1} NAA. The GUS histochemical assay was performed using stem and leaf cuttings of the transformed plants and 7.14% transformation frequency were observed.
- Nutritional rich line of taro such as TRC-369 for antioxidant, TRC-868 for sugar, Andaman for starch, Nycle for manganese, Tripura local-2 for phenolic, crude protein and potassium and NBPGR-37 for phosphorous, iron, copper and zinc content were identified.
- Three flowering lines were identified in elephant foot yam viz., Am-41, Am-141 and the hybrid Sree Padma × Gajendra.
- In 24 accessions of Chinese potato, the tuber yield plant^{-1} ranged from 164 g to 468 g and among these, 20 accessions produced higher yield plant^{-1} than the check variety, Sree Dhara (239.7 g). The highest tuber yield of 18.7 t ha^{-1} was obtained for the accession TCR-138.
- Flower colour inheritance pattern was studied first time in yam bean. The segregation of flower colour suggested monogenic dominant control of purple flower colour in yam bean.
- The DUS testing guidelines in greater yam and yam bean have been developed and published in the PPV&FRA website.
- The phenological growth stages of yam bean through extended BBCH (Biologische Bundesantalt, Bundessortenamnt and Chemische Industrie) scale was studied and reported for the first time.
- *In vitro* plant regeneration protocol was developed for anthocyanin rich purple flesh sweet potato var. Bhu Krishna, β-carotene rich orange flesh sweet potato var. Bhu Sona, white flesh sweet potato var. Kishan, taro var. Muktakeshi, yam var. Orissa Elite and cassava var. Sree Jaya.
- Genome-wide HMM based-analysis led to the identification of 82 *MeMADS* family genes in cassava. These genes were distributed in all the chromosomes except on chromosome no.4. Promoter analysis of *MeMADS* family showed the presence of tissue-specific, biotic, abiotic, light-responsive, circadian and cell cycle-responsive *cis*-regulatory elements.

Crop Production

- The cassava nutrient efficient genotypes viz., CI-905, CI-906, 7 III E3-5 and Sree Pavithra produced sustainable tuber yield of 31.12, 20.12,

28.52 and 28.41 kg ha^{-1} respectively, for the third consecutive season (2019-20) in the same field treated with only 25% of the recommended dose of PoP (NPK @ 25:6.25:25 kg ha^{-1}).

- Sree Reksha was the most drought-tolerant cassava variety based on various morpho-physiological parameters, among the ten cassava varieties evaluated under irrigated and water deficit stress (WDS) conditions (early period stress for 90 days).
- Intercropping grain crops viz., maize and pigeonpea in taro has shown that sole taro produced significantly greater cormel equivalent yield (17.62 t ha^{-1}) followed by taro + maize (5:1) (16.75 t ha^{-1}). Sole maize and pigeonpea systems resulted in lower cormel equivalent yield (4.86 t ha^{-1} and 6.71 t ha^{-1}, respectively). The treatment taro + maize (5:1) resulted in greater B:C ratio of 2.47 followed by taro + maize (5:2) and taro sole cropping with 2.41 each.
- Among the 12 different cassava varieties evaluated for their response to organic farming, Sree Reksha (CR-24-4) produced significantly higher yield (36.97 t ha^{-1}) followed by Sree Vijaya (26.94 t ha^{-1}).
- In the integrated organic farming system model (IOFS), a net return of ₹54,862 was achieved from cassava based cropping system (with animal components for 4 months started during April 2020) from an area of 75 cents.
- Adoption of plant density @74,000 plants ha^{-1} (45 × 30 cm) and paddy straw mulching in taro helped to lower the weed dry mass to an extent of 152.4 gm^{-2} and 118 gm^{-2}, respectively and to achieve higher tuber yield of 14.38 t ha^{-1} and 16.58 t ha^{-1}, respectively. Hand weeding at 30, 60 and 90 DAP significantly reduced weed dry mass (24.5 g m^{-2}) and resulted in higher yield (20.81 t ha^{-1}) than other weed management practices which significantly increased gross and net returns and B:C ratio.
- The suitability of the AquaCrop in estimating the crop's yield irrespective of the agro-climatological conditions was established with percentage error values ranging from 2.33 to 3.92% and 0.3 to 5%, respectively in the case of cassava and sweet potato.
- Plastic ground cover mulching with drip irrigation at 50% CPE was found to be superior among ten water saving treatments in taro with a cormel yield of 29.4 t ha^{-1} and total yield of 38.32 t ha^{-1} followed by biomulching (28.9 t ha^{-1} and 36.5 t ha^{-1} respectively).
- Fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} in 60 splits at 3 days interval in greater yam+maize intercropping system resulted in higher gross return (₹6,10,000) and net return (₹3,97,200) as well as B:C ratio (2.87).
- The sustainable yield index (SYI) of NPK @ 125:50:125 kg ha^{-1} (0.676) was established over absolute control (0.359) after 15 years of continuous experimentation with cassava in the same field. The SYI of different organic manures ranged from 0.626-0.636 whereas that of combination of organic manures alone without chemical fertilizers was 0.432.
- Bulk density was found to be the critical soil parameter that influences the most important hydro physical variables such as saturated hydraulic conductivity and soil sorptivity, based on the soil infiltration and guelph permeameter field estimation studies. Conventional tillage with weed control ground cover sheet is suitable for achieving soil health and optimum yield benefits in cassava under ultisols.
- On-farm experiments and frontline demonstrations conducted in Kerala and Andhra Pradesh on validation of SSNM based customized fertilizers developed for cassava and elephant foot yam. Results of OFTs conducted in Kerala showed an average yield increase of 5.85 t ha^{-1} in SSNM treatment compared to farmer fertilizer practice (18.10% yield increase). The B:C ratio calculated for SSNM and PR for cassava, EFY, greater yam, white yam and taro also has revealed higher values for SSNM technology.
- Combined application of NPK @ 40, 15 and 40 kg ha^{-1} along with incorporation of FYM @ 10 t ha^{-1} resulted in significantly high cormel yield (28.67 t ha^{-1}) and grain (6.35 q ha^{-1}) and haulm (17.22 q ha^{-1}) yields of black gram as an intercrop with elephant foot yam with sustainable soil quality benefits.
- Validation and demonstration of SSNM based customized fertilizers for sweet potato in

Vadakkekara panchayat was conducted under '*Madhuragramam*' project by supplying planting materials and customized fertilizers to all families of the panchayat.

- Customized fertilizer practices were demonstrated and popularized through KVKs of Kollam, Idukki and Alappuzha districts of Kerala and the grade (N, P_2O_5, K_2O, Mg, Zn, B @ 7:12:24:2.5:1.25:0.4) @ 625 kg ha^{-1} was found best for elephant foot yam in coconut cropping system. The tuber yield in elephant foot yam was higher up to 15-20% and 15-30% in cassava over PoP for the customized fertilizer practices.
- On-farm validation of SSNM based customized fertilizers and organic farming over POP and FP conducted in elephant foot yam and greater yam in Kollam and Pathanamthitta districts has shown that SSNM resulted in higher yield, followed by POP and FP. In elephant foot yam, SSNM resulted in higher yield over FP by 52.21% and POP by 7.25%. In yams, SSNM performed better than FP by yielding 52.26% higher and POP by 21.47%.
- Elephant foot yam corms treated with carbon disulphide @ 80 ml100 kg^{-1} was found to be most suitable to produce higher uniform sprouting (84.92% and 99.96% at 15 and 40 days after planting respectively) and higher corm yield (36.84 t ha^{-1}).
- The biological treatments and minisett sizes in yams have influenced the sprouting percentage appreciably and it was maximum (84.14%) under fungicide pre-treatment (control) and increased with increase in sett sizes from 56.91% in 10 g sett to 81.62% in 50 g sett.
- The quality planting materials of improved varieties of cassava viz., Sree Reksha and Sree Jaya were distributed to five farmers in Shenkottai Taluk, Tenkasi district, Tamil Nadu for seed production and 8,000 sweet potato vine cuttings were supplied to the seed village at Karode, Thiruvananthapuram under SCSP programme. Planting materials of Chinese potato (var. Sree Dhara) were distributed to 15 farmers in Tirunelveli and Tenkasi districts of Tamil Nadu under seed village programme.
- Under RKVY, planting materials of improved tuber crop varieties were supplied to 20 ST farmers selected from Peringammala and Nanniyode panchayats in Thiruvananthapuram district during the period. Multiplication of planting materials at ICAR-CTCRI has been taken up with about 3.1 acres of elephant foot yam and 5.5 acres of cassava (var. Sree Reksha, Sree Pavithra, Sree Vijaya, Sree Jaya and Vellayani Hraswa) for supply and demonstration to ST farmer beneficiaries.
- Under RKVY in Odisha, field level demonstrations on tuber crops were conducted in 78.35 ha (sweet potato in 18.85 ha, cassava in 11.5 ha, yam in 12.2 ha, yam bean in 15.85 ha, elephant foot yam in 9.5 ha and taro in 10.35 ha) and 892 farmers were covered. The demonstrations on purple flesh sweet potato (var. Bhu Krishna) in 2.0 ha, orange flesh sweet potato (var. Bhu Sona) in 0.5 ha, white flesh sweet potato (var. Kishan) in 0.5 ha, yam bean in 2.0 ha and greater yam+maize intercropping system in 1.0 ha were laid out in farmers' fields of Nabarangpur district.
- A total of 1,15,000 cassava stems, 37.5 tonnes of elephant foot yam, 32.5 tonnes of greater yam, 3 tonnes of white yam, 3.5 tonnes of lesser yam, 2.5 tonnes of taro, 14,10,000 vine cuttings of sweet potato, 30,000 vine cuttings of chinese potato and 200 kg of yam bean were produced as quality planting materials during the reporting period.

Crop Protection

- Six synthetic insecticides viz., Chlorpyrifos 20 EC, Malathion 50 EC, Dimethoate 30 EC, Dichlorvos 76 EC, Quinalphos 25 EC and Imidacloprid 17.8 SL were evaluated against sweet potato weevil (SPW). Among these, Imidacloprid had the highest toxicity to SPW and a positive correlation (r = 0.8) was found between the mortality and concentration of insecticides. The second was Chlorpyrifos in its efficacy to kill SPW. Sweet potato leaves treated with Malathion and Dimethoate caused little mortality to SPW.
- A distinct genetic variant of whitefly was identified in sweet potato fields of Thiruvananthapuram. It was compared with all available 44 whitefly genetic variants of Bayesian phylogenetic tree inferred from mtCOI data using the GTR+G model.

- A new emerging pest of sweet potato causing about 30% leaf damage in fields of ICAR-CTCRI was identified as sweet potato leaf miner, *Bedellia somnulentella* (Lepidoptera: Bedelliidae) through molecular and morphological characterization. Among the various insecticides evaluated against the pest, application of Spinosad 45% SC (0.3 ml/L) at fortnightly intervals was effective in managing this pest.
- A study was conducted to identify the synthetic insecticides having lesser effect on beneficial soil microbes. Quinalphos at recommended dose caused more than 90% inhibition of the growth of *Trichoderma* in the soil at 96 h after application; however, Imidacloprid was found to be comparatively safer for soil application.
- The expression of host plant resistant genes (HPRGs), protease inhibitor, cysteine inhibitor and kunitz trypsin inhibitor genes against sweet potato weevil infestation in tubers of *I. mauritiana*, *I. palmata*, *I. triloba* and *I. obscura* was validated. For all the plants, both control and weevil infested tubers and roots were used for RNA isolation with replicates and cDNA was synthesized for Reverse Transcriptase-PCR (RT-PCR). All the gene-specific primers were amplified with cDNA from all the samples.
- A survey was undertaken in nematode affected Chinese potato fields of Ravanasamudhram, Kadayam block of Tenkasi district, Tamil Nadu. The nematode infected tubers were malformed and upon dissection of the tissue sample, adult female root nematodes were observed. The soils had *Meloidogyne incognita* with a population density of about 1.5 nematodes per gram of soil.
- A new strain of *Panagrolaimus* sp. was isolated and identified from cassava stems (var. Sree Vijaya). The nematode possessed the characteristic panagrolaimoid oesophagus and gonads. It is the first report of a plant-associated *Panagrolaimus* sp. from cassava.
- A simple *in vitro* soilless culture of root-knot nematode on Chinese potato was developed using indigenous growth pouches. Chinese potato cuttings with roots were transferred to the growth pouches and nematode suspensions were inoculated on fine roots. After a month, the galls and the eggs enclosed in a gelatinous matrix were observed on the root surface.
- Fifteen distinct microorganisms were isolated from infected leaves/pseudostem of elephant foot yam (EFY) collected from ICAR-CTCRI and farmer's field (Kottarakkara, Kerala). Koch's postulates were successfully proved with *Colletotrichum* sp. and *Fusarium* sp. These two organisms were the most predominant ones.
- Field evaluation of Mancozeb + Metalaxyl 0.1%; Mefenoxam + Chlorothalonil 0.1%; mulching with paddy straw; mulching with paddy straw + Mancozeb + Metalaxyl 0.1%; Cymoxanil + Mancozeb 0.1% (I); Potassium phosphonate 0.3%; Copper oxy chloride 0.2%; Cymoxanil + Mancozeb 0.1% (II) and Difenconazole 0.1% to reduce taro leaf blight incidence showed that all the treatments could significantly reduce the disease incidence. The reduction of PDI over control ranged from 29.35% (Cymoxanil + Mancozeb (I)) to 48.05% (Potassium phosphonate).
- Treating the EFY corms with *Trichoderma* in cow dung slurry; Mancozeb 0.2%; Mancozeb+ Carbendazim 0.2%; *Nanma* 0.7%; Mancozeb+ *Nanma* 0.7%; Carbendazim 0.1% + *Nanma* 0.7% and (Mancozeb+ Carbendazim) 0.2% + *Nanma* 0.7%, before storage could bring down both postharvest rot (PHR) and mealybug incidences in corms to less than 10%. The least postharvest rot incidence was recorded with the treatment, Mancozeb + Carbendazim 0.2% (1.8%). Treating the corms with *Trichoderma* enriched cow dung slurry alone could keep PHR and mealybug incidences to less than 8%, which could be adopted in organic cultivation of elephant foot yam.
- Ammonium bicarbonate (0.5% w/v in water) concentration inhibited 100% mycelial growth of eight pathogens associated with postharvest rot in yams.
- Soil and tuber treatment with *Trichoderma asperellum* along with seven sprays of Carbendazim (0.05%) resulted in lowest anthracnose intensity (55%) in greater yam in the field as compared to control (97.5%). The disease intensity was 75% in treatments where sparaying with a combination of Carbendazim (0.025%) and *Nanma* (0.7%) seven times was adopted. Spraying

0.025% Carbendazim and growing of greater yam var. Sree Keerthi resulted in 82% and 83% intensity, respectively.

- The potential endophytes, *Bacillus amyloliquefaciens* isolated from the roots of *Phyllanthus niruri* and *Bacillus licheniformis* from Aloe vera leaf, were evaluated against *Colletotrichum gloeosporioides* causing anthracnose in greater yam. Seed and spraying treatment combination of *Bacillus licheniformis* resulted in higher leaf length and plant height of 13.9±0.1 cm and 28.43±0.5 cm, respectively, followed by seed treatment of *Bacillus licheniformis*, which were 13.7±0.3 cm and 26.9±.52 cm more than those of control.
- Field survey showed that cassava root rot is an emerging problem in Kollam and Thiruvananthapuram districts of Kerala. The infection occurred throughout the crop period. The incidence was 50-80% in Kollam and 10% in Thiruvananthapuram. The analysis of samples showed the presence of '*Fusarium* sp'. and '*Pythium* sp'.
- Screening of fungicides *in vitro* against *Fusarium* sp. showed that Carbendazim was effective up to 5ppm. *Trichoderma asperellum*, one of the potential isolates from the ICAR-CTCRI microbial repository, has highest inhibition of pathogen (80%).
- Eight novel microRNAs were predicted from 123A library, four from 123B and 123C library using miRDeep2 under Small RNA sequencing of cassava mosaic disease (CMD) tolerant cassava variety CMR-123 through NGS approach.
- Micro RNA families miR160, miR319, miR 390, miR 395, miR403, miR482, miR535 have predicted targets in immune receptors like leucine-rich repeats (LRR) and nucleotide-binding site (NBS) and miR403, miR2950, miR3627 regulate resistance (R) genes, and pathogenesis-related (PR) proteins and defensins.
- Differential expression analysis showed that 67 miRNAs were upregulated (Log2≥ 0.5), and 28 miRNAs were down-regulated (Log2≤ 0.5) during cassava mosaic virus infection.
- Targets for editing of *Sri Lankan Cassava Mosaic Virus* (SLCMV) genome (AC1& BV1 gene) using CRISPR/Cas9 and guide RNAs were designed based on various online tools.
- Fifteen cassava breeding lines were evaluated for cassava mosaic disease resistance through chip bud grafting. These lines exhibited a high level of resistance, further confirmed through ELISA, PCR and qPCR.
- Field trials on the impact of Dasheen mosaic virus infection in different cultivars of elephant foot yam showed a significant effect of the virus on biometric and morphological characters in infected plants compared to the healthy ones.
- A diagnostic kit (DsMV ELISA KIT) against Dasheen mosaic virus was developed from the DsMV polyclonal antibody obtained after immunization in two New Zealand white rabbits against Dasheen mosaic virus protein (DsMV-IgG) and validated with more than 250 elephant foot yam leaf samples from different locations.
- A highly efficient and cost-effective diagnostic technique using RPA (Recombinase Polymerase Amplification) was developed for the detection of SLCMV from field samples.
- Sweet potato feathery mottle virus coat protein (SPFMV) polyclonal antibody (SPFMV-IgG) was used for development of DAC ELISA diagnostic kit against SPFMV. The developed IgG reacted very efficiently with SPFMV positive samples and gave positive results upto 1:6000 dilutions.

Crop Utilization

- Static pressing method was standardized for the production of high quality cassava flour (HQCF). The optimum process parameters for HQCF production were as follows: pressure-60 bar, pressing time-30s and loading weight-571g of cassava mash. After dewatering, the moisture content of the pressed/dewatered cassava mash varied from 38.04 to 44.96%. The starch loss in the mash due to pressing was extremely low and it ranged from 0.44 to 1.70%.
- The process conditions were optimized for the development of particle boards from cassava stem-sugarcane bagasse using cashew nut shell liquid (CNSL) as binder.

- In order to explore the possibility of non-conventional applications of cassava starch, it was tested as an ingredient in cement mortar. Starch in the native and different chemically modified forms are being tested in cement to optimize the properties.
- Thermoplastic starch (TPS) sheets were prepared from cassava starch-cassava stem fibrous flour as well as from cassava starch-sorbitol composites. The optimized conditions for the production of TPS from cassava-fibre-glycerol composite were fibre-75%, glycerol-30% and temperature-120ºC and pressure-120 bar. The optimized process parameters for producing TPS from starch-sorbitol composite was as follows: sorbitol-30%, pressure-130 bar and temperature-129.79ºC.
- The reaction conditions were standardized for synthesizing food grade, low temperature gelling cassava starch monophosphates (Phosphorous <0.4% as per FDA regulations) by modification of starch with orthophosphate salts. The modified starches were characterized and successfully tested as gelling agent in model candies.
- The extraction process was standardized for Chinese potato starch to eliminate the phenolic compounds and maximize the starch yield. The physicochemical, pasting and *in vitro* enzymatic digestibility were determined. The starch possessed unique paste stability and very high viscosity and water binding capacity.
- *In silico* QSAR analysis of the structure-antioxidant activity relationship of sweet potato (var. Bhu Krishna) and purple yam (Acc. Da-340) anthocyanins revealed that acylated anthocyanins exhibited higher antioxidant potential than non-acylated anthocyanins. The purple yam anthocyanins acylated with sinapic acid and sweet potato anthocyanins acylated with caffeic and ferulic acids exhibited excellent antioxidant potential than others.
- A prototype continuous steaming machine was developed for the production of sago wafers/sago papad and tested for its performance. The capacity of the steaming tank is 290 litres and the overall length of the machine is 2.83 m.
- A continuous low cost cassava peeling prototype machine for small scale processing was designed, fabricated and evaluated for its performance.
- Rice analogue was developed from the composite flour containing cassava (60-70%), maida (20-30%) and beetroot powder (5-10%). Cassava, maida and beet root powder in concentrations of 68.16%, 22.13% and 9.71%, respectively were found to be optimum for producing the rice analogue.
- Anthocyanin rich nutri-jelly was developed from purple fleshed sweet potato variety, Bhu Krishna and β-carotene rich nutri-jelly from orange fleshed sweet potato variety, Bhu Sona. The anthocyanin rich nutri-jelly had an anthocyanin content of 54.11mg100g^{-1} and the overall acceptability as determined by sensory evaluation was 8.72. The carotene rich nutri-jelly contained 7.20 mg100g^{-1} β-carotene content. Both the nutri-jellies have good storage stability at ambient and refrigerated temperatures up to 90 days of storage period.
- Ready-to-eat extruded puffed snacks were prepared with different combinations of sweet potato, cassava, maize and finger millet flours. Among all combinations, the composite of sweet potato flour (30%), cassava flour (30%), finger-millet flour (15%) and maize flour (25%) was superior in the sensory and textural qualities.
- A process was standardized for preparing nutri-sauce from orange fleshed sweet potato variety, Bhu Sona.

Extension and Social Sciences

- FLDs on Fertilizer Best Management Practices (FBMP) in greater yam (Local cultivar: Bombay yam) intercropped with coconut and turmeric conducted in East Godavari district of Andhra Pradesh revealed that the average yield of greater yam in FBMP treatment was 14.25 t ha^{-1},which was 10.81% more than the yield obtained from farmers' practices (12.86 t ha^{-1}). Similar trend was observed in the gross income (10.81%) and net income (40.13%) in comparison to farmers' practices.
- FLDs on improved varieties of sweet potato viz., Sree Arun, Sree Varun, Sree Kanaka and Bhu Krishna conducted in Thiruvananthapuram district of Kerala showed that Sree Arun produced the maximum yield (22.30 t ha^{-1}) followed by Sree Varun (21.70 t ha^{-1}), Sree Kanaka (17.80 t ha^{-1}) and Bhu Krishna (15.40 t ha^{-1}) under irrigated lowland

conditions. Average yield of improved varieties was 19.30 t ha^{-1} which was (9.66%) greater than the yield of local varieties (17.60 t ha^{-1}). Gross income realized from improved and local varieties was ₹2.89 lakhs ha^{-1} and ₹2.64 lakhs ha^{-1} respectively.

- The per capita consumption of sweet potato from various states revealed that Arunachal Pradesh had highest annual per capita consumption of sweet potato (6.31 kg) followed by Mizoram (2.26 kg) and Meghalaya (1.25 kg). A Biofortification Priority Index (BPI) was developed by modifying the methodology adopted by Harvest Plus for identifying the states which require field interventions to promote biofortified varieties of sweet potato. Results indicated that Meghalaya (36.62%), Odisha (27.86%), Mizoram (25.58%), Assam (19.25%) and Arunachal Pradesh (13.75%) are prioritized states for promoting biofortified varieties of sweet potato.
- Promotional programme of biofortified varieties of sweet potato viz., Bhu Sona and Bhu Krishna was implemented through 10 FLDs in 10 Anganwadis in Tenkasi district of Tamil Nadu.
- Mapping of women empowerment in cassava cultivation was conducted during 2020 among 65 women and 35 men in Thiruvananthapuram and Pathanamthitta districts of Kerala. Majority of the women respondents (61.53%) and men respondents (68.57%) had medium level of participation in cassava cultivation.The overall participation score was more for men (2.43) than women (2.16) in cassava cultivation which was significant at 1% level. Empowerment index was 0.78 for women and 0.86 for men.The mean empowerment index of men was more than women in all indicators except group membership. This may be due to the membership of women in the self help groups at the villages.
- Developed methods and tools in R software to predict the farm harvest price and wholesale market price of cassava and sweet potato using exponential smoothing technique (EST), autoregressive integrated moving average (ARIMA) and artificial neural network model (ANN).
- Growth rate analysis of tuber crops in India revealed that the area under cassava (-1.38%) and sweet potato (0.70%) as a whole is showing a declining trend for the period 2001-02 to 2017-18.
- eCrop based smart farming technology was developed and demonstrated in sweet potato field by setting up a smart fertigation facility. Mobile apps viz., HOMS and TOMS were developed for directly linking the producers, consumers, input suppliers and logistics service providers of all vegetable crops including tuber crops.
- A computational approach was developed for the prediction of plant host proteins with *Phytophthora*, using the protein sequence information on plant and pathogen. An interactive web application for prediction of interacting proteins using RShiny was developed to select the protein features and the methods for prediction of plant host virus interaction.
- A survey of impact of COVID-19 lockdown conducted among nine start-ups revealed that16% startups indicated that their cash flows dampened, followed by problems in getting raw materials and other inputs (13.95%) and additional expenses spent for non-working hours of the employees (11.62%). Among the startups surveyed, 56% startups were severely impacted and fully closed followed by 33% partially closed and 11% had manageable impact.
- A social entrepreneurship meet was organized by ICAR-CTCRI ABI, in collaboration with North Eastern Hill University Incubation Centre (Tura, Meghalaya), ICAR-National Institute for Biotic Stress Management (Raipur, Chhattisgarh) and ICAR-ABI, ICAR Research Complex for NEHR (Umiam, Meghalaya).
- Under the NEH programme, Rainbow diet campaign, comprising mixed methods approach involving campaigns, public rallies, frontline demonstrations, school gardens, entrepreneurship development programmes were organized in four northeastern states viz., Arunachal Pradesh, Mizoram, Meghalaya and Tripura. Two public rallies, 30 frontline demonstrations involving antioxidant rich sweet potato varieties, four entrepreneurship programmes, four campaigns involving 820 farmers and 260 school and college students were conducted. Three ethnic food

festivals were conducted in Arunachal Pradesh, Mizoram and Tripura. During these festivals, 30 farmers displayed 123 food products developed from tuber crops. Fifty recipes from tuber crops from Tripura were also documented.

- Under Tribal Sub-Plan (TSP), 47 tribal households were adopted from six villages of Chakapada, Kandhamal (District) for demonstrating tuber crops based farming system (0.4 ha model). Planting materials of sweet potato (2,25,000 vine cuttings), greater yam (3,000 kg), elephant foot yam (3,000 kg), taro (500 kg), cassava (3,000 stems), yam bean seeds (25 kg), maize seeds (20 kg), red gram (10 kg), vegetable seed kits (125 nos.) and back yard poultry birds (Vanaraja, 1,000 nos.) were distributed to the tribal farmers.
- FLDs on improved varieties of elephant foot yam viz., Gajendra and Sree Padma conducted under the SCSP programme in Tenkasi district of Tamil Nadu revealed that the variety Gajendra produced the maximum yield (39.6 t ha^{-1}) followed by Sree Padma (37.5 t ha^{-1}). Net income realized from improved and local varieties were ₹2.58 lakhs ha^{-1} and ₹1.99 lakhs ha^{-1}, respectively. The B:C ratio of the improved varieties was 1.81, whereas it was 1.58 for local varieties.
- Under SCSP programme, 64 demonstrations on improved varieties/technologies of tuber crops were conducted in Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta and Ernakulam districts of Kerala and Tenkasi and Tirunelveli districts of Tamil Nadu for enhancing the productivity and profitability of tuber crops farming under SCSP programme. Critical inputs viz., planting materials, customized fertilizers, microfood, farm implements and tools were distributed to the SC farmers. Training programmes, field days, farm advisory visits and exhibitions were also conducted in these districts of Kerala and Tamil Nadu for the benefit of 514 SC farmers.

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

- The superabsorbent polymer technology was transferred to one Maharashtra based company and technology for tuber crops based fried snack products was transferred to two entrepreneurs in Kerala. A total of ₹22.56 lakhs was generated through technology commercialization, sale of technological products, student fee and other professional service functions.
- During 2020, ICAR-CTCRI has offered exposure training to B.Sc./B.Tech students, project work of M.Sc. students and imparted technical guidance to Ph.D. students, totalling to 103.
- A total of 657 farmers, 368 students and 69 officials from different parts of the country were imparted training by ICAR-CTCRI. The Institute has participated in 7 exhibitions.
- During the COVID-19 pandemic period, ICAR-CTCRI, Thiruvananthapuram and its Regional Station at Bhubaneswar donated 10 tonnes of cassava tubers, 100 kg elephant foot yam tubers, 260 kg yam tubers, 60 kg taro tubers and 60 kg sweet potatoes to 'Community Kitchens' run by different beneficiaries. Agro-advisories were given through different social media to help tuber crop farmers during lock down period.
- The Institute had a total of 233 publications as follows. Research papers: 60; Symposia: 56; Book: 5; Book chapters: 9; Popular articles: 59; Technical bulletins: 4; Folders/ leaflets/ pamphlets: 8; Business models: 2; Course/Training manuals: 18; Institute publications: 9; E-publications: 3.
- Radio talks: 8; TV talks: 4; Facebook live: 9; YouTube channel: 9; Video:1.

INTRODUCTION

ICAR-CTCRI Headquarters, Thiruvananthapuram (48.19 ha)

ICAR-CTCRI Regional Station, Bhubaneswar (20 ha)

ICAR-CTCRI (1963-2020)

The ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) was established during the Third Five Year Plan for intensification of research on tuber crops (other than potato). The Institute started functioning in July 1963 with its headquarters (HQ) at Sreekariyam, Thiruvananthapuram, Kerala. It has one Regional Station (RS) at Bhubaneswar, Odisha. 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 Station. 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 organization in the world dedicated solely to the research on tropical tuber crops. The Institute celebrated its Golden Jubilee in 2013 and 57 years of concerted research have led to

the development of several sustainable production, protection and processing technologies for tuber crops, besides release of 68 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 popularization 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 germplasm wealth of tuber crops, totalling 5,713. The pioneering role of ICAR-CTCRI in classical breeding of tropical tuber crops attracted international collaborations in the breeding and genetic improvement of these crops. Research on molecular based improvement is also being continued. The ICAR-CTCRI has released 68 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. Four varieties in yams viz., Sree Nidhi, Sree Haritha, Sree Swetha and Sree Hima were also recently released. The Institute has strong research programmes on biotechnology, which includes the development of diagnostic tools for viral and fungal diseases and transgenic plants for conferring resistance to cassava mosaic disease and to enhance the starch content and to develop waxy varieties.

Agro-techniques are available for tuber crops in 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. Improved tuber crop varieties are gaining popularity in Kerala, Tamil Nadu, Odisha, Bihar, Uttar Pradesh and Gujarat through RKVY and other schemes. 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 products like modified starches, super absorbent polymer, adhesives, thermoplastic starch and particle board apart from pre and post harvest machineries. In addition, there are technologies for several value added food products which include pasta, noodles, fried snack foods etc. Development of functional foods from cassava, sweet potato, yams and elephant foot yam are the recent contributions.

Innovative extension programmes and methodologies have been developed for enhancing technology utilization and farm income by the farmers and other stakeholders. The IT tools such as e-Crop, Tuber Crops Online Marketing System and growth simulation and self-learning growth models for different crops were developed and validated for applications in smart farming. Intelligent bioinformatics tools were developed to predict plant-pathogen interaction, biological network construction, omics data integration and visualization. Molecular markers, miRNAs, lncRNAs and differentially expressed genes associated with biotic/abiotic stress and quality parameters of tuber crops were identified. The North Eastern Hill (NEH) programme, Tribal Sub-Plan (TSP) and Scheduled Caste Sub Plan (SCSP) are the important development programmes implemented successfully and have greatly helped to increase livelihood security of the farmers and other stakeholders across the country.

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 Deshmukh 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 11-15 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.

Extramural support by way of research schemes from both international (CIAT, CIP, CIRAD, European Union, IFAD and Indo-Swiss) and national agencies (DBT, DIT, DST, DRDO, DSIR, ICAR, KSCSTE, LSRB, MOEF, DoA, Kerala, KSPB, NABARD, PPIC, RKVY, PPV&FRA, SHM, CDB, UGC and Network and Consortia projects of ICAR) are enriching the research activities.

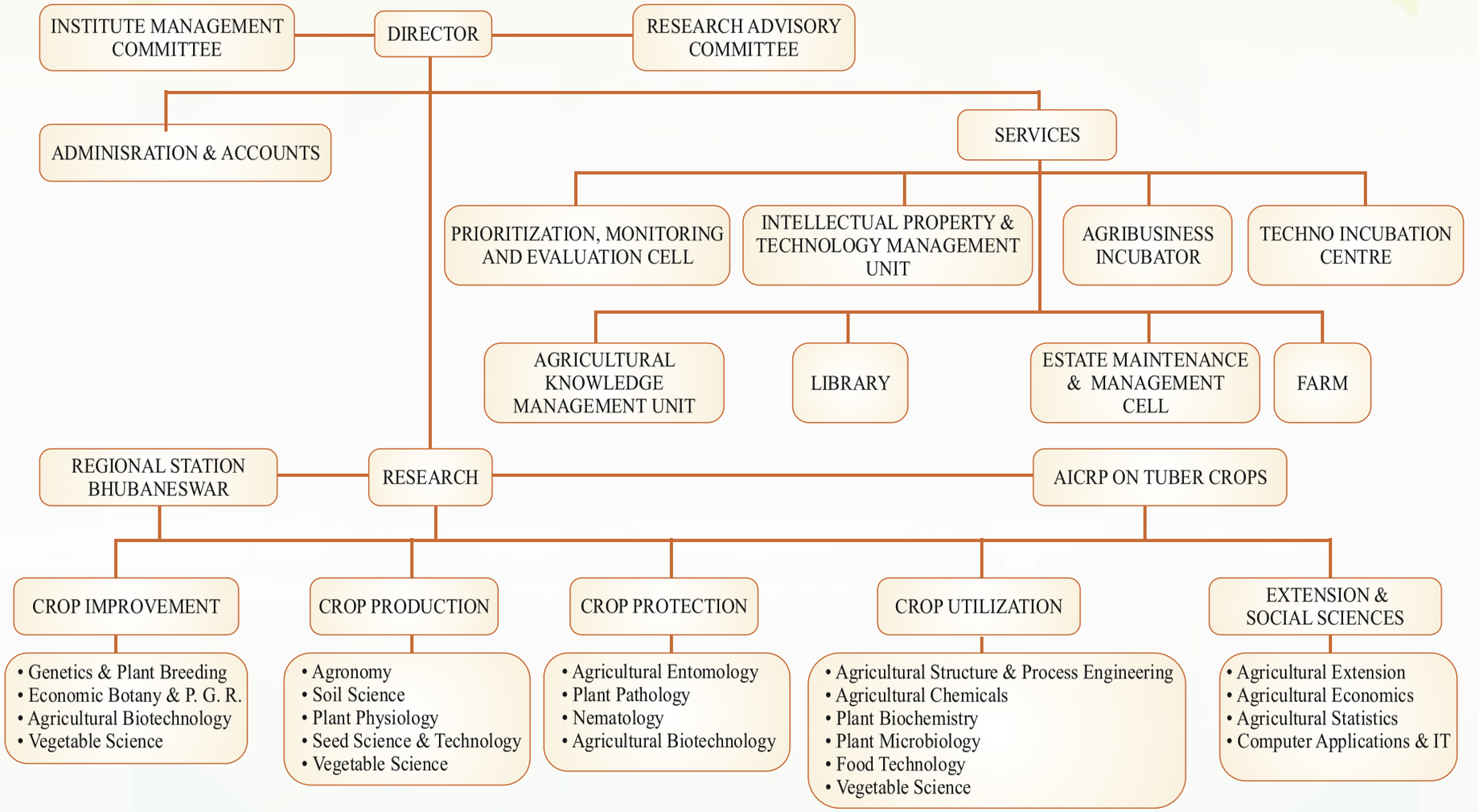
The Intellectaul Property & Technology Management Unit (IPTMU) has been active in carrying out IP activities. Various technologies related to value addition have been commercialized through IPTMU under consultancy, licensing and contract research mode. The Bioinformatics & Statistical laboratory is equipped with Linux and Windows workstations, 6 stand alone terminals and 8TB network assisted storage to assist high performance computing. The lab is installed with commercial software packages such as SAS, DNASTAR, BioBam (Blast 2GO) and other open source softwares for statistical and bioinformatics applications.

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. The VPN connectivity is established for global access to the servers. The Institute home page can be accessed at http://www.ctcri.org, which provides comprehensive information about the various activities of the Institute and online facilities like sales counter, discussion forum etc.

MANDATE CROPS

1. Cassava: *Manihot esculenta* Crantz, Euphorbiaceae	8. Elephant foot yam: *Amorphophallus paeoniifolius* (Dennst.) Nicolson, Araceae
2. Sweet potato: *Ipomoea batatas* (L.) Lam., Convolvulaceae	9. Giant taro: *Alocasia macrorrhiza* (L.) Schott., Araceae
3. Greater yam: *Dioscorea alata* L., Dioscoreaceae	10. Swamp taro: *Cyrtosperma chamissonis* (Schott.) Merr., Araceae
4. White yam: *Dioscorea rotundata* Poir., Dioscoreaceae	11. Chinese potato: *Plectranthus rotundifolius* (Poir.) J.K. Morton, 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

ORGANIZATIONAL SETUP



Staff Position (2020)

Category	Sanctioned	In-position	Vacant
RMP	1	0	1
Scientific	44	46	-2
Technical	47	32	15
Administrative	31	25	6
Skilled Support Staff	38	30	8
Total	**161**	**133**	**28**

Progressive Expenditure 2020-21

Sl.No.	Head of Account	Amount (₹ in lakhs)	
	Capital	**RE 2020-21**	**Expenditure**
1.	Works		
	Office building - Institute	32.64	32.64
2.	Equipments Institute	0.00	0.00
	- NEH	15.00	11.88
	- TSP	0.37	0.00
	- SCSP	5.00	4.95
3.	Vehicle & Vessels	5.33	5.33
4.	Library Books and Journals	0.00	0.00
5.	Furniture & Fixtures	2.03	2.03
	Total Capital	**60.37**	**56.83**
	Revenue		
1.	**Establishment Expenses and Salaries**		
	i. Establishment Expenses	1791.12	1791.12
	ii. Overtime Allowances	0.00	0.00
	iii. Pension & Other Retirement Benefits	245.64	245.46
	Total	**2036.76**	**2036.58**
2.	**Traveling Allowance**		
	a. Domestic TA/Transfer TA	**7.61**	**7.61**
	b. Foreign TA	**0.00**	**0.00**
	Total TA	**7.61**	**7.61**
3.	**Research & Operational Expenses**		
	a. Research Expenses		
	i. Institute Expenditure - Institute	49.00	48.89
	- SCSP	5.00	4.05
	b. Operational Expenses		
	i. Institute	90.67	90.22
	ii. TSP	20.00	20.00
	iii. NEH	27.00	24.16
	iv. SCSP	7.00	4.57
	Total Research & Operational Expenses	**198.67**	**191.89**
4.	**Administrative Expenses**		
	a. Infrastructure	115.50	115.50
	b. Communication	2.34	2.34
	c. Repair & Maintenance		
	i. Equipment, Vehicles & Others	18.29	18.28
	ii. Office building	11.85	11.85
	iii. Residential building	9.63	9.63
	iv. Minor Works	12.87	12.86
	d. Others (excluding TA) - Institute	37.06	37.08
	- SCSP	18.00	11.63
	Total Administrative Expenses	**225.54**	**219.17**
5.	**Miscellaneous Expenses**		
	a. HRD	0.00	0.00
	b. Other Items (Fellowships, Scholarships etc.)	---	---
	c. Publicity & Exhibitions	0.32	0.32
	d. Guest House - Maintenance	0.19	0.19
	e. Other Miscellaneous	1.24	1.24
	Total Miscellaneous Expenses	**1.75**	**1.75**
	Total Revenue	**2470.33**	**2457.00**
	Grand Total (Capital + Revenue)	**2530.70**	**2513.83**

ONGOING RESEARCH PROJECTS

Institute Projects (from April 2020 onwards)

Sl. No.	Project code	Project title	PI	Co-PIs
1.	HORTCTCRISIL 202000901465	Conservation and utilization of germplasm of tuber crops for sustaining production	K. I. Asha	M. N. Sheela, P. Murugesan, A. Asha Devi, Shirly Raichal Anil, Kalidas Pati, V.B.S. Chauhan, N. Krishna Radhika, Vivek Hegde, A.V.V. Koundinya, K.M. Senthilkumar, C. Visalakshi Chandra, T. Makeshkumar, M. L. Jeeva, S. S. Veena, E. R. Harish, H. Kesava Kumar, A. N. Jyothi, J. Sreekumar, T. Krishnakumar, V. V. Bansode, M. Nedunchezhiyan
2.	HORTCTCRISIL 202001001466	Genetic improvement of tuber crops through conventional breeding and molecular approaches	M. N. Sheela	Asha K.I., P. Murugesan, A. Asha Devi, C. Mohan, Shirly Raichal Anil, Kalidas Pati, V. B. S. Chauhan, Krishna Radhika N, Vivek Hegde, Koundinya A.V.V, Senthilkumar K.M, Visalakshi Chandra C, Makesh Kumar T, M.L.Jeeva, S.S.Veena, E.R.Harish, A.N.Jyothi, J.Sreekumar, T. Krishnakumar, V.V.Bansode, M.Nedunchezhiyan, K.Laxminararyana, S.Sunitha, Saravanan Raju, Prakash P, P.S.Sivakumar, Arutselvan R, Muthuraj R, D.Jaganathan
3.	HORTCTCRISIL 202001101467	Resource management and climate smart agriculture for sustainable production of tropical tuber crops	G. Suja	G. Byju, J. Suresh Kumar, S. Sunitha, K. Laxminarayana, K. Susan John, V. Ramesh, Sanket J. More, Saravanan Raju, V. Ravi, M. Nedunchezhiyan, R. Muthuraj, K. Sunil Kumar, K. I. Asha, D. Jaganathan, E. R. Harish, J. Sreekumar, Kalidas Pati, P. Prakash

Sl. No.	Project code	Project title	PI	Co-PIs
4.	HORTCTCRISIL 202001201468	Quality planting material production of tropical tuber crops	R. Muthuraj	K. Sunil Kumar, V. Ravi, G. Byju, M. Nedunchezhiyan, G. Suja, K. Susan John, S. Sunitha, Saravanan Raju, V. Ramesh, A. Asha Devi, D. Jaganathan, V.B.S. Chauhan, E. R. Harish, H. Kesava Kumar, M. N. Sheela, M. L. Jeeva, S. S. Veena, Shirly Raichal Anil, T. Krishnakumar, T. Makeshkumar, Vivek Hegde
5.	HORTCTCRISIL 202001301469	Development of innovative technologies for the intensification of pest management in tuber crops through biorational approaches	C. A. Jayaprakas	E.R. Harish, B.G. Sangeetha, H. Kesava Kumar, S. S. Veena, Shirly Raichal Anil, M.L. Jeeva, Sirisha T.
6.	HORTCTCRISIL 202001401470	Development and refinement of integrated disease management and forecasting system for improved tuber crop production	M. L. Jeeva	S. S. Veena, T. Makeshkumar, M. N. Sheela, G. Byju, A. Asha Devi, V.S. Santhosh Mithra, R. Arutselvan, Shirly Raichal Anil, H. Kesava Kumar, B.G. Sangeetha, J. Sreekumar, Sirisha T.
7.	HORTCTCRISIL 202001501471	Pre and post harvest machinery, processing techniques and product diversification in tropical tuber crops	M. S. Sajeev	A. N. Jyothi, V. V. Bansode, T. Krishnakumar, M. Nedunchezhiyan, M. N. Sheela, G. Byju, S. S. Veena, A. Asha Devi, K. I. Asha, P. Prakash, V.B.S. Chauhan, Kalidas Pati, Namrata Ankush Giri
8.	HORTCTCRISIL 202001601472	Developing methodologies and tools for assessment and transfer of tuber crops technologies	Sheela Immanuel	D. Jaganathan, P. S. Sivakumar, P. Prakash, V.S. Santhosh Mithra, J. Sreekumar, G. Byju, G. Suja, R. Muthuraj, P. Murugesan, A.V.V.Koundinya, H. Kesava Kumar, T. Krishnakumar, M. Nedunchezhiyan, K. Laxminarayana, K. Sunil Kumar, V. V. Bansode, Sanket J. More, M. L. Jeeva, Shirly Raichal Anil, S. Sunitha, T. Makeshkumar, M.N. Sheela, K. Susan John, K.M. Senthilkumar

NEH, TSP and SCSP Programmes of ICAR-CTCRI

Sl. No.	Title	Nodal Officer /PI	Co-PIs	Funding Agency
1.	Livelihood improvement of tribal farmers through tuber crops technologies (ICAR-CTCRI-Tribal Sub Plan)	Nodal Officer: Sheela Immanuel PI: M. Nedunchezhiyan	K. Laxminarayana Kalidas Pati V. B. S. Chauhan K. Hanume Gowda V. V. Bansode	ICAR, New Delhi
2.	Scaling up biofortified tuber crops through 'Rainbow Diet Approach' in the North Eastern Hills Region (ICAR-CTCRI NEH programme)	Nodal Officer: Sheela Immanuel PI: P. S. Sivakumar	M. Nedunchezhiyan K. Laxminarayana V. B. S. Chauhan M. S. Sajeev P. Murugesan H. Kesava Kumar T. Krishnakumar P. Prakash	ICAR, New Delhi
3.	Empowerment of farmers through tuber crops based technological interventions (ICAR-CTCRI SCSP programme)	Nodal Officer: Sheela Immanuel PI: D. Jaganathan	G. Byju K. Susan John K. Sunilkumar V. Ramesh R. Muthuraj M. S. Sajeev T. Krishnakumar A. V. V. Koundinya B. G. Sangeetha E. R. Harish	ICAR, New Delhi

Externally Aided Projects

Sl. No.	Title	PI	Co-PIs	Funding Agency
1.	Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro	Kalidas Pati	J. Sreekumar J. Tarafdar (BCKV, Kalyani)	PPV & FRA, New Delhi
2.	Establishment of varietal gene bank and development of standards of DUS testing in yam bean (*Pachyrhizus erosus*) and greater yam (*Dioscorea alata*)	M. N. Sheela (Lead Centre) Kalidas Pati (Collaborating Centre)	J. Sreekumar Vivek Hedge M. Nedunchezhiyan P. P. Singh (RAU, Dholi) Ashish Narayan (DRPCAU, Dholi)	PPV & FRA, New Delhi
3.	Establishment of varietal gene bank and development of standards of DUS testing in cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*)	M. N. Sheela	K. I. Asha A. Asha Devi Shirly Raichal Anil Kalidas Pati N. Krishna Radhika	PPV & FRA, New Delhi

Sl. No.	Title	PI	Co-PIs	Funding Agency
4.	ICAR-CIP collaborative work plan activity on crop improvement and varietal selection of sweet potato	Shirly Raichal Anil	C. Visalakshi Chandra	CIP, New Delhi
5.	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. S. Sivakumar	DBT, New Delhi
6.	Applied mutagenesis in cassava for improved agronomic, disease resistance and post-harvest traits	A.V.V. Koundinya	-	Department of Atomic Energy, Govt. of India
7.	*In vitro* quality planting material production of tuber crops to meet the demand of Odisha	V.B.S. Chauhan	Kalidas Pati K. Hanume Gowda V.V. Bansode M. Nedunchezhiyan	RKVY, Dept. of Agriculture & Farmers Welfare, Government of Odisha
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 polysul phate under ultisols (Laterites) and entisols (Sandy soils) of Kerala	K. Susan John	Jeena Mathew (ICAR-CPCRI)	International Potash Institute (India Region)
11.	Higher productivity and profita bility from coconut gardens through soil health management in tuber crops	G. Byju G. Suja	D. Jaganathan	Coconut Development Board, Govt. of India
12.	Potential impact of climate change on tropical tuber crops yield in major growing areas of India	G. Byju (Scientist Mentor)	P. Raji (Woman Scientist)	DST-WOS-A, Govt. of India
13.	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	K. Sunilkuamr 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-RAFTAAR, Govt. of Kerala

Sl. No.	Title	PI	Co-PIs	Funding Agency
14.	Popularization of climate resilient and nutritionally rich varieties of tuber crops for economic development and nutritional security of farmers of Odisha	M. Nedunchezhiyan	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
15.	Inter Institutional Project:Farm based S&T interventions for socio-economic development in the aspirational district of Nabarangpur Odisha; Sub project: Tuber crops technologies for food and nutrition security and livelihood improvement of farmers of Nabarangpur	M. Nedunchezhiyan	K. Laxminarayana Kalidas Pati V. B. S. Chauhan K. Hanume Gowda V. V. Bansode	RKVY, Govt. of Odisha
16.	Development and application of diagnostics to viruses infecting tuber crops (*Amorphophallus*, cassava, sweet potato and yam)	T. Makeshkumar	M. L. Jeeva R. Arutselvan R. Muthuraj	ICAR-CRP on Vaccines and Diagnostics
17.	High value compounds/ Phytochemicals	A. N. Jyothi	J. Sreekumar Shirly Raichal Anil	ICAR Network Project
18.	Techno-Incubation Centre	M. S. Sajeev	T. Krishnakumar	Small Farmers Agribusiness Consortium, Govt. of Kerala
19.	National Agricultural Innovation Foundation (NAIF) (Component I Innovation Fund)	P. S. Sivakumar	Sheela Immanuel R. Muthuraj P. Prakash	ICAR- NAIF, New Delhi
20.	NAIF-Component II-Agri Business Incubator	P. S. Sivakumar	Sheela Immanuel	ICAR-IP & TM Unit, New Delhi
21.	Chlorophyll fluorescence kinetics and monitoring of photochemical efficiency in cassava (*Manihot esculenta* Crantz) genotypes for energy efficient cassava	Saravanan Raju (Scientist Mentor)	Raji S. Nair (Woman Scientist)	KSCSTE, Govt. of Kerala
22.	Smart-farming technologies in horticultural crops for improving rural agro system	V.S. Santhosh Mithra	G. Byju J. Sreekumar D. Jaganathan	Kerala State Horticulture Mission
23.	Development of smart solutions for estimating starch content of cassava tubers and managing biotic and abiotic stresses in cassava field through artificial intelligence	V.S.Santhosh Mithra	G. Byju T. Makeshkumar M.S. Sajeev E.R. Harish	Department of Science and Technology, Govt. of India

RESEARCH ACHIEVEMENTS
INSTITUTE PROJECTS
CROP IMPROVEMENT

Conservation and Utilization of Germplasm of Tuber Crops for Sustaining Production

Field gene bank

Cassava

In cassava, the existing 1,217 accessions comprising of the indigenous, exotic, landraces and breeding lines were planted in the field for maintenance, characterization and preliminary evaluation. Four hundred and fifty-four accessions were subjected to preliminary characterization for six juvenile plant characters viz., plant colour, young stem colour, apical leaf colour, young leaf colour, young petiole colour and cassava mosaic disease incidence at 4 months after planting. Plant colour as such was greenish purple in 220 accessions followed by green in 189 accessions. Young stem colour was green in 295 and greenish purple in 145 accessions (Fig. 1). Apical leaf colour was green in 166 accessions, while purple in 164 accessions. The young leaf colour was green in 450 accessions, light green in one and greenish purple in 3 accessions. Purple, pink, greenish purple, green and greenish pink colour variations were observed in the young petiole. Cassava mosaic disease incidence in the early growth stage was low in 39 accessions, medium in 123, high in 93 and very high in 62 accessions, while 137 accessions were free without showing any disease symptoms (Fig. 2). Thirty-five accessions of cassava germplasm are being evaluated for chlorophyll, fluorescence kinetics and photochemical efficiency under a post-doctoral programme of KSCSTE, Government of Kerala.

Ten accessions of cassava received on 04 September 2020 through AICRP TC from HRS, Peddapuram, East Godavari, Andhra Pradesh were planted in the field.

Among 100 accessions of cassava analyzed for biochemical characterization of the roots, 43 accessions had starch content above 60% on dry weight basis (Fig. 3), the highest being in CI-690 (68.4%) and lowest in CI-643 (54.3%) on dry weight basis. Total sugars were highest in the roots of accession CI-666 (2.31%) and lowest in CI-889 (0.94%). Crude fibre content ranged from 0.57% in CI-697 to 1.07% in CI-743 and ash content from 0.65% in CI-611 to 1.94% in CI-286.

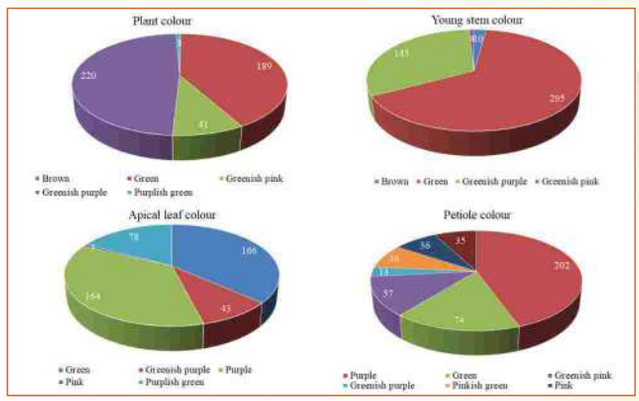


Fig. 1. Phenotypic variability in the early growth stages of cassava germplasm

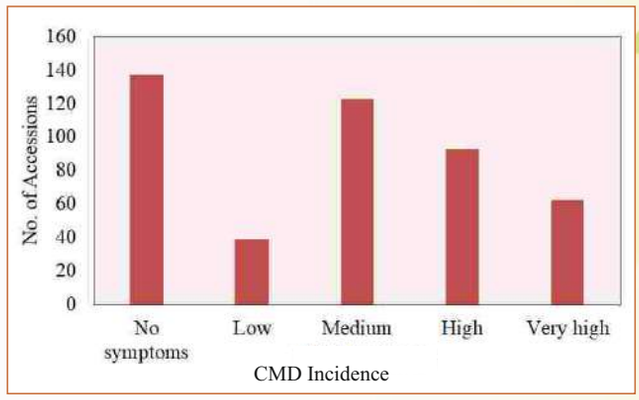


Fig. 2. Cassava mosaic disease incidence in the early growth stages of cassava germplasm

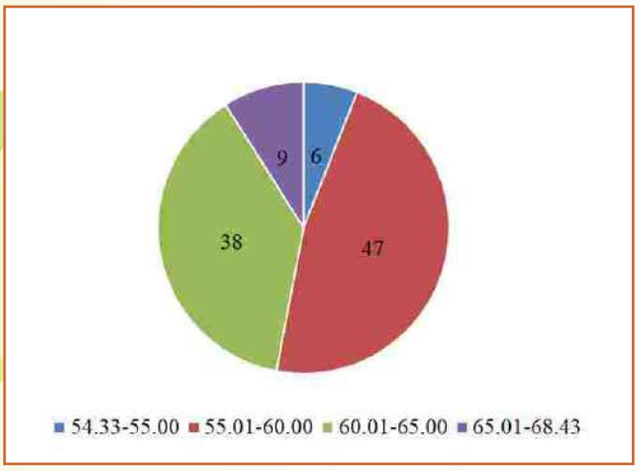


Fig. 3. Starch content variability among 100 accessions of cassava

Sweet potato

A total of 1,129 accessions of sweet potato are being maintained in the National Active germplasm site of ICAR-CTCRI. Morphological and molecular characterization of 47 accessions which included 41 sweet potato accessions and six wild species of *Ipomoea* were done. Morphological characterization comprised of recording the observations of all the aerial parts of sweet potato based on the IPGRI descriptors for sweet potato. The recorded data were subjected to statistical analysis using Multivariate statistical package (MVSP 3.22). The dendrogram showed separation of accessions into two principal clusters at a Euclidean distance of 1.7 (Fig. 4). The first three principal components (PC) accounted for 60.9% of the variability and the highly loaded characters in PC1, PC2 and PC3 was petiole pigmentation. The traits included in PC1 and PC3 were predominant vine colour, shape of central leaf lobe and leaf lobe shape. Immature leaf colour was the trait included in PC2, PC3 and PC4. Hence, predominant vine colour, leaf lobes type, shape of central leaf lobe, immature leaf colour and petiole pigmentation were important in distinguishing the accessions.

Molecular characterization of 41 accessions along with six wild accessions was done using 11 ISSR primers. For molecular characterization, DNA was isolated from fresh young leaves of the plants using Dellaporta method. The DNA obtained had an A260/A280 ratio of 1.90-2.35. A total of 211 polymorphic bands were obtained. NTSYS PC Version 2.02 programme was used to generate a dendrogram using ISSR marker data, which grouped the accessions on the basis of Jaccard's similarity coefficient. Thus, the 47 accessions were grouped into two principal clusters at 0.58 on similarity index scale (Fig. 5).

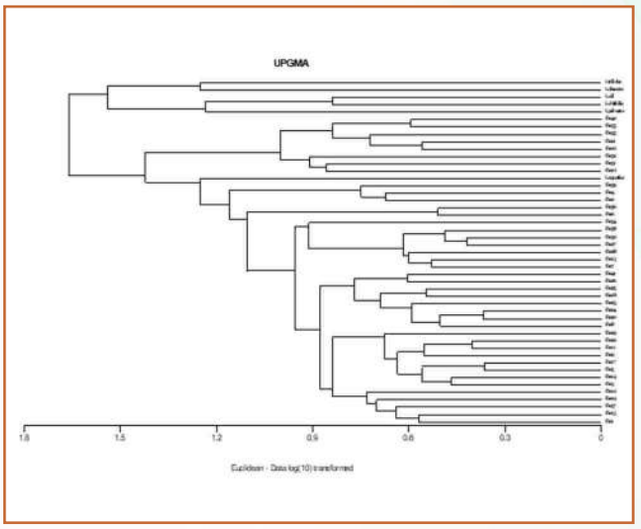


Fig. 4. Dendrogram showing the grouping of sweet potato accessions based on morphological characters

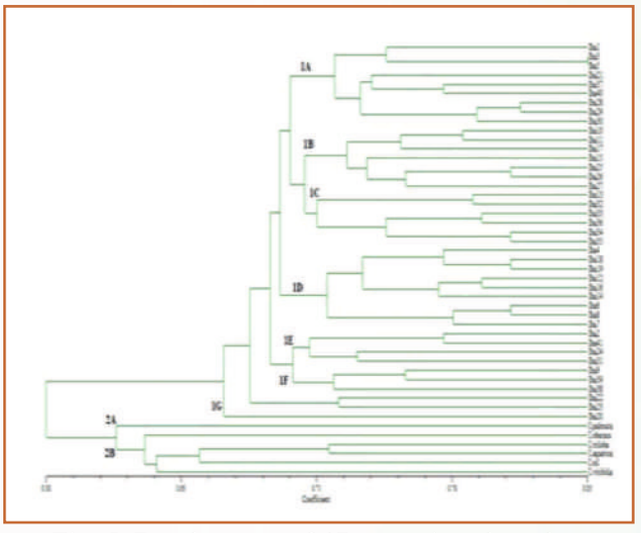


Fig. 5. Dendrogram of 47 accessions based on hierarchical clustering

The genetic similarity between the accessions ranged from a maximum of 0.85 to 0.50. Thus, the genetic diversity between the accessions ranged between 0.15 - 0.50 with a mean of 33%. All the accessions were grouped together in the first principal cluster, which was sub divided into seven sub-clusters with lot of intra-cluster variations within a distance of 0.59 - 0.82. The second principal cluster comprised of all the six wild species with *I. palmata* as the outlier. The maximum similarity was observed between S-623 and S-632 (Iba 3 and Iba 5) and least similarity between AR-2017-2 and *I. vitifolia* (Iba 19 and *I. vitifolia*) (similarity coefficients 0.85 and 0.35, respectively).

The morphological and molecular data were found to be positively correlated based on Spearman rank correlation coefficient using Mantel's test indicating that the morphological characters are genetically fixed.

Preliminary evaluation was done for 102 accessions of sweet potato germplasm for yield and tuber traits in augmented design with six blocks and five controls (Sree Arun, Sree Varun, Sree Bhadra, Sree Nandhini and Bhu Sona) during May 2019 and harvested in August after 120 days. During the season, the vine yield, tuber yield and tuber characters were recorded. Vine yield was significant between the accessions and it ranged from 0.1 to 2.25 kg plant^{-1} and was highest in S-644 followed by S-131 (1.9 kg plant^{-1}) and S-346 (1.5 kg plant^{-1}). Significant differences were not noticed in tuber yield among the accessions. Among the 102 accessions under the trial, only 29 accessions showed tuberization. The highest tuber yield was recorded in S-4 (0.5 kg plant^{-1}) followed by S-3 (0.33 kg plant^{-1}) and S-390 (0.200 kg plant^{-1}). The Harvest Index (HI) recorded was not significant between the accessions and it ranged from 0.003 to 0.571 in the accessions which were tuberising. The highest HI was recorded in S-4 (0.571) followed by S-3 (0.455). White flesh improved lines/selections from previous trials, S-1401 and S-1609, are being multiplied for AICRP trials.

Yams

A total of 1,121 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. Seven accessions of greater yam, one accession each of potato yam and lesser yam were added to the field gene bank (Fig. 6). The greater yam germplasm was characterized based on 38 IPGRI descriptors and database and catalogue were updated. The germplasm was planted during April 2020 at ICAR-CTCRI, Thiruvananthapuram as rainfed crop and harvested after nine months. Molecular characterization of 45 accessions of greater yam was carried out using 15 ISSR and 10 SSR primers.

Among 158 white yam accessions, 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 found to be high yielding (>5 kg plant^{-1}). The accession, Dr-59 produced high yield coupled with compact tuber shape, while Dr-80, Dr-57 and Dr-113 showed excellent cooking quality.

The tuber yield per plant ranged from 1.0 kg (CTDE-81) to 4.3 kg (CTDE-145) among the 220 accessions of lesser yam. Higher number of tubers/plant (>50) was recorded in accessions viz., CTDE-39, De-49 and CTDE-53. High tuber yield (>4.0 kg plant^{-1}) was recorded in De-62, De-103 and De-145.

Fig. 6. New lesser yam accession, *D. esculenta* var. *spinosa*

Edible aroids

The edible aroid germplasm was augmented with a total of 33 aroids comprising of 24 taro, one swamp taro, one tannia and seven elephant foot yam collected from Tripura (Dhalai, Teliamura and Brigudasbari), Mizoram (Kolazib and Lengpui) (Fig. 7) and Kerala (Kollam). 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. Three flowering lines were identified in elephant foot yam viz., Am-41, Am-141 and the hybrid Sree Padma × Gajendra. Aroid database was updated with tuber photos of 33 edible aroids comprising of 24 taro, 1 tannia, 7 elephant foot yam and 1swamp taro accession.

Fig. 7. Variation amongst the aroid collections from Tripura and Mizoram

Under morphological characterization of tannia, above ground characters of six tannia accessions for 27 traits viz., growth habit, height of plant, petiole attachment, lamina orientation, leaf, vein and petiole characters

were taken including four quantitative traits (height of the plant, length/breadth ratio of lamina, petiole length and petiole sheath length) as per IPGRI descriptors. Except petiole colour and leaf colour, all the other qualitative traits showed no variation in this morphologically less distinct crop. However, variation was observed in the underground traits of 30 tannia accessions subjected to morphological and molecular characterization. Morphological characterization was done based on 19 underground tuber traits comprising 14 qualitative and five quantitative traits as per IPGRI descriptors. Characters like time of harvest, position of cormel apex and exterior surface of corm showed no variation and remained constant. Corm size (H - 0.98 cm, D - 0.62 cm) and cormel size (H - 0.82 cm, D - 0.55 cm) showed maximum variability as indicated by Shannon weaver as well as Simpson's diversity indices. The PCA also indicated that shape and size of corm/cormel were responsible for maximum variability. Degree of variability was found to be high for corm weight, number of cormels produced per plant and cormel weight. Duncan's multiple range test showed that all the five characters were statistically significant. Cluster analysis could identify three sets of duplicates and one divergent line with purple flesh colour (Xa-JG/2016-1). Molecular characterization was done using 14 ISSR markers and two sets of duplicates could be identified. Apart from ISSR markers, nine taro SSR primers belonging to the common Ce and uq series were tried on 30 tannia accessions to check for cross compatibility using different temperature regimes and PCR conditions. However, the taro SSR primers tested were found to be non-transferable to tannia.

Preliminary yield evaluation was done for 36 taro accessions including few hybrids. Wide variation was observed in the yield traits. Corm yield ranged from 0.67 t ha^{-1} (IC089624) to 26.22 t ha^{-1} (HDG/PAK/2016-152, a collection from Assam) (Fig. 8). Cormel yield ranged from 1.19 t ha^{-1} (IC089813) to 25.93 t ha^{-1} (Line 24, a hybrid line).

Fig. 8. A dasheen type taro from Assam (HDG/ PAK/ 2016-152)

Total yield ranged from 3.04 t ha^{-1} (IC089813) to 43.19 t ha^{-1} (HDG/PAK/2016-152, a dasheen type taro). The corm, cormel and total yields were greater than 20.00 t ha^{-1} in one, four and twelve entries, respectively. The check variety, Sree Rashmi yielded 10.89 t ha^{-1} and 13.70 t ha^{-1} cormel and total yield, respectively.

Minor tuber crops

In the exploration and collection trip undertaken to the Chinese potato growing belts of Tirunelveli and Tenkasi districts of Tamil Nadu (Fig. 9), five accessions were collected and newly added to the existing germplasm.

Fig. 9. Chinese potato growing belts in Tirunelveli district

In Chinese potato, top shoot cuttings of 24 accessions were planted at ICAR-CTCRI farm during July 2019 and the crop was harvested in January 2020 (Fig. 10). Tuber yield ranged from 4.04 t ha^{-1} in ASAKI-1 to 18.70 t ha^{-1} in TCR-138 (Fig. 11). The tuber yield per plant ranged from 164 g in JAS/2015-17 to 468 g in VCS/19-1. The number of tubers/plant was highest in TCR-136 (50) and the least in ASAKI-8 (16). Eighteen of the accessions recorded the number above than that of Sree Dhara (29.7). Among the 24 accessions, twenty recorded higher tuber yield/plant than the check variety, Sree Dhara (239.67 g) (Fig. 12). The tuber size was highest in ASAKI-1 (7×7.1cm).

Fig. 10.(a) Field view of Chinese potato and (b) Plants at flowering stage

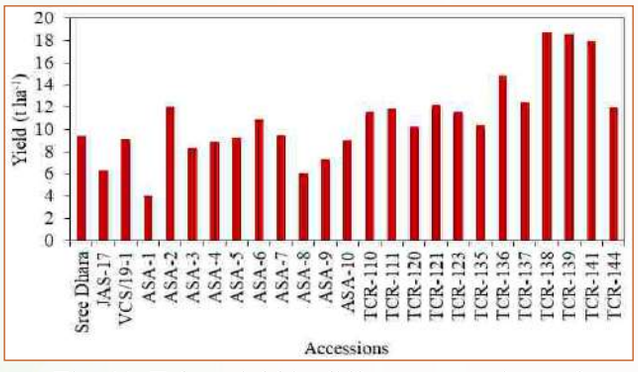


Fig. 11. Tuber yield in different accessions of Chinese potato

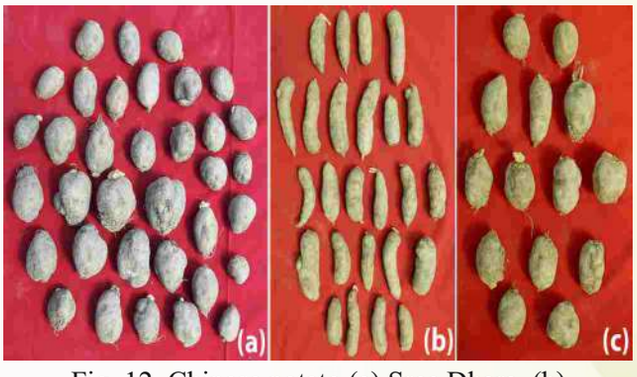


Fig. 12. Chinese potato (a) Sree Dhara, (b) JAS/2015-17 and (c) TCR-138

Two Tacca and two starchy curcuma germplasm were collected during the exploration trip to ChikalvavTapi district of South Gujarat in collaboration with NBPGR and ICAR-DMAPR, Anand during January 2020. The procedure for germination of true seeds of Tacca and tuber (Fig. 13) were standardized by employing special germination improvement technique for conservation and further improvement. The true seeds and the tuber of Tacca took 9 and 14 days, respectively to initiate germination in the lab condition. Three arrowroot germplasm accessions possessing slight and intense variegated leaves and petiole and another normal one (Fig. 14) with lengthy rhizomes were collected from Velloorkonam village/hamlet in Nedumangad block of Thiruvananthapuram district during May 2020. The study revealed that petiole length and colour are the key identifying feature of arrowroot germplasm.

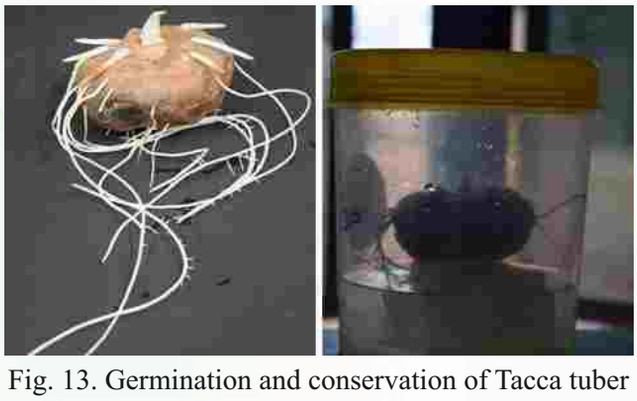


Fig. 13. Germination and conservation of Tacca tuber

Fig.14. Petiole colour of three arrowroot accessions

Germplasm at Regional Station

A total of 1,248 germplasm of tropical tuber crops comprising of cassava, sweet potato, taro, elephant foot yam, yam, yam bean and minor tuber crops are maintained at the Regional Station (Fig. 15). Eight germplasm of tuber crops comprising three taro, three yam and two EFY were collected from Kandhamal district of Odisha (Fig. 16). These lines were planted in the field for characterization as per DUS guidelines. Hundred sweet potato germplasm accessions were planted at research farm of Regional Station, ICAR-CTCRI, Bhubaneswar, Odisha for evaluation of yield and flesh colour of the tuber. Ten yam bean lines were selected in 2019 and these lines were planted for re-evaluation of the yield. Thirty yam bean lines were planted for evaluation of micronutrient and phytochemical analysis. Fifty taro accessions were planted separately for checking acridity level in the leaf and petiole.

Fig. 15. Tuber crops germplasm at Regional Station, ICAR-CTCRI, Bhubaneswar

Fig.16. New collection of tuber crops from Kandhamal, Odisha

The phenological observations of yam bean were carried out at the experimental plot of Regional Station, ICAR-CTCRI, Bhubaneswar, Odisha. Phenological stages in yam bean have been described for the first time according to an extended BBCH (Biologische Bundesanstalt, Bundessortenamnt and Chemische Industrie) scale separating the different growth stages, including germination (stage 0), leaf development (stage 1), formation of side shoots (stage 2), stem elongation (stage 3), tuber formation (stage 4), inflorescence emergence (stage 5), flowering (stage 6), development of pods (stage 7), ripening of pods (stage 8) and senescence (stage 9) (Fig. 17). This scale will be useful for the yield enhancement of this crop as it is an emerging underutilized tuber crop. Inheritance pattern of flower colour in yam bean was reported for the first time. The segregation of flower colour suggested monogenic dominant control of purple flower colour in yam bean.

Fig. 17. Phenological growth stages of yam bean according to the extended BBCH scale

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 yam were sub-cultured and maintained in the *in vitro* gene bank. *In vitro* cultures of released, pre-released and exotic lines comprising of 58 accessions of sweet potato, 62 accessions of yams (includes accessions received from ICAR-NBPGR) 15 accessions of cassava, 5 accessions of taro and 5 accessions of minor tuber crops are maintained. The *in vitro* cultures of new CMD resistant cassava varieties have been initiated. At the Regional Station, 500 cultures of released, pre-released and exotic lines including 10 varieties in cassava, 11 varieties in sweet potato, 5 varieties in taro, 4 varieties in yams, 2 varieties in elephant foot yam and four varieties in Chinese potato were maintained in the *in vitro* gene bank facility (Fig. 18).

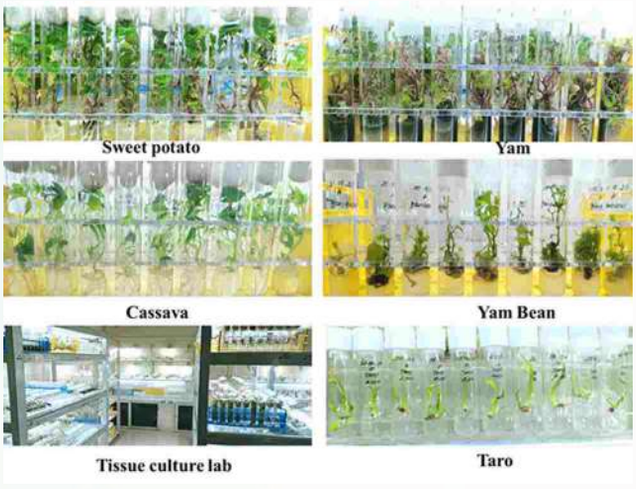


Fig. 18. *In vitro* conservation of tuber crops at Regional Station, Bhubaneswar

Fig. 19. The biofortified cassava line 17S-325

Gene bioprospecting for novel traits in tuber crops

The aqueous extracts of tubers of Bhu Krishna variety of sweet potato showed anti-angiogenic effect through CAM assay done in chick embryo. *UDP-glycosyltransferase* genes, a precursor in Saponin bio synthesis was confirmed in Bhu Krishna and S-1467 accession of sweet potato using the designed primers. Through *in silico* similarity search, AYE39534.1 *UDP-glycosyltransferase* gene was found in *Dioscorea alata.*

Genetic Improvement of Tuber Crops through Conventional Breeding and Molecular Approaches

Cassava

Breeding to evolve trait specific varieties in cassava for productivity, earliness, quality and resistance to biotic stresses

To develop biofortified cassava varieties with high carotene levels and micronutrient content, gene pool development programme was initiated through crossing yellow fleshed varieties from the existing genetic resources. A clone, 17S-325 with high yield (57.7 t ha^{-1}) and good culinary quality was developed through the crossing of yellow fleshed genotype with cassava mosaic resistant varieties (Fig. 19). It has higher carotene content (6.01 mg 100 g^{-1}) than all the released varieties of cassava in India. The tubers also have high starch (27.6%), sugar (0.59%), protein (3.9%), potassium (0.46%), calcium (1840 ppm), Fe (80.60 ppm) and Zn (23 ppm) contents. It could be promoted as a dual-purpose variety for direct consumption as well as for processing into biofortified value-added products.

Among the CMD resistant varieties evaluated for dry matter content, 15S-156 had the highest dry matter (47.5%), followed by D-143 (44.2%). In the replicated yield trial of CMD resistant varieties for culinary purpose, 15S-59 yielded the highest (95.05 t ha^{-1}), followed by 15S-184 (90.11 t ha^{-1}) and 15S-433 (85.18 t ha^{-1}). The CMD resistant varieties were significantly high yielding as compared to the check variety, M-4 (37.04 t ha^{-1}). Eight CMD resistant early bulking cassava varieties were evaluated under lowland conditions during 2020 along with the popular variety, Vellayani Hraswa as control. The tuber yield of the varieties at seven months after planting is presented in Fig. 20.

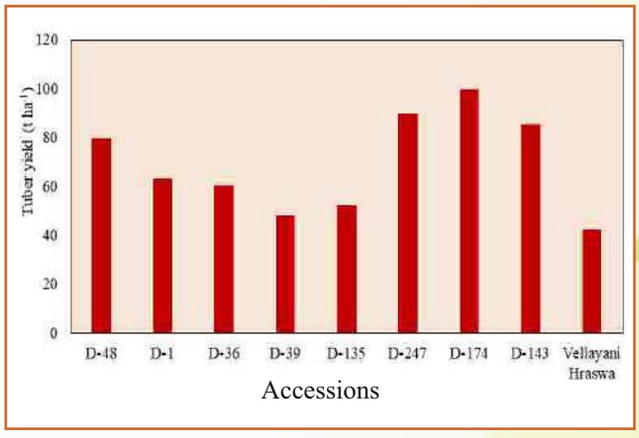


Fig. 20. Performance of CMD resistant cassava varieties under lowland conditions

The new varieties were found to be resistant to cassava mosaic disease and significantly superior to the CMD susceptible check variety, Vellayani Hraswa. The accession D-174 recorded the highest tuber yield

(99.7 t ha^{-1}) followed by D-247 (89.9 t ha^{-1}), D-143 (85.3 t ha^{-1}) and D-48 (79.6 t ha^{-1}) as compared to Vellayani Hraswa (42.3 t ha^{-1}). The accession, D-48 recorded the highest number of tubers/plant (8).

Selection of drought tolerant clones in cassava

Twenty-five cassava genotypes were grown in Randomized Block Design with three replications in rainy seasons 2017-18 and 2018-19; water deficit stress 2018-19 and 2019-20 to select the stable and superior genotypes that effectively tolerate water deficit stress. The number of rainy days were extremely low i.e., only 5 and 10 in mid period of water deficit stress 2018-19 and 2019-20 amounting for a very less rainfall of 66.4 and 188.0 mm, respectively when compared to the rainy seasons 2017-18 and 2018-19 which had 60 and 51 rainy days and 979.3 mm and 980.6 mm rainfall, respectively. AMMI ANOVA indicated significant G×E interaction for all the traits, Leaf Area Index (LAI), Yield per Plant (YPP), Harvest Index (HI), Dry Matter (DM) and Starch Yield per Plant (SYP). A high environment effect of 68.38% of the total sum of squares was observed for DM followed by SYP, LAI, YPP and HI. A significant residual variation in G×E for YPP, HI and DM demonstrated the presence of considerable noise in the model of these traits. Higher PCV and GCV values, moderate level of broad-sense heritability and high genetic advance as per cent of mean were observed for LAI, YPP and SYP indicating the possibility of high genetic gains for these traits through selection. CI-158 for LAI, CR43-11 for YPP, M-4 for HI, Sree Pavithra and 9S-127 for DM were identified as stable. Among all the environments, 8S-501 (Fig. 21) and CR43-7 were recorded higher YPP. The rainy season and water deficit stress were the two mega environments whose influence on traits was crucial. The accuracy of selection was very high for the trait HI followed by YPP and SYP. 8S-501 followed by CR43-7 for YPP; 8S-501 followed by CR43-7 for HI; 8S-501 followed by Sree Athulya for DM; CI-130 followed by 8S-501 for SYP had the highest predicted mean values. Based on Multi Trait Stability Index (Fig. 22), 8S-501 followed by Sree Athulya, CR 43-7 and 9S-127 were selected as drought tolerant clones considering their mean performance and stability.

Fig. 21. Drought tolerant cassava genotype 8S-501

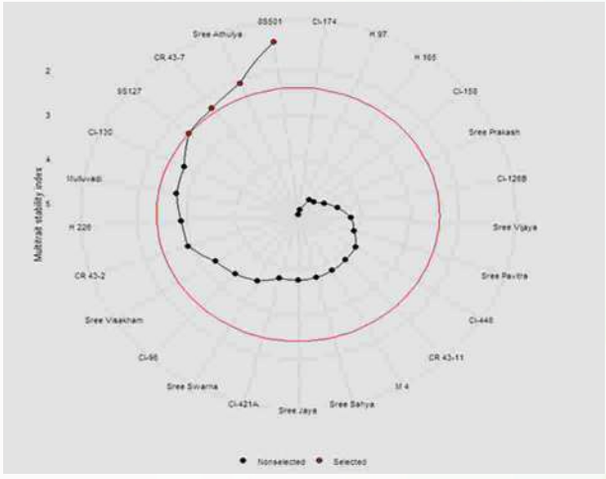


Fig. 22. Multi trait stability index showing stable and superior cassava genotypes

Sweet Potato

Development of high yielding nutritionally enriched photo-insensitive, processable and multipurpose sweet potato varieties

The selected orange fleshed hybrids from CIP project and the improved germplasm lines are maintained as clonal generations. Two hundred forty orange fleshed hybrids were laid out in augmented trial along with three controls, viz., Sree Kanaka, Sree Retna and Bhu Sona for evaluation of yield and tuber characters in upland conditions. Forty four hybrids did not tuberise in the upland condition. Among the remaining tuberising hybrids, the tuber yield per plant ranged from 25 to 750 g and dry matter from 18 to 35%. Hybrids 50/14 showed highest per plant yield of 750 g plant^{-1} followed by 43/25 (356 g), 45/108 (264 g), 100/2 (202 g), 120/16 (198 g). However, dry matter was highest for 43/25 (31.25%). A second trial with 300 hybrids are being evaluated in the lowland conditions in augmented design for preliminary evaluation of yield and tuber characters along with Sree Kanaka and Bhu

Sona as controls. S-1401 and S-1609, white fleshed improved lines/selection from previous trials are being multiplied for AICRP trials.

Breeding for development of high starch, anthocyanin and β-carotene rich varieties in sweet potato

Out of 33 hybrid lines, best thirteen sweet potato hybrid lines were selected during 2019 which include 4 white flesh (SPH-65, SPH-19, SPH-61 and SPH-60) 4 orange flesh (SPH-44, SPH-21, SPH-52 and SPH-40) and 5 purple flesh (SPH-31, SPH-30, SPH-29, SPH-15 and SPH-14). These hybrid lines were planted in October 2020 at the experimental plots of Regional Station, ICAR-CTCRI, Bhubaneswar, Odisha for evaluation of yield and other qualitative traits such as starch, β-carotene/anthocyanins, total phenols and flavonoids. Irrigation was given at an interval of 7-10 days. During 2019, all the hybrids showed very less weevil infestation (≤ 5%) and SPH-29 had no weevil infestation. Hence, SPH-29 was again replanted in October 2020 with other susceptible sweet potato lines for revalidation.

Breeding for drought tolerance in sweet potato

Selected 100 lines of sweet potato were planted in field for screening for drought tolerance at ICAR-CTCRI Regional Station during September 2020, dry spell was experienced from October. These selected lines were also inoculated on different concentration of polyethylene glycol (0, 5, 10 and 15 g l^{-1} of PEG) mediated MS medium for screening for drought tolerance in *in vitro* conditions. Five genotypes, viz., SB-5/61, Megh-2, BP-2, Dhenkanal Local-2 and RS-III-3 were identified as drought tolerance lines, which exhibited maximum shoot length, root length, number of leaves, number of roots and fresh plant weight at concentration of 15 g l^{-1} of PEG in MS medium. Data related to screening under field condition, yet to be analyzed for interpretation of results.

Developing sweet potato hybrid clones for processing

Forty five sweet potato genotypes including released varieties and germplasm accessions were evaluated for processing traits in 2018-19 and 2019-20. Significant variability was observed for important tuber physical traits such as tuber shape, size and flesh colour affecting sweet potato processing and genotypes such as CO3-4, S-1609, S-1652, S-1712, Bhu Krishna, S-1603 and S-27 were found to be highly suitable for processing based on evaluation of important processing traits such as dry matter content, total starch content, total sugar content, flour content and peel loss and sensory evaluation of fried chips.

Yams

In yams, the evaluation trials were planted during April 2020 at ICAR-CTCRI, Thiruvananthapuram as rainfed crop. In the advanced yield trial of greater yam hybrids, DaH-10-1-2 yielded the highest (55.95 t ha^{-1}) followed by DaH-66 (48.31 t ha^{-1}). A high yielding greater yam variety, TGy12-1 (Fig. 23), was recommended for state release in Kerala with the name 'Sree Hima'. It is a hybrid (Da-402) with high yield (57.87 t ha^{-1}), high dry matter (30.19%), starch (26.3%), crude protein (5.28%) and excellent culinary quality with high organoleptic score (7.97). Among the new bushy white yam genotypes evaluated, the hybrid, Drd-9495 produced the highest yield (36.41t ha^{-1}) followed by Drd-835 (30.25 t ha^{-1}) as compared to the check variety, Sree Dhanya (25.55 t ha^{-1}). In the on-farm trials, the non-trailing white yam, SD-15 produced significantly higher yield (41.72 t ha^{-1}).

Fig. 23. Sree Hima, a greater yam variety recommended for state level release in Kerala

Mapping anthracnose resistance gene(s) in greater yam using molecular markers

Improvement of greater yam through breeding is difficult because of its non-synchronous, dioecious, poor and irregular flowering. Therefore, it is necessary to adjust the planting time of the parents and convenient to store the pollen from male parent. Hence, assessment of pollen viability and its germination capability are essential before the hybridization programme. Pollen from the variety, Sree Karthika were collected from the freshly opened flowers and evaluated for their viability using acetocarmine staining test and *in vitro* pollen germination test. The pollen staining recorded was 81.43% (Fig. 24). Study was carried out with different culture media to optimize the pollen germination medium. Maximum pollen germination (41.67%) was recorded in modified brewbaker and kwack medium containing 15.0% sucrose (Fig. 25). Freshly collected male flowers were stored at different storage conditions (room temperature, 4°C, -20°C, -80°C). Total loss of pollen viability was observed after a day of storage in different conditions.

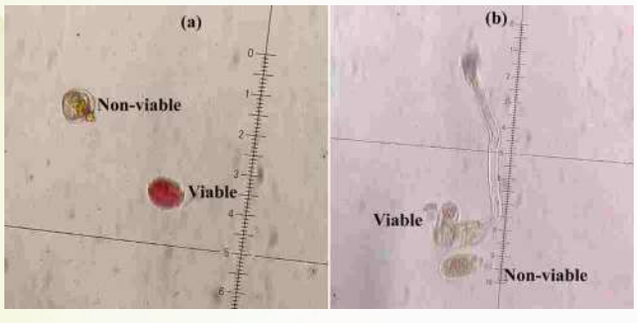


Fig. 24. Viability of yam pollen assessed by (a) Acetocarmine test and (b) *In vitro* germination test

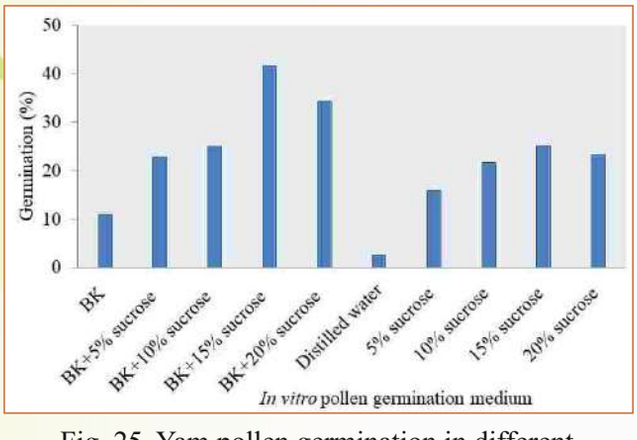


Fig. 25. Yam pollen germination in different germination medium under *in vitro* conditions

Edible Aroids

Taro

Around 80 accessions of taro (*Colocasia esculenta* L.) were screened for resistance to taro leaf blight (TLB) at ICAR-CTCRI field. Twelve accessions viz., C-568, C-621, TCR-696, TCR-961, IC-089813, IC-410320, IC-420620, IC-545308, Line 42, Line 44A, UL-89 and HDG/PAK/2016-200 exhibited field tolerance. Under the evaluation trial, 12 entries were planted during June 2020 at ICAR-CTCRI farm along with the check variety, Sree Rashmi and the crop is yet to be harvested.

Under the genetic improvement programme of high yielding, disease tolerant, nutritionally rich taro lines, the taro lines selected previously for their screening for nutritional values were replanted with clones of seven F_1 crosses comprising, 18 × TCR-369, Nycle × 224, 12 × TCR-369, 12 × TCR-429, 12 × IC-022067, TCR-369 × TCR-429 and TCR-813 × IC-419746 during July 2019 at ICAR-CTCRI Regional Station research field and harvested during January 2020. Corms were harvested, cleaned and chopped for drying and prepared fine dry powder for evaluation of nutritional attributes such as antioxidant activity (DPPH and CUPRAC), total phenolics, sugar, starch, crude protein, and mineral contents. Previously screened lines (50) of taro were again evaluated for their nutritional values and based on two years data, nutritional rich lines were identified such as, TCR-369 for antioxidant, TCR-868 for sugar, Andaman-1 for starch, Nycle for manganese, Tripura local-2 for phenolic, crude protein & potassium and NBPGR-37 for phosphorous, iron, copper and zinc content.

Taro clones of F_1 crosses were also evaluated for their nutritional values. Free radical scavenging ability against DPPH assay ranged from 41.34 to 72.67% dry mass, CUPRAC assay from 17.96 to 31.25 µ moltrolox g^{-1} dry mass and total phenolics content from 3.05 to 7.18 mg gallic acid/g dry mass. The sugar and starch contents were 1.78-2.60% and 18.15-60.73%, respectively. The crude protein content ranged from 4.08 to 18.85 g 100 g^{-1} dry mass and P, K, Fe, Cu, Zn and Mn contents were in the range of 217.0-460.4 mg, 842.9-1232.2 mg, 6.2-17.2 mg, 0.86-1.56 mg, 7.9-15.2 and 4.3-6.9 mg 100 g^{-1} dry mass, respectively.

Taro clones of all the crosses were planted in field during July 2020 at ICAR-CTCRI Regional Station and

leaf were collected in the month of September for nutritional analysis. The radical scavenging activity determined by DPPH assay and CUPRAC assay ranged from 57.85 to 96.98% and 55.76 to 97.67 µ moltrolox g^{-1} dry mass, respectively. Total phenolics content ranged from 26.95 to 66.07 mg gallic acid/g dry mass and sugar content was in the range of 1.24-2.16% in dry leaf. Crude protein content ranged from 8.03 to 23.69 g 100 g^{-1} and P content from 114.43 to 323.96 mg 100 g^{-1} dry mass in leaf. Potassium, iron and copper contents were 896.13-1272.20 mg, 7.66-20.59 mg and 0.66-1.89 mg 100 g^{-1} dry mass. Tubers of all the clones are yet to be harvested.

Early line Telia and leaf blight tolerant variety Muktakeshi were planted in crossing block for hybridization to transfer leaf blight tolerance gene in leaf blight susceptible line Telia and hybridization were done and F1 seeds were collected for further evaluation (Fig. 26).

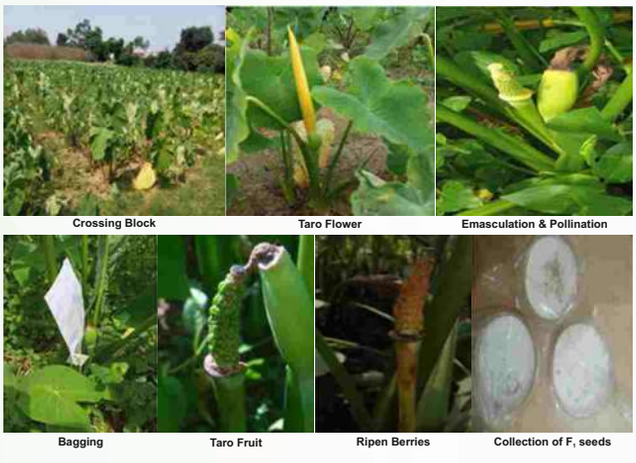


Fig. 26. Crossing between Telia & Muktakeshi and collection of F_1 seeds

Elephant foot yam

Two accessions, Am-41 and Am-141 were crossed with pollen from the hybrid Sree Padma × Gajendra. Twenty five elephant foot yam accessions were subjected to artificial screening by Division of Crop Protection for the identification of collar rot resistant lines. Under a new trial for developing high yielding lines, 14 accessions were evaluated at ICAR-CTCRI farm, Thiruvananthapuram with Sree Padma as the check. The accession, Am-141 (20.93 t ha^{-1}) was found superior to Sree Padma (9.87 t ha^{-1}) and eleven accessions were on par with Sree Padma.

Tannia

Under the evaluation trial of tannia, the selected lines could not be taken to the farmer's field for multi-location trial due to the unexpected lockdown. Hence, these were multiplied at the Institute farm at ICAR-CTCRI, Thiruvananthapuram for one more year. The crop is yet to be harvested.

Arrowroot

In arrowroot, third year advanced yield trial of seven arrowroot genotypes planted in RBD showed that the tuber yield ranged from 23.48 t ha^{-1} in M-3 to the highest value of 33.10 t ha^{-1} in the genotype M-7 (Fig. 27). Highest single plant tuber weight was recorded in M-1 (1.26 kg) and the lowest in M-6 (0.31 kg). The number of tubers per plant ranged from 17 in M-5 to 22.67 in M-1. Plant height was highest in the genotype M-1 (143.33 cm) and lowest in M-7 (96.67 cm). Number of tillers per plant was highest in M-1 and M-6 (13) and lowest of 9 in M-7.

Fig. 27. (a) Field view of arrowroot genotypes and (b) Harvested tubers

Biochemical evaluation of the tubers of the 7 genotypes of arrowroot was done for moisture, total starch, sugar, crude fibre and ash on fresh weight basis and the data were analyzed. The total starch content ranged from 15.65% in the accession M-5 to 20.23% in M-1 (Fig. 28) and total sugar from 0.11% in M-3 and M-7 to 0.13% in M-2. The total crude fibre content was lowest for the accession M-1 (0.52%) and highest for M-6 (1.27%).

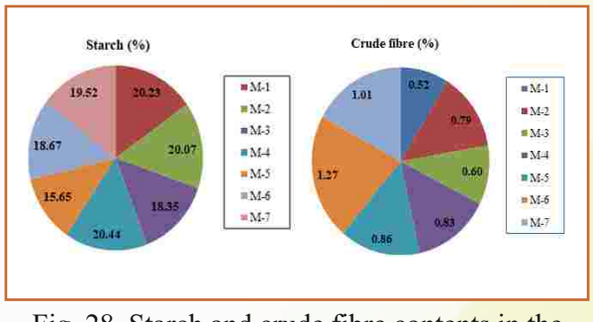


Fig. 28. Starch and crude fibre contents in the tubers of arrowroot genotypes

Yam bean

In yam bean, seeds of F_5 generation of five best F_{1s} (3×5, 3 ×8, 3×9, 3×10 and 9×10) were generated during 2019. These hybrid lines were sown in October 2020 along with the check variety, RM-1 for on farm

trial (OFT) at RS ICAR-CTCRI for evaluation of yield and other biochemical traits such as ascorbic acid, total phenol and total flavonoids. Another set of five F_5 generation seeds were raised at the experimental plots for the production of seeds for multilocation trials. Irrigation was given at an interval of 7-10 days. After one month of planting first earthing up and intercultural operations were done. Flower removal was done after 45 days and 60 days of sowing. Proximate analysis of 2019 harvested tuber samples was done during 2020. The starch content in yam bean tubers ranged from 7.56 to 14.78% and sugar content ranged from 3.78 to 7.24% based on dry mass.

Developing breeder seed standards and precocity of genetic vigour for tropical tuber crops

In Yam bean, a field trial conducted using 10 accessions resulted in identification of unique white colour inflorescences and rest of the accessions showed velvet colour flowers. One yam bean variety from Rajendra Prasad Agricultural University, Rajendra Misrik-1(RM-1) released by AICRP TC Dholi and the breeder seed obtained from ICAR-CTCRI RS were studied for seed germination and other seed quality parameters. When germination test was conducted using pure seeds of RM-1 with 12% moisture content, an average germination of 81% with normal seedlings was observed and the rest of the seeds gave raise to abnormal seedlings, un-germinated seeds and hard seeds. Another important observation in breeder/basic seeds were the presence of four different lots of seeds viz., light brown, dark brown, black and green colour seeds (Fig. 29). Germination test was conducted using normal light brown seeds which constituted 80% of the total seeds.

Fig. 29. Yam bean seed colour and germination

In sweet potato, two types of vine cuttings viz., apical cuttings and middle stem with 30 cm length were subjected to sprouting study. In all the cuttings, 100% sprouting was recorded with 100% survival in the field also. The apical cuttings showed faster sprouting than middle or central vines. Apical cuttings with three nodes showed vigorous seedling growth when compared to middle stem vines. This preliminary study was initiated for developing breeder seed standards for sweet potato apart from other tuber crops.

Marker assisted breeding

Map based cloning of CMD resistant gene(s) using cassava genome sequence and CMD associated markers

To develop CMD mapping population using resistant/susceptible parents, four susceptible varieties (Sree Jaya, Sree Vijaya, M-4, Sree Swarna) and five resistant lines (MNga-1, PDP CMR-1, 9S-127, CR43-7 and Aromal) were planted during June 2020 at the pollination block of ICAR-CTCRI, Thiruvananthapuram. Among all the parents, Sree Jaya, Sree Vijaya and 9S-127 had profuse flowering and fruit set. The parents, Sree Jaya, Sree Vijaya were used as female parents and 9S-127 was used as the male parent for mapping population development. More than 500 female flowers of each parent were pollinated with 9S-127 from November-December 2020. Around 35-40% fruit set was observed and around 250-300 seeds are expected from each cross. These seeds will be used for developing F_1 seedling mapping population. The CMD resistant variety, Sree Padmanabha (MNga-1) was used as the parent to develop selfed (S_1) progenies by self-pollination, to isolate homozygous resistant line for future breeding and study the gene action. The four parents (Sree Jaya, Sree Vijaya, 9S-127 and Sree Padmanabha) will be used for transcriptome profiling using leaf mRNA for identification of CMD resistant genes, differential gene expression analysis, functional annotation, SSR and SNP mining.

Identification of marker associated with high starch content in cassava

The parent 9S-127 and Sree Padmanabha (MNga-1) along with 145 F_1C_2 clonal progenies in the field were used for evaluating starch content and gene mapping study. Fifty SSR markers along with two starch gene specific candidate markers viz., AGPase and GBSS were used for parental screening. Most of the SSR primers showed polymorphism in the parents. The AGPase and GBSS gene specific candidate markers showed similar bands between parents but need to be sequenced for the identification of sequence variation among the parents. This information can be used for

SCAR or CAPS marker identification. The polymorphic SSR markers were screened with 145 clonal progenies. The starch content estimated for both parents and progenies showed wide variation in the clonal progenies. This clonal population planted during July 2019 was not established well in the field due to climatic condition. The two parents, 9S-127 and Sree Padmanabha will be used for transcriptome profiling using tuber mRNA for identification and isolation of starch specific genes, differential gene expression analysis between two parents, functional annotation, SSR and SNP marker identification.

Genetic analysis and QTL mapping for determining genetic basis of postharvest physiological deterioration tolerance and enhanced shelf life in cassava

The cassava parents contrasting for PPD tolerance, F_1 clonal progenies of crosses were made during 2018-19 and the F_1 seedlings of hybrid seeds collected from 2019-20 crosses were planted for evaluation of PPD and other traits (Fig. 30).The hybrid seeds were raised in pots after germination. The germination percentage and Seed Vigour Index (SVI-1) of the F_1 seedlings were 68.8% and 1658.52, respectively. The mean seedling length, seedling girth and seedling vigour (0 to 5 scale) were16.52 cm, 1.02 cm and 3.24, respectively. The F_1 clonal progenies of crosses made during 2018-19 were planted in the field for evaluation of PPD and other traits. The morphological data such as colour of apical leaves, pubescence of apical leaves (3 MAP), leaf retention, shape of central leaflet, petiole colour, leaf colour, number of lobes, lobe margins, orientation of petiole, colour of leaf vein and flowering (6 MAP) were recorded. Significant variation was observed for all the recorded traits among the clonal progenies. Parental polymorphism study was conducted with 35 new SSR markers and is being continued. Only two markers were found to be polymorphic between the parents. Hybridization between parents contrasting for PPD tolerance is being done to increase the mapping population size.

Fig. 30. (a) Field view of the F_1 clonal progenies (b) F_1 seedlings in glasshouse and (c) F_1 seedlings in main field

Genetic modifications for quality improvement in cassava

For developing transgenic cassava plants with increased starch content, *in vitro* cultures of cassava 9S-127, CR-501-2, H-226 and CR43-2 were multiplied and maintained. Friable Embryogenic Callus (FEC) induced in cassava genotypes namely, Sree Apoorva, Sree Padmanabha, Sree Sakthi, CR43-2 along with H-226 and 9S-127. FEC was developed in cassava 9S-127 and H-226 variety of cassava. The embryogenic calli as well as nodes of 9S-127 and H-226 were co-cultivated with *Agrobacterium* having *glgC* gene. Green cotyledonary structures were developed from FEC of cassava H-226 variety, which was maintained in selection media after transformation with *glgC* gene. Nine sets of primers designed for *gbss* gene in cassava for amplifying the *gbss* gene from cassava accessions.

Characterization of floral and tuberization related *MADS-Box* homeotic genes in cassava

Genome-wide HMM based-analysis led to the identification of 82 family genes in cassava. The *MeMADS* family genes were distributed in all the chromosomes except on chromosome no.4. Promoter analysis of 82 *MeMADS* family genes of cassava revealed the presence of tissue-specific, biotic, abiotic, light-responsive, circadian and cell cycle-responsive *cis*-regulatory elements. Phylogenetic/Evolutionary analysis of cassava *MeMADS* family genes with *MADS* family of Malpighiales genomes grouped the members into 23 sub-groups (Fig. 31). The data obtained from

this study contributes to a better understanding of the complexity of *MeMADS* family members in cassava and provide the basis for further studies to dissect the function of these genes during plant growth and development as well as in response to environmental stimuli.

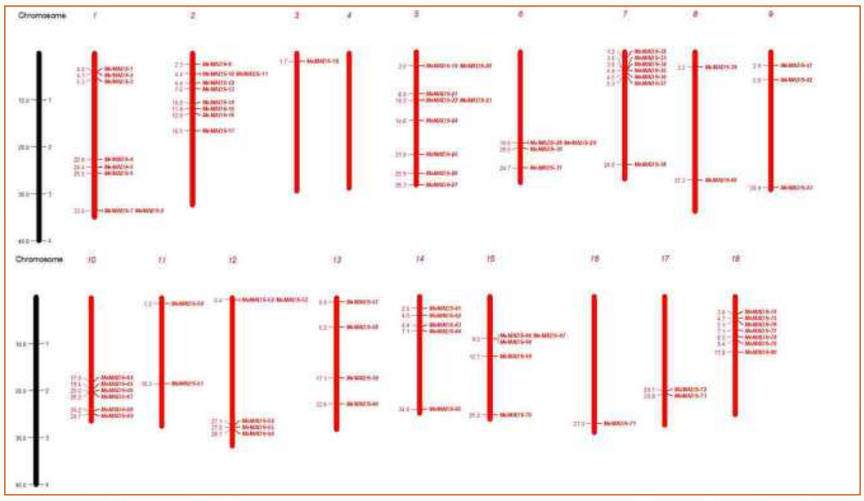


Fig. 31. Chromosomal distribution pattern of *MeMADS-box* family genes in cassava

CROP PRODUCTION

Integrated Crop, Water and Nutrient Management for Improving Productivity of Tropical Tuber Crops

Production of disease free planting materials in tropical tuber crops

Under this five year programme (2015-2020), which was concluded in March 2020, a total of 3,64,000 stems of cassava (varieties: Sree Vijaya, Sree Jaya, Sree Swarna, Sree Pavithra, Sree Athulya and Sree Reksha), 20,67,000 vine cuttings of sweet potato (varieties: Bhu Sona, Bhu Krishna, Sree Kanaka and Sree Arun) were produced. In elephant foot yam, a total of 94 tons of quality planting materials of varieties Gajendra and Sree Padma and in yams, 81 tons of planting materials of Sree Keerthi, Sree Karthika, Sree Shilpa, Sree Roopa, Orissa Elite and Sree Nidhi were produced. About 12 tons of taro varieties, Muktakeshi and Telia; 29,000 vine cutting of Chinese potato variety, Sree Dhara and 1,100 kg of yam bean seeds were also produced and distributed to farmers.

In addition, 870 micro plants of five cassava varieties were indexed against cassava mosaic virus through micro propagation technique in the tissue culture laboratory during the period 2015-2020. A total of 400 numbers of micro plants of H-226, 500 numbers of H-165, 450 numbers of Sree Prakash, 950 numbers of Sree Vijaya and 850 numbers of Sree Jaya were produced and further multiplied in the net house. In elephant foot yam, a total of 540 numbers of micro plants of var. Gajendra were indexed.

Induction of early and uniform sprouting in elephant foot yam

Elephant foot yam corms subjected to fumigation treatment of carbon disulphide @ 80 ml per 100 kg corm resulted in maximum uniform sprouting of 84.92 and 99.96% at 15 and 40 days after planting (DAP) respectively, followed by GA_3 (200 ppm) treatment (82.24% and 97.58% at 15 and 40 DAP, respectively). Fumigation of carbon disulphide solution @ 80 ml 100 kg^{-1} of corm produced significantly higher corm yield of 36.84 t ha^{-1}. Based on the results (2017-2020), it is concluded that corms treated with carbon disulphide @ 80 ml 100 kg^{-1} is most suitable to produce higher uniform sprouting and higher corm yield.

Cropping systems involving tuber crops and legumes

The concluded results of the four experiments taken up during the period 2015-2020 are reported below:

Experiment 1: Intercropping system involving short-duration cassava and pulses in rice based cropping system

Pooled analysis of two years data indicated that rice var. Kanchana followed by short-duration cassava var. Sree Vijaya + black gram at the reduced fertility level was productive (tuber equivalent yield of 40.19 t ha^{-1} and production efficiency of 111.64 kg ha^{-1} day^{-1}), energy efficient (191.11 × 10^3 M J ha^{-1}) and profitable (added profit of ₹61,736 ha^{-1} over sole cassava), besides nutrient saving to the extent of half FYM & N and full P to cassava (Table 1). Thus, a nutrient recommendation of FYM @ 6.25 t ha^{-1} and NPK @ 50:0:100 kg ha^{-1} was sufficient for cassava in the system.

Experiment 2: Intercropping system involving elephant foot yam and pulse crops

Combined over two years, elephant foot yam var. Gajendra + soybean under full fertility level to elephant foot yam (FYM @ 25 t ha^{-1}; NPK @ 100:0:150 kg ha^{-1}) resulted in higher yield (66.40 t ha^{-1}), equivalent energy (239.91×10^3 M J ha^{-1}), production efficiency (247.30 kg ha^{-1} day^{-1}), tuber equivalent yield (66.77

t ha^{-1}), net income (₹10,09, 856 ha^{-1}), B:C ratio (3.20) and added profit of ₹2,33,164 ha^{-1} over sole cropping of elephant foot yam var. Gajendra (46.48 t ha^{-1}, 167.33 × 10^{3} M J ha^{-1}, 172.45 kg ha^{-1} day^{-1}).

Experiment 3: Intercropping system involving taro and pulse crops

Taro var. 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}), equivalent energy (45.66 and 44.69 × 10^{3} M J ha^{-1} respectively), net income (₹2,90,508 and ₹2,78,362 ha^{-1}), B:C ratio (2.72 and 2.59) and added profit (₹2,24,152 and ₹2,12,006 ha^{-1}) over sole taro. Nutrient saving in taro to the extent of half FYM & N and full P was possible. Thus, a nutrient recommendation of FYM @ 6.25 t ha^{-1} and NPK @ 40:0:100 kg ha^{-1} was sufficient for taro in the system.

Experiment 4: Intercropping system involving dwarf white yam and pulse crops

Averaging over two years, dwarf white yam intercropped with green gram at the reduced fertility level was productive and profitable (net returns of ₹8,09,095 ha^{-1}; B:C ratio of 3.52) and better than sole dwarf white yam (added profit of ₹1,83,842 ha^{-1} over sole crop). This was closely followed by dwarf white yam intercropped with soybean under half fertility level. Nutrient saving to dwarf white yam to the extent of half FYM & N and full P was possible. Thus, a nutrient recommendation of FYM @ 5.0 t ha^{-1} and NPK @ 50:0:100 kg ha^{-1} was sufficient for dwarf white yam in the system. The pH, organic C, electrical conductivity, available P, K and S status of the soil were unaffected. Available N status of the soil was

Table 1. Summary of yield variations and added profit in the cropping systems involving tuber crops and legumes

Cropping system involving tuber crops	Yield increase/decrease in the associated tuber crop (%)	Added profit (₹ ha^{-1})
Rice-short-duration cassava + black gram	-26	61,736
Rice-short-duration cassava + cluster bean	+7	Study under progress
Elephant foot yam + soybean	-8.57	2,33,164
Dwarf white yam + green gram/ soybean	+1	1,83,842
Taro + green gram/black gram	+5.68	2,12,006 to 2,24,152

Experiment 5: Intercropping system involving short-duration cassava and legumes in rice based system

Rice-short-duration cassava + cluster bean was productive in the first year. This is being confirmed in the new project mode.

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 FBMP by SSNM treatment proved to be more profitable and environmentally sustainable than present recommendation, PR (Cassava : SSNM - 29.45 t ha^{-1} and PR - 28.34 t ha^{-1}, 3.92% increase; Elephant foot yam : SSNM - 28.52 t ha^{-1} and PR - 25.05 t ha^{-1}, 13.85% increase; Greater yam : SSNM - 12.22 t ha^{-1} and PR - 11.35 t ha^{-1}, 7.67% increase; White yam : SSNM - 20.15 t ha^{-1} and PR - 18.21 t ha^{-1}, 10.65% increase; Taro : 12.11 t ha^{-1} and PR - 10.27 t ha^{-1}, 17.92% increase). The B:C ratio was also higher under SSNM in comparison to PR (Fig. 32).

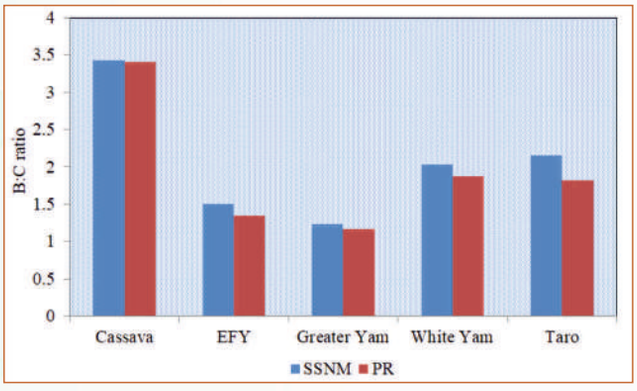


Fig. 32. B: C ratio of five SSNM on-station experiments

Sixteen on-farm experiments were conducted during 2020 to demonstrate and validate the SSNM based customized fertilizers developed for elephant foot yam (11 trials in East Godavari and West Godavari districts, Andhra Pradesh and 5 trials in Manjali, Karumalloor, Ernakulam, Kerala). Fourteen frontline demonstrations were also conducted to demonstrate the performance of SSNM based customized fertilizers developed for cassava (9 trials under KVK, Pathanamthitta and 5 trials under KVK, Kozhikode). Results of OFTs conducted in Kerala showed an average yield increase of 5.85 t ha^{-1} in SSNM treatment compared to farmer fertilizer practice (18.10% yield increase) (Fig. 33).

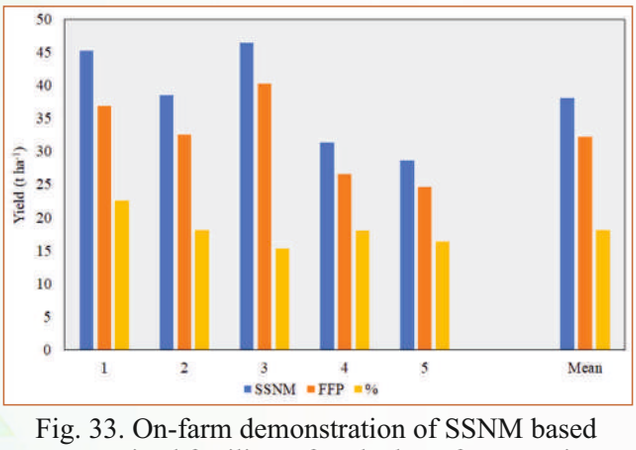


Fig. 33. On-farm demonstration of SSNM based customized fertilizers for elephant foot yam in Manjali, Ernakulam, Kerala

The overall achievements of the activity for the past 5 years (2020-2025) are summarized here. Site specific nutrient management (SSNM) recommendations using calibrated QUEFTS model were developed for cassava, sweet potato, elephant foot yam, yams and taro. Nutrient management zones were delineated based on agro-ecological zones/units and separate recommendations were developed for each zone/unit and validated. Accordingly, customized nutrient formulations were also developed and tested in major growing zones/units. On average, the SSNM recommendations resulted in 22% yield increase in cassava (+ 5 t ha^{-1}), 27.5% in elephant foot yam (+ 8 t ha^{-1}), 15% in sweet potato (+ 3 t ha^{-1}), 18% in yams (+ 4 t ha^{-1}) and 13% in taro (+ 1 t ha^{-1}). Five different foliar liquid micro nutrient formulations were developed for cassava (2 products), elephant foot yam, sweet potato and yams and these five products were commercialized through Agrinnovate, ICAR to M/s Linga Chemicals, Madurai for ₹2.95 lakhs and are available in the market. On an average, 5-9% yield increase could be obtained by application of these micronutrients. Six nutrient decision support tools were developed during the period. Nutrient decision support system for SSNM of cassava (CASSNUM) is an online tool developed and hosted at ICAR-CTCRI website (http://ctcri.org). FERTCALC_CTCRI is another tool developed for SSNM of individual farms of ICAR-CTCRI and is available at http://ctcri.org. Other two online decision support systems, NRRPUP (Nutrient Recommendation for Potato Production in Uttar Pradesh) and NRRPP (Nutrient Recommendation for Potato Production in Punjab) are available at https://cpri.icar.gov.in. A stand-alone decision support tool, a newer version CASSNUM version 1.1 was released as CD. A mobile app, *Sree Poshini*, for site specific nutrient management of tropical tuber crops was also developed and made available at Google Playstore.

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

Results obtained from the field experiment conducted during April 2019 at the Regional Station of ICAR-CTCRI, Bhubaneswar to study the effect of fertigation interval and number of splits in greater yam+maize intercropping system. The results have shown that the treatment I_2 (3 days interval) and I_3 (4 days interval) were on par with each other and resulted in significantly higher greater yam yield compared to other treatments (36.1 and 35.3 t ha^{-1}, respectively). The greater yam tuber yield and tuber equivalent yield (TEY) were increased with increasing fertigation interval. Increasing number of splits of the recommended dose of fertilizer decreased maize yield, whereas it increased greater yam and tuber equivalent yield. The former case may be due to insufficient quantity of fertilizers received by the maize during crop growth period and the latter case may be due to

availability of fertilizer for longer period for the long duration greater yam crop. The treatment I_1S_1 (40 splits in 2 days interval) resulted in higher maize yield (3.3 t ha^{-1}) as compared to other treatments. It indicated that maize utilized maximum of the applied N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1}. However, fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} in 60 splits at 3 days interval (I_2S_3) resulted in higher greater yam yield (38.2 t ha^{-1}) and tuber equivalent yield (40.7 t ha^{-1}). Fertigation beyond 180 days after planting resulted in decrease of greater yam yield (Fig. 34). The treatment I_2S_3 resulted in 30.8% higher greater yam yield (38.2 t ha^{-1}) and tuber equivalent yield (40.7 t ha^{-1}), respectively over check (NPK soil application). The lowest maize, greater yam and tuber equivalent yield were observed in control (no fertilizers). The nutrient use efficiency in the treatment I_2S_3 was higher compared to other treatments (110 kg kg^{-1}) and it was 28.4% more than check (NPK soil application).

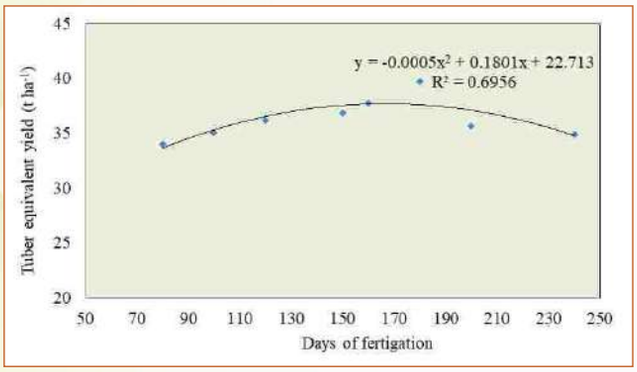


Fig. 34. Relationship of fertigation duration and yam tuber yield

The economic analysis of the intercropping system revealed that fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} in 60 splits at 3 days interval (I_2S_3) resulted in higher gross (₹6,10,000) and net returns (₹3,97,200) as well as B: C ratio (2.87). Significantly lowest gross and net returns as well as B: C ratio was noticed in control (no fertilizer) with the values of ₹2,45,500 ha^{-1}, ₹1,09,900 ha^{-1} and 1.81, respectively.

Drip irrigation and fertigation management in greater yam

A field experiment was conducted at RS ICAR-CTCRI, Bhubaneswar during 2020 to study the effect of levels of drip irrigation and fertigation on greater yam. The experiment was laid out in split plot design with different levels of drip irrigation in main plots and fertigation levels in sub plots. In fertigation treatments, water soluble fertilizer N-P_2O_5-K_2O through fertigation as per treatment at basal (40%), 30 (30%) and 60 (30%) days after planting (DAP) were applied. In control/check 1, P_2O_5 was applied with the last plough. The N and K were applied in 3 splits at basal (40%), 30 DAP (30%) and 60 DAP (30%). Farm yard manure @ 10 t ha^{-1} was incorporated with the last plough in all the treatments except control/check. The greater yam weighing 200 g cut tubers were planted on ridges formed at 90 cm spacing on 01 June 2020. The growth observations recorded at 3 and 5 months after planting (MAP) indicated that vine (plant) length and number of leaves per plant were higher in irrigation at 100% CPE and fertigation of N-P_2O_5-K_2O @ 100-60-100 kg ha^{-1}. The treatment control resulted in lower vine (plant) length and number of leaves per plant. The crop is yet to be harvested.

Long term fertilizer cum manurial experiment in cassava

The third phase of the experiment initiated in 2005 was completed by April 2020 by the harvest of the 15th season crop. The experiment had 20 treatments replicated thrice in RBD and the cassava variety used was H-1687 (Sree Visakham). The effect of treatments was studied on sustainable yield index (SYI), tuber yield, plant dry matter production, tuber quality parameters (cyanogenic glucosides and starch), post harvest soil nutrient (pH, EC, organic carbon, available N, P, K, Ca, Mg, S, Fe, Cu, Mn, Zn, B) status and total plant nutrient uptake. Among the different levels, NPK @125:50:125 kg ha^{-1} resulted in the highest SYI of 0.676 and the lowest under absolute control (0.359) (Fig. 35). The SYI with respect to different organic manures were almost same ranging from 0.626 to 0.636 except combination of organic manures alone without chemical fertilizers, which caused a SYI of 0.432. SYI under secondary and micronutrients did not show significant difference over PoP. Two nutrient combination involving Mg and B and three nutrient combination involving Mg, Zn and B resulted in low SYI of 0.584 and 0.562, respectively compared to 0.636 in the case of PoP.

Soil test based application of fertilizers (STBF) as FYM @ 5 t ha^{-1} along with N:P:K @71:0:71 kg ha^{-1} resulted in the highest tuber yield of 34.25 t ha^{-1} on par with all treatments except N:P:K @ 50:25:50 kg ha^{-1} (21.62 t ha^{-1}) and absolute control (14.73 t ha^{-1}) (Fig. 36). Among the different organic manures, coir pith compost gave the highest tuber yield (36.68 t ha^{-1}),

which was on par with all other organic manure sources. Application of organic manures alone through combined use of vermicompost, coirpith compost, ash and crop residue without chemical fertilizers recorded significantly lower tuber yield (21.11 t ha^{-1}). Application of Mg along with B resulted in significantly higher tuber yield of 34.90 kg ha^{-1} on par with application of Zn and Mg independently, Zn and Mg together and Zn and B together. Over PoP, there was no significant yield increase with application of secondary nutrient Mg and micronutrients Zn and B alone or together. Application of B alone or conjoint application of Mg, Zn and B resulted in a significantly low yield to the tune of 23.68 and 25.03 t ha^{-1} respectively.

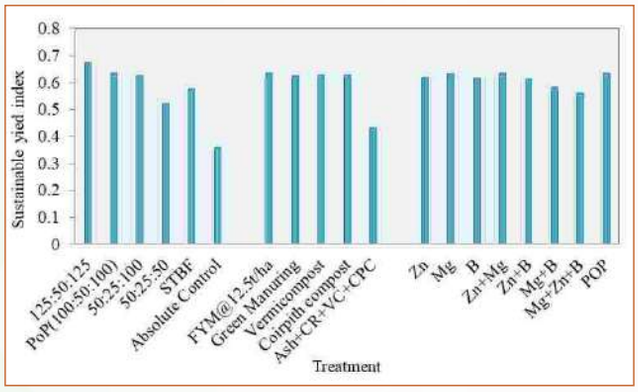


Fig. 35. Sustainable yield index under different treatments in cassava

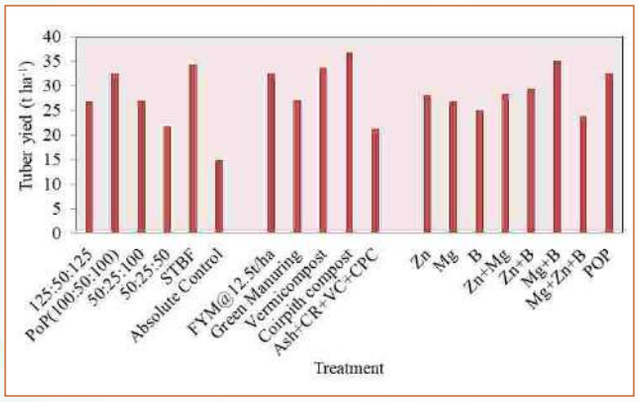


Fig. 36. Tuber yield under different treatments in cassava

No significant effect of treatments was noticed in the leaf, stem, tuber and total plant dry matter production. Among the different levels of fertilizers, leaf dry matter production was maximum with NPK @125:50:125 kg ha^{-1}, while stem, tuber and total plant dry matter production was maximum under STBF. In the case of organic manures, coir pith compost resulted in the maximum leaf, tuber and total plant dry matter production.

The highest (150.8 ppm) and lowest (38.8 ppm) cyanogenic glucoside contents among the different fertilizer treatments, were shown by STBF and the absolute control respectively, and the HCN content of the latter being on par with NPK @50:25:50 kg ha^{-1} (58.8 ppm). Organic manures resulted in significantly the least HCN content. Application of Mg alone resulted in the highest tuber cyanogen content of 112.3 ppm on par with application of Zn along with B (108.6 ppm). The available N was highest in STBF (244.6 kg ha^{-1}), which was on par with all the treatments except absolute control (165.5 kg ha^{-1}), while NPK @ 125:50:125 kg ha^{-1} recorded the highest available P (441.6 kg ha^{-1}). The highest soil status of available K (419.3 kg ha^{-1}) was observed with NPK @ 125:50:125 kg. Different organic manures significantly raised the soil pH to 7.05. Application of FYM @ 12.5 t ha^{-1} resulted in maximum soil organic carbon (2.01%). Soil exchangeable Ca and Mg were significantly higher under conjoint application of organic manures without chemical fertilizers to the tune of 3.63 and 0.33 meq 100 g^{-1}.

The long term fertilizer cum manurial experiment for 15 years brought out the most significant scientific information as follows. Cassava is a sustainable crop for long term cultivation in the same field as the sustainable yield index over these 15 years ranged from 0.47 (tuber yield: 14.27 t ha^{-1}) under absolute control to 0.89 (tuber yield: 27.23 t ha^{-1}) under NPK @ 125:50:125 kg ha^{-1}. Soil test based application of FYM and NPK @ 6.0 t ha^{-1}, 80: 0:71 kg ha^{-1} based on the mean soil organic carbon content of 1.26% and soil available P, K @ 123.2 and 211.1 kg ha^{-1} resulted in a tuber yield of 23.46 t ha^{-1} on par with PoP (25.57 t ha^{-1}). The different sources of organic manures tried to substitute FYM @ 12.5 t ha^{-1} (25.66 t ha^{-1}) viz., green manuring *in situ* with cowpea (25.63 t ha^{-1}), vermicompost (25.15 t ha^{-1}) and coir pith compost (24.68 t ha^{-1}) was found as alternate sources. There was no significant advantage of applying secondary nutrient Mg and micronutrients Zn and B based on soil test independently and together as two nutrient and three nutrient combination over PoP unless the level of the particular nutrient is below their soil critical limit.

The soil analysis has shown that bulk density (1.24±0.04 Mg m^{-3}), porosity (48.40±3.80%) and maximum water holding capacity (46.70±4.40%) were higher under the treatment consisting of combination of organic materials viz., vermicompost, coir pith compost, ash and crop residue compared to the rest of the treatments.

Screening nutrient efficient genotypes in cassava for low input management

The four NPK use efficient genotypes identified viz., CI-905, CI-906, 7 III E3-5 and Sree Pavithra which require only 25% of the recommended dose of PoP were multiplied in the same plot with 25% of PoP for the third season (May 2019) to see the sustainability of these genotypes at low levels of NPK @ 25:6.25:25 kg ha^{-1}. The yield recorded this year during harvest in the month of April was 31.12, 20.12, 28.52 and 28.41 t ha^{-1} respectively for CI-905, CI-906, 7 III E3-5 and Sree Pavithra. These genotypes were found to have high nutrient use efficiency in terms of the NUE parameters viz., agronomic efficiency, physiological efficiency, apparent recovery efficiency, utilization efficiency, harvest index, uptake ratio, NPK utilization ratio and physiological parameters like crop growth rate, relative growth rate and tuber bulking rate. These genotypes have good cooking quality, low cyanogenic glucosides and medium to high starch content.

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

Sweet Potato

Application of lime/gypsum/dolomite @ 8 t ha^{-1} depending upon its availability is a must to increase the soil pH and tuberization. Independent soil application of $MgSO_4$ @ 80 kg ha^{-1}, $ZnSO_4$ @ 20 kg ha^{-1} and borax @ 10 kg ha^{-1} at an interval of 5-10 days between applications can be resorted to depending upon the soil status. In the case of foliar, better tuberization was resulted with 0.1% solubor, 0.1% Zn EDTA and 0.5% $MgSO_4$ @ 500-750 g ha^{-1} independently depending on the requirement. The first foliar spray during the peak vegetative growth stage of the crop followed by two sprays at an interval of 20 days during the tuber bulking stage and can be done at 45-85 DAP. In combined application along with major nutrients, foliar application of 19:19:19 (1%) + Zn EDTA (1%) @ 625 litres ha^{-1} during the peak vegetative growth stage and 1% KNO_3 along with 0.1% solubor (together @ 625 litres ha^{-1}) at tuber bulking stage at an interval of 15-20 days can be adopted.

Elephant foot yam

The integrated package on secondary and micro nutrients developed for EFY (var. Gajendra) include application of dolomite @ 2 t ha^{-1} as basal dose. Soil application of $MgSO_4$, $ZnSO_4$ and borax/solubor @ 60-90, 20-30 and 10-15 kg ha^{-1}, respectively can be done depending upon the soil status and soil critical level of these nutrients. Foliar application of Zn EDTA (0.5%), solubor (0.1%) and $MgSO_4$ (1%) as per requirement thrice during the peak vegetative growth stage followed by tuber bulking stage (4-6 MAP) at an interval of 20 days can also be adopted depending upon the crop condition to rectify the disorder due to these nutrients or to enhance growth and yield of the crop (Fig. 37).

Fig. 37. Crop growth under soil and foliar applications of Mg, Zn and B

Management of tuber cracking in sweet potato

Liming was found to be effective in the management of tuber cracking in sweet potato (var. Sree Arun) (Fig. 38). Liming of the soil either with lime or dolomite @ 2 t ha^{-1} twice at an interval of 15 days prior to land preparation helped to raise the soil pH and increase Ca content of the soil (amount of lime can go up to 8 t ha^{-1} depending upon the soil pH). Application of NPK was done as per recommendation. Solubor @ 5 kg ha^{-1} can be given in the ridge/mound at planting with irrigation and after top dressing, solubor was applied at 5 kg ha^{-1} in the soil at 50-60 DAP. Solubor 0.1% as foliar spray was applied @ 650 litres ha^{-1} at maximum vegetative growth stage (45-60 DAP) and tuber bulking stages at 70-80 DAP and 80-90 DAP.

Fig. 38. Tuber cracking and related woodiness in sweet potato tuber flesh (var. Sree Arun)

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

Results of the field experiment conducted for the second consecutive Kharif season during 2019-20 and harvested during March 2020, with 14 treatment combinations revealed that combined application of NPK @ 40, 15 and 40 kg ha^{-1} along with incorporation of FYM @ 10 t ha^{-1} has recorded significantly highest cormel yield (28.67 t ha^{-1}) with an increase of 3.4% yield over that of $N_{80}P_{30}K_{80}$ (27.73 t ha^{-1}). Application of NPK has recorded higher yield response (63.96%) over that of other nutrient combinations. Significantly highest dry matter (25.29%) and starch (14.15%) were observed due to application of FYM + $N_{40}P_{15}K_{40}$. Increased doses of K application resulted in highest starch and dry matter rather than N application. The starch content was comparatively higher (13.92%) in combined application of NPK than that in the application of NK (13.92%), NP (13.24%) and PK (12.61%).

Significantly highest grain and haulm yields (6.35 and 17.22 q ha^{-1}, respectively) of black gram as an intercrop with elephant foot yam were recorded due to application of FYM + $N_{40}P_{15}K_{40}$. Highest soil organic C content (0.474%) was observed in integrated use of FYM + 40-15-40 kg NPK ha^{-1} at par with 80-30-80 kg N, P and K ha^{-1} (0.449%). Significantly highest build up of available N (199 kg ha^{-1}), P (89 kg ha^{-1}) and K (320 kg ha^{-1}) was observed due to addition of $N_{80}P_{30}K_{80}$. Dehydrogenase activity (1.860 µg TPF h^{-1} g^{-1}), Fluorescein diacetate hydrolysis assay (2.856 µg g^{-1} h^{-1}), urease activity (281.8 µg NH_4-N g^{-1} h^{-1}) and acid phosphatase activity (82.27 µg PNP g^{-1} h^{-1}) were recorded highest due to integrated application of FYM and 40-15-40 kg NPK ha^{-1}. Actinomycetes and bacteria play major role in enzyme mediated reactions in the soil. Organic carbon showed highly significant relationship with yield and proximate composition of elephant foot yam and black gram as the application of organic amendments improved the organic matter status of the soil, which has contributed in yield and quality of both the crops. Cormel yield had positive and significant relationship with all the enzyme activities and the correlation coefficient (r value) were found to be 0.779**, 0.545*, 0.758**, 0.596* and 0.638* in respect of dehydrogenase, FDA, urease, acid phosphatase and alkaline phosphatase activities. Grain yield of black gram showed highly significant relationship with the soil enzymes in respect of dehydrogenase (r=0.911**), urease (r=0.727**), acid phosphatase (r=0.685**), alkaline phosphatase (r=0.632*) and FDA (r=0.538*). Long term application of soil amendments, organic and inorganic chemical fertilizers at balanced proportion not only helps to augment the crop yields but also enhances the microbial activities and sustains the soil productivity.

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

Under this programme, which was concluded in March 2020, field experiments were conducted at ICAR-CTCRI, Thiruvananthapuram for five consecutive seasons to study the long term impact of different tillage and mulching practices in Ultisols under cassava. The changes in soil physical, physico-chemical including hydro-physical and biological properties together with root characteristics and plant growth parameters including plant nutrient uptake at initial periods and cassava tuber yield at harvest during the experiments was studied. During February 2020, the final season crop has yielded an average tuber of 24.77, 24.20 and 18.80 t ha^{-1} under conventional, deep and minimum tillage treatments, respectively. Regarding the mulch effects, the weed control ground cover plastic sheet mulches (GCM), crop mulch (CM) and no mulch (NM) registered a yield of 23.66, 22.84 and 21.27 t ha^{-1}, respectively. The results of the pooled analysis of tuber yield due to different treatments is presented in Fig. 39.

Bulk density of soils under minimum tillage (MT) was maximum under minimum tillage (1.62±0.06 Mg m^{-3}) whereas it was on par under conventional (CT) and deep tillage (DT) treatments with 1.47 to 1.54±0.06 Mg m^{-3}. The average soil water storage values were found to be 7.4, 7.9 and 6.2 % (v/v) and the soil temperature values were 37.2, 36.9 and 37.5°C under CT, DT and MT practices, respectively. The effect of weed control ground cover sheets was not remarkable under low soil

moisture conditions of below 8% (v/v). The interaction of conventional tilled soils applied with weed control plastic sheets was found to have the highest yield among the treatments (26.17 t ha^{-1}). Soil infiltration rate (using double ring infiltration method) after the harvest of final season crop was found to be highest under soils of deep tillage (0.63 mm min^{-1}) whereas in minimum tillage soils, lowest value of 0.19 mm min^{-1} was obtained. The soil infiltration characteristics of the two mulch treatments viz., weed control ground cover mulch and no mulch was found to have steady state IR values of 0.49 and 0.33 mm min^{-1}, respectively. Similarly, the two treatments differed considerably in respect of steady state infiltration rate (mm min^{-1}) and cumulative infiltration (cm). There was no significant effect of soil dehydrogenase activity noticed among the treatments during the final season crop.

The study identified the importance of soil bulk density as a critical parameter that will highly influence the most important hydro physical variables such as saturated hydraulic conductivity and soil sorptivity to preserve and maintain the soil organic matter in these soils under tropical conditions. Overall results suggested that conventional tillage with weed control ground cover sheet was found to be suitable for achieving soil health and for achieving optimum yield for cassava under Ultisols.

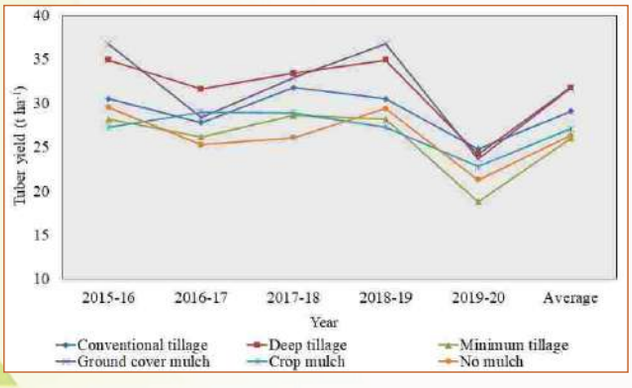


Fig. 39. Cassava tuber yield as influenced by treatments during study period

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

In the activity on the development of best carbon sequestration packages for the hill cassava production systems, results were obtained from the second and final year of study based on the collection of soil samples made during January 2020 and cassava tuber harvest from the field experiment during July 2020 at Pachamalai hills, Tamil Nadu (11°20.711' N; 078°35.669' E longitude; 693 m ± 4 m elevation amsl). The treatments were humic acid granules applied @ 3 kg ha^{-1}, FYM applied @ 12.5 t ha^{-1} and Vesicular Arbuscular Mycorrhiza (VAM) applied @ 5 g plant^{-1} besides control and the cassava variety, Sree Athulya was the test crop. Soil pH ranged from 5.56 in control soil to 6.26 in VAM applied plots and were found to be significant. The soil organic carbon content in soils of control, VAM, humic acid and FYM treated was found to be 8.2, 11.6, 12.6 and 13.7 g kg^{-1} soil and the labile carbon constituted 11-19% of organic carbon among various treatments and ranged from 0.9 to 2.6 g kg^{-1}. Soil moisture observations taken during January 2020 has shown the values with a range of 7.8 % (v/v) in control to 9.1 % in soils applied with humic acid. The tuber yield was obtained as follows: FYM (28.7 t ha^{-1}) > humic acid (26.4 t ha^{-1})>VAM (24.7 t ha^{-1})>control (21.6 t ha^{-1}).

Studies on the Impact of Climate Change and Devising Mitigation and Adaptation Strategies for Sustaining Productivity of Tuber Crops

Impact of nutrients on soil microbes, enzyme activities and yield of colocasia in marshy/low lands of eastern India

Results of field experiment conducted for the second consecutive kharif season during 2019-20 at RS ICAR-CTCRI, Bhubaneswar has shown that significantly highest cormel yield of 29.26 t ha^{-1}was recorded with a yield response of 90.7% over control due to integrated use of FYM + 40-15-40 kg ha^{-1} of NPK. Increased doses of N resulted in 43.5, 69.6 and 66.5% increase of cormel yield due to addition of 40, 80 and 120 kg N ha^{-1} over control, respectively. Application of graded doses of K showed a yield response of 51.5, 67.5 and 74.2% over control in respect of 40, 80 and 120 kg K_2O ha^{-1}. Application of $N_{80}P_{30}$, $N_{80}K_{80}$, $P_{30}K_{80}$ and $N_{80}P_{30}K_{80}$ resulted in 57.1, 76.6, 66.3 and 86.9% increase of cormel yield over control, respectively. Significantly highest starch content (14.33%) and dry matter (24.76%) were recorded due to combined application of 80-30-80 kg N, P_2O_5 and K_2O, respectively. The dry matter content significantly increased due to combined application of NK (24.15%) followed by NP (23.90%). Incorporation of FYM resulted in highest efficiency of N (211 kg cormels kg^{-1} of N). Highest P efficiency (445 kg tubers kg^{-1} P) was observed due to application of $N_{80}P_{30}K_{80}$. Balanced application of 80-30-80 kg ha^{-1} of N, P_2O_5 and K_2O ha^{-1} resulted in highest nutrient

recovery in terms of N, P and K (92, 83 and 46%, respectively). Significantly highest organic carbon (0.37%) in the post harvest soils was recorded due to integrated application of FYM + $N_{40}P_{15}K_{40}$. Highest available N (224 kg ha^{-1}) and available K (269 kg ha^{-1}) were recorded due to balanced application of $N_{80}P_{30}K_{80}$.

Higher dehydrogenase activity (1.582 µg TPF h^{-1} g^{-1}), fluorescein diacetate hydrolysis assay (FDA) (2.356 µg $g^{-1}h^{-1}$) and urease activity (303.2 µg NH_4-N g^{-1} h^{-1}) were observed due to combined application of FYM + $N_{40}P_{15}K_{40}$. Significantly higher relationship was observed between dehydrogenase activity and bacteria ($r=0.881^{**}$) followed by fungi ($r=0.873^{**}$). Organic C showed significant relationship with cormel yield ($r=0.776^{**}$), starch ($r=0.834^{**}$), total sugars ($r=0.727^{**}$) and dry matter ($r=0.811^{**}$) as well as the enzyme activities in respect of dehydrogenase, FDA, urease and acid phosphatase ($r=0.712^{**}$, 0.709^{**}, 0.895^{**} and 0.680^{**}) as the application of organic amendments improved the organic matter status of the soil. Conjunctive use of organic manure and limited doses of chemical fertilizers improved the physico-chemical and biological properties of the soil and thus produces sustainable crop yields of colocasia.

Climate smart agriculture (CSA) practices for tropical tuber crops

Significantly higher tuber yield was recorded in CSA practice (27.80 t ha^{-1}) compared to conventional practice (21.60 t ha^{-1}; 28.7% yield increase). The results of the study showed substantially low carbon emission in CSA compared to conventional practice. Also, the carbon efficiency calculated was found to be substantially low in CSA compared to conventional practice.

Overall results of the activity during the past five years are given here. Remote sensing methodologies for cassava acreage estimation were developed following two approaches, possibilistic c-means classifier and support vector machine (SVM) classifier. Methodologies were developed to study the impact of future climate on change in suitability of cassava using EcoCrop and WOFOST models. The study also resulted in the development of a climate smart agriculture (CSA) practice for cassava to sustainably increase productivity and income, build resilience and adaptive capacity, and where possible reduce greenhouse gas emissions. The components of the CSA practice include (i) water smart practices (drip irrigation), (ii) nutrient smart practices (vermicompost 5 t ha^{-1}, liming to increase soil pH to 6.5 (SMP buffer method), precision fertilizer application using CASSNUM version 1.1 decision support tool, neem coated urea, application of *Azospirillum* and phosphobacterium @ 3 kg ha^{-1}, alleys of cassava sandwiched between green manure trees (*Gliricidia*) and (iii) carbon and energy smart practices (use of disease free, quality planting materials, ridge and furrow method of planting, use of weed control ground cover, green manure cowpea-cassava-black gram sequential cropping system).

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

Ten improved varieties of cassava, viz., H-165, H-226, Sree Reksha, PDP CMR-1, Sree Jaya, Sree Vijaya, Sree Athulya, Sree Pavithra, Sree Swarna and Sree Visakham were evaluated under irrigated and water deficit stress (WDS) conditions (early period stress for 90 days) during November 2019 - August 2020 (3rd season) to identify the drought-tolerant variety based on morpho-physiological parameters. Based on the three season's pooled data, Sree Reksha produced the highest root yield and gaseous exchange parameters under both, irrigated and WDS conditions. Cluster analysis grouped Sree Reksha variety in a separate cluster under both conditions, depicting its superior performance under both conditions in comparison to other varieties. Pearson correlation analysis revealed that physiological (net photosynthesis rate, transpiration, stomatal conductance and intrinsic water use efficiency), biometric (plant height, LAI, leaf retention index, number of leaves and harvest index) and biochemical (Relative water content, chlorophyll content and protein content) parameters were significantly correlated with the root yield. Principal component analysis and biplot analysis indicated that the above mentioned parameters were closely associated with Sree Reksha variety under both the growing conditions, which facilitated its higher root yield. Early water stress period for 90 days, diminished the leaf area index and number of leaves by 40-50%, whereas the root yield was reduced to 55-60%. Conclusively, Sree Reksha was found to be the most drought-tolerant variety based on various morpho-physiological parameters. Drought-tolerance associated morpho-physiological parameters were identified which may be integrated in future breeding

programmes to develop drought tolerant variety/ breeding lines.

Resource Management and Climate Smart Agriculture for Sustainable Production of Tropical Tuber Crops

Crop diversification involving tropical tuber crops

At ICAR-CTCRI, Thiruvananthapuram, the field experiment 'Intercropping system involving short-duration cassava and legumes in rice based system' was taken up for the second year (2020) for confirmatory results. Short-duration rice var. Manu Ratna has been harvested. At Regional Station, Bhubaneswar, the effect of grain crop intercropping in taro on yield potential, biological efficiency and economics studies are ongoing for the third season (2020) for confirmatory results. The experiment was conducted during June 2020 employing the seven treatments laid out in randomized block design with three replications.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 was harvested 165 days after planting and pigeonpea was harvested 200 days after sowing.

The results revealed that sole taro produced significantly greater cormel equivalent yield (17,619 kg ha^{-1}). This was due to higher yield potential of taro. The next best treatment was taro + maize (5:1) (16,753 kg ha^{-1}). Sole maize and pigeonpea systems resulted in lower cormel equivalent yield (4855 and 6706 kg 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 found to be >1 (Fig. 40). This indicated that all the above intercropping systems were biologically efficient. Economic analysis indicated that the sole taro system resulted in higher gross and net returns of ₹2,64,300 and ₹1,54,800 ha^{-1}, respectively. Sole pigeonpea and maize system resulted in lower gross and net returns (₹50,400 and ₹17,700 ha^{-1} of net returns, respectively). This was due to lower yield of pigeonpea and maize. The treatment taro + maize (5:1) resulted in higher B:C ratio of 2.47, followed by taro + maize (5:2) and taro sole cropping 2.41 each. The above ratio was calculated by considering the price of taro corm as ₹10 per kg; cormel ₹15 per kg; maize ₹15 per kg and pigeonpea ₹50 per kg.

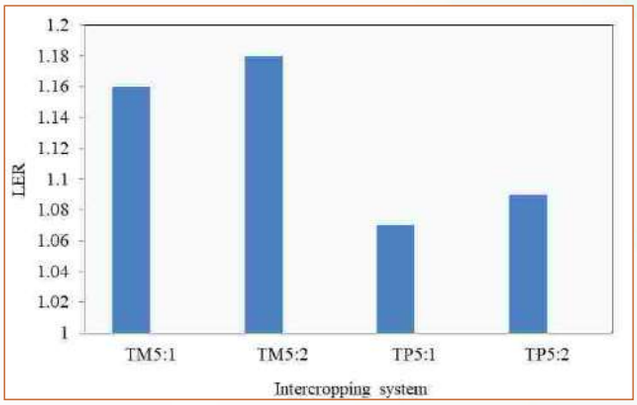


Fig. 40. Effect of taro intercropping system on LER

Vertical farming of tropical tuber crops

Standardization of nutrient solution for hydroponics based vertical farming of sweet potato

A prototype of hydroponic NFT (nutrient film technique) for sweet potato with vertical farming was fabricated in the open field. Standardization of nutrient solution is under progress.

Weed management in tropical tuber crops

Experiment 1: Integrated weed management in taro

A field experiment was conducted at ICAR-CTCRI, Thiruvananthapuram to study the effect of integrated weed management on taro yield and economics. The experiment was laid out in randomized block design. The FYM @ 25 t ha^{-1} was applied at final ploughing and then pits were made for planting. The variety Muktakeshi (taro) was planted on 01 September 2020 and crop is in the field with active growth stage (Fig. 41). The data on plant and weed parameters were taken up to 31 December 2020. The harvesting will be done in the month of February after senescence of the crop.

The results revealed that use of weed control ground cover mat (nurserymen mat) (120 g) is effective in growth of the crop and recorded higher plant height, number of leaves, and leaf area index at 2 and 4 months after planting to the rest of the treatments and recorded less weed density and dry weight of the weeds.

Fig. 41. View of the integrated weed management experiment in taro at 2 MAP and 3 MAP

Experiment 2: Bio intensive weed management in taro

A field experiment was conducted during June 2020 at RS ICAR-CTCRI, Bhubaneswar to study the effect of bio-intensive weed management in taro on yield and economics (Fig. 42). The experiment was laid out in split plot design with plant density in main plots [P_1-55500 (60 × 30 cm) and P_2-74000 (45 × 30 cm) plants ha^{-1}] and in sub plots Mulching (M_1-Sunhemp live mulching, M_2-Daincha live mulching, M_3-Cowpea live mulching, M_4-Paddy straw mulching, M_5-Hand weeding at 30, 60 and 90 days after planting (DAP) and M_6-Control). The treatments were replicated thrice. FYM @ 25 t ha^{-1} was applied at final ploughing and then ridge and furrows were made for planting. The variety Muktakeshi (taro) was planted on 11.06.2020 and harvested on 22.11.2020 (165 days after planting).

The results revealed that increasing taro plant density decreased weed dry weight and increased tuber yield significantly. Plant density of 74000 plants ha^{-1} resulted in lower weed dry weight of 152.4 g m^{-2} and higher tuber yield of 14378 kg ha^{-1}. Hand weeding at 30, 60 and 90 DAP recorded significantly lower weed dry weight (24.5 g m^{-2}) and higher yield (20814 kg ha^{-1}) than other weed management practices. Mulching suppressed the weeds considerably and increased the taro yield compared to control (weedy check). Among mulching, paddy straw mulching was resulted in lower weed dry weight (118 g m^{-2}) and higher tuber yield (16,581 kg ha^{-1}) than other live mulching. The result also revealed that mulching alone is not enough for controlling the weeds in taro. This was ably indicated by higher weed dry weight and lower tuber yield in all the mulching treatments compared to hand weeding (30, 60 and 90 DAP) treatment. Higher gross and net returns (₹1,97,540 and ₹91,620 ha^{-1}, respectively) and B:C ratio (1.79) were obtained at higher plant density of 74,000 plants ha^{-1}. Among weed management practices, hand weeding resulted in significantly higher gross and net returns and B: C ratio. Among mulching, paddy straw mulching resulted in higher gross and net returns as well as B: C ratio. Control (weedy check) treatment resulted in negative net returns. The interaction effect showed that the planting density of 74,000 plants ha^{-1} along with hand weeding at 30, 60 and 90 days after planting resulted in lower weed dry weight and higher tuber yield, gross and net returns as well as B:C ratio (22,928 kg ha^{-1}, ₹3,16,330 ha^{-1}, ₹1,84,200 ha^{-1} and 2.39, respectively).

Fig. 42. (a) View of the weed management experiment plot of taro and (b) Straw mulching plot in taro

Water and nutrient management in tropical tuber crops through precision approaches

Water saving techniques in taro

The field experiment on water saving techniques in upland taro was carried out during January 2020. The experiment was laid out with 10 treatments viz., drip irrigation at 50% CPE combined with water saving techniques such as plastic porous ground cover (T_1), bio mulching (T_2), soil application of coir pith (T_3), foliar application of anti-transpirant (T_4), Pusa hydrogel (T_5),

super absorbent polymer (synthetic) (T_6), drip irrigation at 50% CPE (T_7), drip irrigation at 100% CPE (T_8), flood irrigation (T_9) and a rainfed control (T_{10}) for comparison purpose. Taro variety, Muktakeshi was planted during January 2020 and early sprouting was achieved with bio mulching (21 days). Fifty per cent sprouting of cormels was achieved within 37-42 days under different treatments. The crop was harvested during August 2020. There was significant difference in cormel yield as well as total yield among the treatments and the corm yields were at par. Plastic ground cover mulching with drip irrigation at 50% CPE resulted in the maximum cormel yield (29.4 t ha^{-1}) and total yield (38.32 t ha^{-1}), closely followed by bio mulching (28.9 and 36.5 t ha^{-1} respectively). The cormel yields from treatment on soil application of Pusa hydrogel and drip irrigation at 100% CPE were also at par with the maximum yield. Rainfed crop recorded 4.3 t ha^{-1} of cormel yield. Ground cover mulching resulted in 40% increase in cormel yield and 50% saving in irrigation water compared to drip irrigation at 100% CPE (Fig. 43).

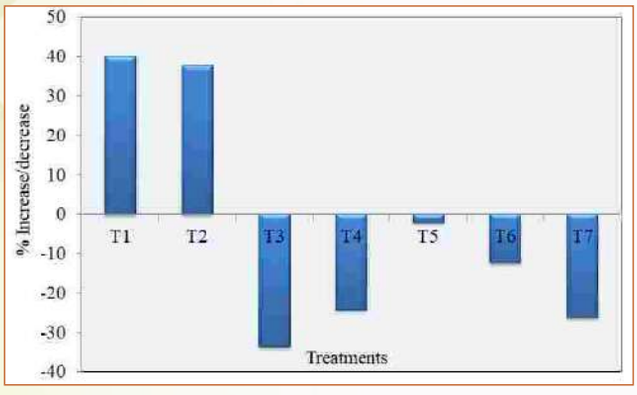


Fig. 43. Percentage increase/decrease in cormel yield under water saving treatments as compared to irrigation at 100% CPE

Fertigation studies in taro

A new field experiment on fertigation in taro was initiated during September 2020. The trial was laid out in split plot design with four levels of nutrients in main plots (M_1: 60-25-75; M_2: 60-25-100; M_3: 80-25-100; M_4: 80-25-125 kg N, P_2O_5 and K_2O ha^{-1}) and three schedules of fertilizer application in sub plots (S_1: 50 % N and K < 60 DAP; 25 % 60-120 DAP; 25% 120-150 DAP; S_2: 50 % N and K < 90 DAP; 25% 90-120 DAP; 25% 120-150 DAP and S_3: 25 % N and K < 60 DAP; 50% 60-120 DAP; 25% 120-150 DAP). Taro variety, Muktakeshi was planted and fertigation was given as per schedule at weekly intervals. Biometric observations were recorded at monthly intervals from 3 MAP onwards. The crop is yet to be harvested.

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

Five on-station experiments on SSNM of cassava, elephant foot yam, greater yam, white yam and taro were studied as per the approved technical programme. Soil and plant data are being analyzed to improve the modified QUEFTS model based on harvest index, indigenous nutrient supplies and nutrient use efficiency. Data are also being generated to calibrate and validate the LINTUL-Cassava-NPK model to improve nutrient recommendations for cassava under water limited conditions. The crops are yet to be harvested. To assess the diversity among cassava farmers with special emphasis on nutrient management, farm surveys are being conducted in 60 selected farmers across five different panchayats in Kerala state and the data is being processed. Farmer participatory SSNM trials were laid out in 60 farms (10 in Kootilangadi panchayat, Malappuram (cassava), 10 each in Vadakkekara panchayat, Ernakulam (elephant foot yam and taro), Thiruvankulam panchayat, Ernakulam (elephant foot yam and taro), Chenkal panchayat, Thiruvananthapuram (cassava), Kulathoor panchayat, Thiruvananthapuram (cassava) and Karode panchayat, Thiruvananthapuram (cassava). Performance of SSNM based customized fertilizers and 'Micronol Cassava' micronutrient formulation were studied and demonstrated in these locations. The crops are yet to be harvested. In order to validate and demonstrate SSNM based customized fertilizers for sweet potato, a massive programme was started in February 2020 in Vadakkekara panchayat by supplying planting materials and customized fertilizers to all families of the panchayat under '*Madhuragramam*' project and the crops are yet to be harvested. Women self-help groups were also involved in the project.

Sustainable nutrient management in tropical tuber crops

INM in Greater Yam + Maize system and Arrowroot

Experiment 1: Effect of integrated use of inorganic and organic sources on yield, proximate composition and soil quality in greater yam + maize system

A field experiment was laid out during kharif season, 2020-21 to study the effect of inorganic and organic manures on soil quality, yield and proximate

composition of yam + sweet corn cropping system in an Alfisol. The experiment involved 16 treatments with different levels of NPK, $MgSO_4$, $ZnSO_4$, farm yard manure and vermicompost. One-third of N, entire P and 1/3 K were applied before planting, 1/3 N and K at 2 months after planting and the balance 1/3 N and K was applied 4 months after planting. A fertilizer dose of 50-25-50 kg ha^{-1} of N, P_2O_5 and K_2O was followed for sweet corn, in which 1/3 N, entire P and 1/2 K was applied before dibbling the seeds as basal dose, 1/3 N at 45 days after sowing and the balance 1/3 N and 1/2 K at 60 days after sowing were applied. Greater yam (var. Orissa Elite) tubers were planted during the first week of June 2020. Simultaneously, sweet corn (var. SUM Sugar Gobal-F_1 Hybrid) seeds were dibbled in between yam as an intercrop at a spacing of 45×30 cm and grown up to 110 days. Intercultural operations for both yam and sweet corn were followed as per schedule. Sweet corn cobs were harvested at physiological maturity, recorded the yield parameters and the data is under compilation. The yam will be harvested at complete senescence of the plants during February 2021.

Screening nutrient efficient genotypes of sweet potato

Screening of elite sweet potato genotypes for physiological efficiency

A field experiment was laid out during kharif season, 2020-21 to study the nutrient use efficient genotypes of sweet potato. The trial was laid out with 90 elite genotypes of sweet potato. The vine cuttings of sweet potato were planted during September 2020 in two replications in rows at a spacing of 60×20 cm without addition of any inorganic fertilizers, followed the intercultural operations as per the schedule and the crop will be harvested during first week of February 2021.

Long term integrated nutrient management in tropical tuber crops

Based on the information gathered from LTFE and other INM research programmes in cassava, the next phase (phase IV) of the LTFE was conceived to study the sustainability of the scientific information/ technologies developed from these projects.

Long term effect of advanced integrated nutrient management practices on the sustainability of cassava

The first season experiment was conducted during July 2020 with 20 treatments replicated thrice in RBD in a plot size of 5.4×5.4 m with varieties viz., Sree Visakham and Sree Pavithra and nutrient use efficient genotypes viz., CI-905, CI-906, and 7 III E3-5. Biometric observations at 3 and 6 MAP were taken and the disease grading before the soil and foliar treatments also was done.

Diagnosis and correction of emerging soil-plant nutritional disorders in tropical tuber crops

During the last five years (2015-2020), major problems encountered in cassava, sweet potato and yams is suspected to be linked to B deficiency, since the symptoms found are tuber cracking in the case of cassava and sweet potato and hollow/brown heart in the case of yams (Fig. 44). These are associated with tubers and has been found affecting the marketable tuber yield.

During the first year (2020-21), three experiments viz., rapid appraisal of the B status of ICAR-CTCRI farm, sorption characteristics of the soil to arrive at the optimum B requirement of the soils and an observational trial in greater yam and white yam to manage the suspected B deficiency disorder were conducted.

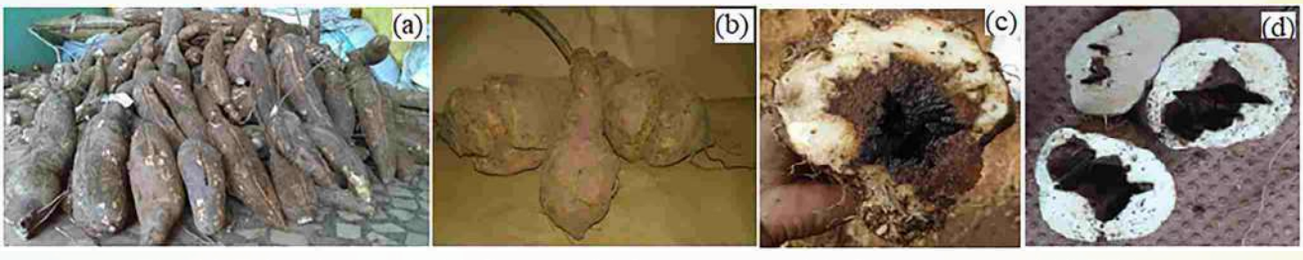


Fig. 44. Tuber damage in (a) Cassava, (b) Sweet potato, (c) Greater yam and (d) White yam

Rapid appraisal of the B status of the soil

A total of 95 surface soil samples from the five blocks of ICAR-CTCRI farm @ 25, 16, 14, 18 and 22 were collected following the map of blocks considering the slope and crop grown/fallow. Among the blocks, not much variation was seen in the B status and it ranged

from 0.14-0.419 ppm with mean value as 0.317 and 0.242 ppm at block I and II respectively and 0.172-0.419 ppm and 0.172-0.848 ppm with mean values as 0.289 and 0.331 ppm at block III and IV respectively and 0.150-1.052 ppm with mean value as 0.356 ppm at block V. Since there was no symptom expression in Block II for these varieties and already the synergism between B and Ca is known, the exchangeable Ca content of these samples were also analyzed and is found that the mean Ca content of the five blocks were 0.896, 1.015, 0.640, 0.989 and 0.877 meq 100 g^{-1} respectively. The correlation worked out between these two nutrients for the five blocks did not reveal any significant relationship except block V, where it was significantly positive (r = 0.537).

Sorption studies of boron

Boron sorption study was conducted to predict the quantity of B to be added to the soils to attain the B status either critical level (0.5 ppm), double (1.00 ppm) or thrice the critical levels (1.5 ppm). The prediction was done using an inverse prediction method function in the R package chemCal (Johannes Ranke 2018, chemical, CRAN-Package chemCal (r-project.org). For sorption study, nine composite soil samples were prepared by mixing soils taken from different blocks with B concentrations 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.9 and 1.0 ppm. Five ml of 0.25, 0.5, 1.0, 2.0 and 4 ppm B were added to these soil samples (5 g) and incubated for 3 days till the soil became air dried. The samples were then analyzed for soil available B and sorption curves were fitted with concentration of applied B in X-axis *vs* available B in the Y-axis. The fitted curve were almost linear and hence linear regression models were fitted (Fig. 45). The quantity of B to be added to attain 0.5, 1.0 and 1.5 ppm ranged from 0.78-3.09, 1.80-7.21 and 7.4-11.33 ppm, respectively as determined by inverse prediction.

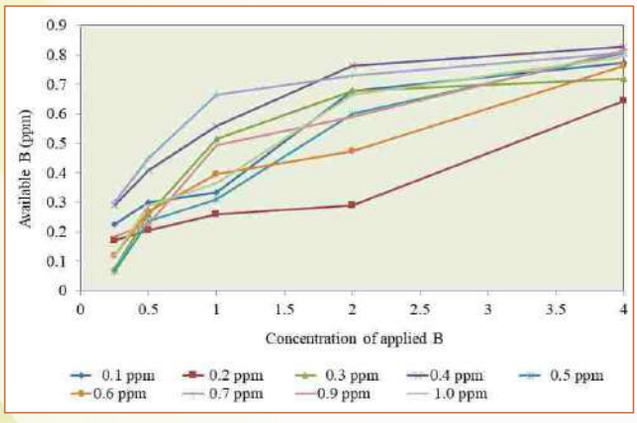


Fig. 45. Sorption curve fitted for B with soils of varying B content

Observational trial to manage B deficiency disorder in greater yam/white yam

An observational trial was conducted in RBD with nine treatments replicated thrice, in block IV of ICAR-CTCRI farm where the suspected symptoms of B deficiency was noticed. Greater yam varieties (Sree Swathi, Sree Nidhi) and white yam variety (Sree Haritha) were planted during April 2020. All treatments had PoP where FYM @ 12.5 t ha^{-1} was applied along with NPK @ 80:60:80 kg ha^{-1}. The treatments consisted of soil and foliar application of B and lime alone and together. Lime was applied @ 2 t ha^{-1} and soil application of B as borax @ 25 kg ha^{-1}, foliar application of B as 0.5% solubor and Ca as 1% $CaNO_3$ was also done. These treatments were compared with existing PoP. Soil application was done twice as basal and 3-4 MAP and foliar application thrice at maximum vegetative growth stage (3-4 MAP) and tuber bulking stages (5-6 MAP and 7-8 MAP). Occurrence of the suspected B deficiency disorder was examined in the tuber at different tuber formation, development and bulking stages and not any distinct symptoms as earlier were noticed.

Soil carbon quality and conservation studies in tropical tuber crops

Geo spatial soil sample collections were made from major tuber crops areas of India especially from Kanyakumari, Salem and Tenkasi districts of Tamil Nadu besides ICAR-CTCRI under cassava and EFY/ Chinese potato production systems (Fig. 46). In addition to the above locations, soil samples of two AICRP TC centers viz., Raipur and Peddapuram were also received. Analysis of soil properties for texture, bulk density, porosity and water holding capacity values have shown that the soils are in clay to sandy clay loam in texture with the bulk density ranged from 1.38 to 1.52 Mg m^{-3} and maximum WHC from 39 to 48 % (v/v) among the analyzed soil samples. The pH varied from 5.1 to 6.8 among soil samples. Analysis of soil samples for different carbon fractions is under progress.

Fig. 46. Collection of soil samples from fields of (a) Elephant foot yam and (b) Chinese potato from Tamil Nadu

Climate change adaptation and mitigation in tropical tuber crops

Field experiment on climate smart agriculture (CSA) practices was laid out at ICAR-CTCRI farm with two treatments, CSA and conventional practice (CP). The green house gas emission carbon footprints of the treatments are being studied. The crop is yet to be harvested.

Physiological studies related to climate change in tropical tuber crops

Photosynthetic response of sweet potato varieties to eCO_2 and nitrogen application

A field experiment on response of sweet potato to elevated CO_2 and nitrogen application was carried out during January 2020. The net photosynthetic rate (P_n), stomatal conductance (g_s) and intercellular CO_2 (Ci) was studied in two varieties of sweet potato viz., Sree Arun (V1), Sree Kanaka (V2) with different doses of nitrogen application (N0, N1, N2, N3, N4: 0%, 25%, 50%, 100% and 125%) under ambient (400 ppm) and eCO_2 (600, 800 ppm), and the P_n at photosynthetic photon flux density (PPFDs) 1500 µmol m^{-2} h^{-1} at 30°C using portable photosynthesis system LI-6400, LICOR, USA. The data are being analyzed. The P_n steadily increased due to short-term (ten minutes) exposure at eCO_2 concentrations between 400 ppm and 8000 ppm (Fig. 47). Max increment was recorded between 400-600 ppm CO_2 with the increased levels of nitrogen applied. In both varieties Ci steadily increased between 400 and 8000 ppm Co_2.

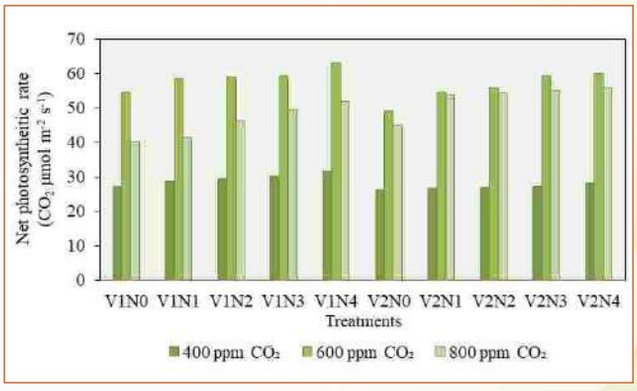


Fig. 47. Effect of different levels of nitrogen and elevated carbon dioxide (eCO_2) on net photosynthetic rate of sweet potato varieties

Quality planting material production of tropical tuber crops

Developing innovative techniques for seed production in tropical tuber crops and quality planting material production in cassava, sweet potato and minor tuber crops

Cassava varieties, viz., Sree Reksha, Sree Sakthi, Sree Suvarna, Sree Vijaya and Sree Jaya were planted in an area of 4.20 acres at ICAR-CTCRI Farm in block III and V during April 2020 (Fig. 48). Sweet potato (var. Sree Arun and Sree Kanaka) was planted in an area of 0.30 acre and Chinese potato (var. Sree Dhara) in 0.10 acre, for quality planting material production. The seed crops were grown as per the seed production standards. The standing crops were monitored for pest and disease at regular intervals. The field inspection, rogueing and intercultural operations were carried out as and when required. The planting materials of seed crops were harvested at the maturity stage.

Fig. 48. Quality planting material production in (a) Cassava, (b) Sweet potato and (c) Chinese potato

Multiplication through minisetts technique in cassava

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

Establishment of seed villages for quality planting material production of tuber crops

The quality planting materials of improved varieties of cassava viz., Sree Reksha and Sree Jaya were distributed to five farmers in the Kanakapillai Valasai village, Shenkottai taluk, Tenkasi district, Tamil Nadu for seed production under seed village programme with regular monitoring by ICAR-CTCRI scientists. The seed crop is yet to be harvested. The sweet potato varieties, Sree Arun and Sree Kanaka were planted in an area of 0.30 acres in block IV and V in the farm area. Healthy vines were harvested and a total of 8,000 sweet potato vine cuttings were supplied for the seed village at Karode, Thiruvananthapuram (Fig. 49a). The Chinese potato crop (var. Sree Dhara) was planted in 0.20 acres and a total of 15,000 vine cuttings were produced and distributed to 15 farmers in Pellakal Pudhukudi of Tirunelveli district and Kuthapanchan, Alankulamtaluk of Tenkasi district, Tamil Nadu under seed village programme (Fig. 49b).

Fig. 49. (a) Distribution of sweet potato vines at Karode village, Thiruvananthapuram and (b) Quality planting material production of Chinese potato at Kuthapanchan village, Tenkasi

Seed entrepreneurship development programme

A total of 10,000 cassava stems of Sree Athulya variety were distributed to ten famers in the village of Narasingapuram, Ramanayaganpalayam, Attur taluk in Salem district, Tamil Nadu for production of quality planting materials of cassava. A total of 75,000 quality cassava stems were produced and distributed to other farmers in the village and neighbouring villages of Attur taluk in Salem district.

Effect of growth regulators on vegetative growth and yield parameters in cassava

A field experiment was conducted during 2020 at ICAR-CTCRI, Thiruvananthapuram to study the effect of different growth regulators on the growth and yield

of cassava with nine treatments in RBD with five varieties, viz., Sree Reksha, Sree Pavithra, Sree Suvarna, Sree Vijaya and Sree Jaya. Cassava setts were treated for 30 min with different growth regulators viz., $GA_3$100 ppm, GA_3 200 ppm, IAA 100 ppm, IAA 200 ppm, IBA 100 ppm, IBA 200 ppm, Thiourea 0.5% and Thiourea 1%. The treated cassava setts were planted in the experimental trial along with control and standard recommended package of practices was followed. The field observation revealed that cassava stems treated with $GA_3$200 ppm resulted in higher field emergence of 88.74 and 99.69%, respectively at 15 and 30 DAP, followed by IAA200 ppm treated stems. The higher plant height (81 cm), stem girth (12 cm) and leaf spread (45 cm) were recorded in the treatment with GA_3 200 ppm followed by IAA200 ppm treatment at 90 days after planting. The yield data will be analyzed after harvesting.

In vivo and *in vitro* multiplication of planting materials of yams and aroids

Yams: On-station large scale multiplication of released varieties of white yam, greater yam and lesser yam was initiated. Quality seed materials of released and popular varieties of greater yam (var. Sree Swathi- 30 cents, Sree Nidhi- 5 cents, Sree Keerthi and Sree Karthika - 15 cents), lesser yam (var. Sree Latha- 40 cents) and white yam (var. Sree Priya- 5 cents, Sree Dhanya- 10 cents) were planted in one acre of land in Block I. The best agronomic practices timely crop management was followed and the crop stand is good and will be harvested in the month of January 2021.

Elephant foot yam: The EFY variety Gajendra was multiplied in an area of 1.7 acres and produced 9.5 tons corms.

Taro: Taro variety Muktakeshi was multiplied under irrigated conditions and produced 187 kg of mother corms and 552 kg of cormels. The second cycle of multiplication is in progress. Mother corms and cormels were planted separately to assess the seed production potential and the trial is in progress.

Studies on rapid multiplication techniques in tuber crops

An experiment was initiated during March 2020 on microsett (single node cuttings) method of multiplication in cassava (Fig. 50) using 6 varieties viz., Sree Pavithra, Vellayani Hraswa, Sree Reksha, Sree Jaya, Sree Vijaya and M-4. The microsetts were subjected to six pre-treatments viz., *Arbuscular Mycorrhizal Fungi* (AMF), *Trichoderma*, *Pseudomonas*, PGPR Mix-1, cow dung slurry and control (1% saaf treatment) to study their effect on improving sprouting percent, vigour of sprouts and establishment in field. The mean sprouting varied from 93.3% in Vellayani Hraswa to 97.2% in Sree Jaya (Fig. 51). The sprouting percent was significantly influenced by the pre-treatments and it was maximum (99.12%) for the microsetts treated with PGPR Mix-1, which was on par with that treated with cow dung slurry. The microsetts were raised in field and evaluated for tuber yield. Mean yields of plants raised through microsett and conventional sett were on par in respect of Sree Pavithra (4.1kg each) whereas in the case of Sree Vijaya it was slightly higher for conventional sett propagation (5.01 kg) against microsett (4.09 kg per plant).

Fig. 50. (a) Microsett propagation of cassava in protrays and (b) Harvested tubers

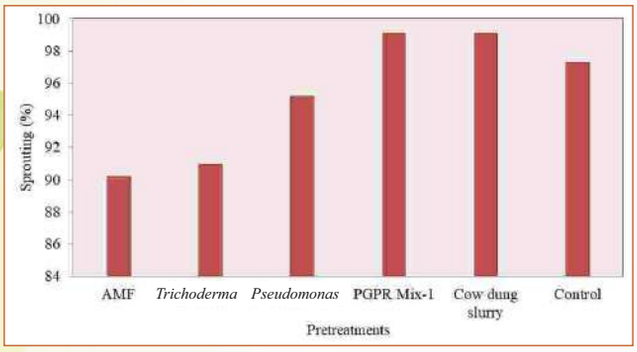


Fig. 51. Effect of pre-treatments on the sprouting percentage of cassava microsetts

The minisett multiplication of yams (var. Sree Subhra, Sree Nidhi, Sree Neelima, Sree Swetha and Sree Keerthi) was done in protrays. The minisetts of 30 g size were subjected to different pre-treatments in a factorial CRD design. Results have shown that percent sprouting was the highest (66.7% each) in case of AMF and PGPR Mix-1 treatment, followed by *Pseudomonas*. Cow dung slurry treatment resulted in the lowest sprouting of 33.3%. Among the varieties, Sree Neelima had the highest sprouting percent of 81.48%, which was followed by Sree Nidhi and Sree Keerthi. The least sprouting was observed in Sree Subhra (35.56%). In general, *D. alata* varieties had higher sprouting percentage than *D. rotundata* varieties, while the former took longer time for sprouting than the latter.

Refinement of micro/minisett multiplication technique in yams

In this experiment, two varieties of yams (Sree Nidhi and Sree Neelima) with five pre-treatments viz., *Trichoderma* (T1), *Pseudomonas* (T2), PGPR Mix-1 (T3), Control (1% saaf treatment) (T4) and cow dung slurry (T5) and four sizes of minisetts viz., 10 g (S1), 20 g (S2), 30 g (S3) and 50 g (S4) were used in a factorial CRD design. After pre-treatment, the setts were planted and maintained in protrays (Fig. 52). The sprouting percentage varied significantly among different pre-treatments. The maximum sprouting of 84.14% was recorded in fungicide pre-treatment and lowest (63.48%) in cow dung slurry. The sprouting percentage was significantly influenced by sett sizes and it was 56.91% in S1 (10 g) 77.99% in S2 (20 g), 73.49% in S3 (30 g) and 81.62% in S4 (50 g). There was no variation among varieties. Interaction between pre-treatment and sett size was significant with the maximum sprouting being 88.34% in 20, 30 and 50 g sizes with *Trichoderma* pre-treatment.The sett size was positively correlated with number of leaves, number of vines and fresh weight of tuber.

Fig. 52. (a) Mini/microsetts of greater yam in protrays ready for field planting and (b) Minisett raised greater yam plants established in field

CROP PROTECTION

Eco-friendly strategy for the management of insect pests in tuber crops

Under this project, which was concluded in March 2020, the molecular characterization of endosymbiotic bacteria associated with *Aphis gossypii* was carried out. Aphids are one of the important sucking pests which affect the yield of crops. Based on comparative analysis of 16S rDNA sequences and seven different strains affiliated to five different genera comprising of *Bacillus, Acinetobacter, Pseudomonas, Pantoea* and *Staphylococcus* were found to be associated with the insect pest. The intensity of feeding of sweet potato weevil on the tubers of sweet potato varieties, *Ipomoea mauritiana* and roots of *I. palmata, I. triloba,* and *I. obscura*) was studied. Infestation was significantly less in *I. mauritiana* than that of other *Ipomoea* sp. DNA was isolated from the tubers and roots of all the *Ipomoea* sp. and the PCR conditions with all the gene specific primers such as protease inhibitor, cysteine inhibitor and kunitz trypsin inhibitor genes were standardized.

Development of innovative technologies for the intensification of pest management in tuber crops through biorational approach

Development of biorational control measures for the management of insect pests of tuber crops

Screening synthetic insecticides against sweet potato weevil

To develop a combination product of organic and synthetic insecticides, the locally available synthetic insecticides were screened against sweet potato weevil to identify relatively the safer ones. Six synthetic insecticides in three different groups viz., organophosphates (Chlorpyrifos 20 EC, Malathion 50 EC, Dimethoate 30 EC and Dichlorvos 76 EC), organothiophosphate (Quinalphos 25 EC) and neonicotinoid (Imidacloprid 17.8 SL) at three concentrations (0.001, 0.01 and 0.05%) were evaluated against SPW. Sweet potato plants of variety, Sree Arun raised in pots were sprayed with the prepared insecticide solutions and water sprayed plants were used as control. Leaves with petiole collected from sweet potato plants from 1, 3, 5, 7 and 9 days after treatment (DAT) were transferred into Petri dishes (90 × 20 mm), and into which male adults of SPW were released. Mortality of SPW was recorded 24 h after treatment for 9 days. The mortality of SPW was found to be 100% on 1 DAT with 0.05% Imidacloprid, Chlorpyrifos, Dichlorvos and Quinalphos (Fig. 53). Complete mortality of SPW at 0.01% treatment was observed only in the Imidacloprid treated batches, but Malathion and Dimethoate were found relatively less toxic to SPW. On 5 DAT, the mortality was highest in the batches treated with 0.05% Imidacloprid, followed by Chlorpyrifos and Dichlorvos. Toxicity of the insecticides declined considerably with respect to the DAT. On 9 DAT, except the treatment with Imidacloprid, none of the other treatments caused over 50% mortality of the target pest. Of the six insecticides evaluated, Imidacloprid had the highest toxicity to SPW and a positive correlation ($r = 0.8$) was found between the mortality and concentration of insecticides (Fig. 54). Chlorpyrifos was found next to Imidacloprid in its efficacy to kill SPW. Sweet potato leaves treated with Malathion and Dimethoate caused very little mortality to SPW.

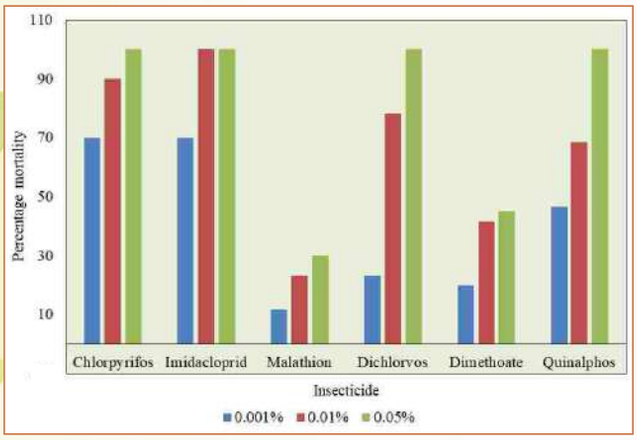


Fig. 53. Mortality of sweet potato weevil on first day after feeding with sweet potato leaves treated with synthetic insecticides by foliar application

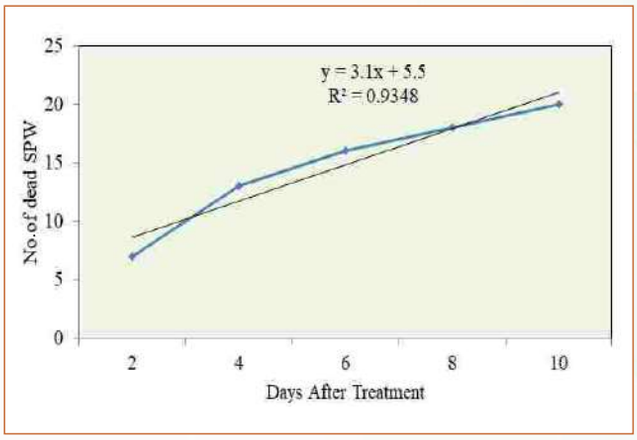


Fig. 54. Linear relationship between mortality of sweet potato weevil and DAT with 0.01% Imidacloprid

Management of important pests and documentation of emerging pests in tuber crops

A 'distinct' genetic variant of whitefly was identified in sweet potato fields of Thiruvananthapuram and is found to be quite different when compared with all available 44 whitefly genetic variants of Bayesian phylogenetic tree inferred from mtCOI data using the GTR+G model.

Sweet potato leaves were heavily infested by a new emerging pest causing about 30% damage of the crop. The molecular and morphological characterization of this insect showed that it was the sweet potato leaf miner, *Bedellia somnulentella (*Lepidoptera: Bedelliidae) (Fig. 55). A pilot study was conducted to manage this infestation using various insecticides and it was found that application of Spinosad 45% SC (0.3 ml l^{-1}) at fortnightly intervals was effective against this insect.

Fig. 55. (a) Leaf miner damage in sweet potato leaves and (b) Adult of leaf miner *(Bedellia somnulentella)*

A study was conducted to screen the synthetic insecticides which have adverse effect on beneficial soil microbes (Fig. 56). It was found that Quinalphos at recommended dose is causing more than 90% inhibition of the growth of *Trichoderma* in soil at 96h after application; however, Imidacloprid was found to be comparatively safer for soil application.

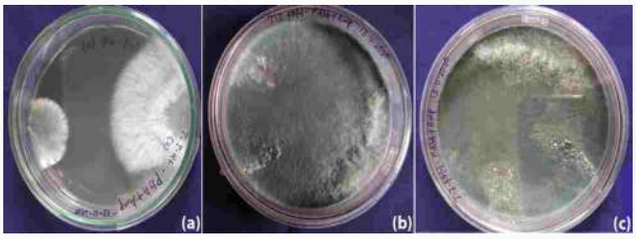


Fig. 56. Growth pattern of *Trichoderma* in PDA plates treated with (a) Quinalphos, (b) Imidacloprid and (c) Control

Characterization of insect resistance genes in sweet potato and related *Ipomoea* sp. against sweet potato weevil infestation

Identification of host plant resistance genes against sweet potato weevil is one of the alternative pest control method and these genes have an important role in the management of this pest. In this context the experiment was designed to identify those genes related to sweet potato weevil infestation. The validation of protease inhibitor, cysteine inhibitor and kunitz trypsin inhibitor gene expression in tubers of sweet potato varieties, *I. mauritiana* and from the roots of *I. palmata, I. triloba, I. obscura* was studied. For all the plants, both control and weevil infested tubers and roots were used for RNA isolation with replicates and cDNA was synthesized for Reverse Transcriptase-PCR (RT-PCR). All the gene specific primers were amplified with cDNA from all the samples.

Screening of newer molecules for the management of nematodes in tuber crops

Survey and collection of soil samples from tuber crops in Kerala and Tamil Nadu for the identification of nematodes

A survey was undertaken in nematode affected Chinese potato fields of Ravanasamudhram, Kadayam block of Tenkasi distict, Tamil Nadu during December 2020. The nematode infected tubers were malformed and upon dissection of tissue sample, adult female root nematodes were observed. The soils had *Meloidogyne incognita* with a population density of about 1.5 nematodes per gram of soil. A new strain of *Panagrolaimus* sp. was isolated and identified from the stems of cassava (var. Sree Vijaya) from ICAR-CTCRI during December 2020. The nematode possessed the characteristic panagrolaimoid oesophagus and gonads. The anterior part of oesophagus was cylindrical and the isthmus was shorter than anterior part (Fig. 57). In females, the ovary was reflexed beyond the vulva and extended near anus. Post-vulval sac was about a body-width long. Hundreds of nematodes were observed from a small tissue in distilled water taken from the stem region. All stages were observed including eggs. This is the first report of a plant associated *Panagrolaimus* sp. from cassava.

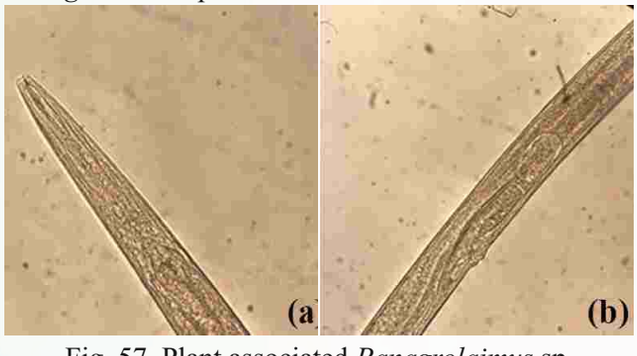


Fig. 57. Plant associated *Panagrolaimus* sp.
(a) Anterior region showing Panagrolaimoid oesophagus and (b) Adult female with mature eggs

In vitro soilless culture of root knot nematode on Chinese potato plants

Indigenous growth pouch (a soilless medium) was designed to maintain pure culture of root knot nematode on Chinese potato plants. These pouches can be used for studying the complete biology and development of nematodes and also maintenance of pure cultures of root knot nematode without soil. The growth pouch is made up of Whatman paper enclosed in a thin transparent polythene envelope. Chinese potato vine cuttings with roots were transferred to these growth pouches and 20 µl nematode suspensions with 20-25 second stage nematode juveniles were inoculated on fine roots. These pouches were supported with two thermocol sheets of 0.5 inch thickness and were kept vertically in plastic/glass trays with sufficient water to moisten the paper through capillary action. The trays were kept at room temperature for 30 days. The nematode growth and development were monitored through transparent polythene sheet until completion of life cycle. After 30 days, the presence of galls was observed and the root-knot nematode eggs enclosed in gelatinous matrix were also observed on the root surface (Fig. 58). Therefore, these growth pouches are potential soilless low-cost option for maintaining axenic culture of root knot nematode on Chinese potato plants.

Fig. 58. Development of root-knot nematodes in growth pouches

Development and refinement of integrated disease management and forecasting system for improved tuber crop production

The salient achievements of the completed activities under this programme during the last five years are summarized below. Management strategies for taro leaf blight, collar rot of EFY and anthracnose in yam were refined and bio intensive strategies were developed by exploring rhizosphere organisms from tuber crops ecosystem and endophytes from medicinal plants and tropical tuber crops. *Piriformospora indica*, a root colonizing endophyte had been exploited to manage taro leaf blight. Disease development pattern of taro leaf blight and anthracnose in greater yam were studied to develop decision support system. Formulations of

bio agents were prepared by utilizing cost-effective materials. Etiology of post harvest rot of elephant foot yam was studied and management strategies were developed. Resistant gene analogues have been characterized in taro and greater yam in response to leaf blight and anthracnose, respectively. LAMP based diagnosis of *Phytophthora colocasiae*, *Sclerotium rolfsii* and *Colletotrichum gloeosporioides* causing fungal diseases has been standardized. *Dasheen mosaic virus* (DsMV) free tissue culture plants were developed and evaluated in farmers' field. Three viruses from lesser yam, viz., *Yam mild mosaic virus* (YMMV), *Yam mottling virus* and *Yam badna virus* were identified. The specific primers were designed for YMMV and *Yam maclura virus* and tested in lesser yam samples. YMMV was diagnosed from lesser yam tubers and validated with more samples. Presence of *Taro bacilliform* China virus which has 100% sequence similarity with *Taro bacilliform CH* isolates, was confirmed in taro leaf samples. Analysis of S*weet potato feathery mottle virus* (SPFMV) infected leaf samples through cloning and sequence analysis showed that out of eight clones, five were closely related to SPFMV- Argentinean isolate, two with Korean isolate and one with Chinese isolate.

Emerging fungal diseases and management strategies for major diseases of aroids

Sample collection and isolation of pathogens associated with leaf rot and pseudostem rot in EFY

Infected leaves/pseudostem of elephant foot yam (EFY) with distinct symptoms were collected from ICAR-CTCRI and farmer's fields from Kottarakkara. Ten distinct symptoms were noticed in the infected portions (Fig. 59). Microbes associated with the samples were isolated and purified. Fifteen organisms were obtained and among them, *Colletotrichum* sp. and *Fusarium* sp. were the most predominant. Koch's postulates were successfully proved with the isolates of *Colletotrichum* sp. and *Fusarium* sp. (Fig. 60).

Fig. 59. Various symptoms on the foliage and pseudostem of EFY

Fig. 60. Symptom produced by isolates of *Colletotrichum* sp. and *Fusarium* sp. on EFY on challenge inoculation

Field evaluation of various fungicides to manage taro leaf blight

Field trial was conducted to refine management strategies by incorporating new generation fungicides and cultural practices. The effect of ten combinations of fungicides viz., spraying with Mancozeb + Metalaxyl 0.1% (T1), Mefenoxam + Chlorothalonil 0.1% (T2), mulching with paddy straw (T3), mulching with paddy straw + Mancozeb + Metalaxyl 0.1% (T4), Cymoxanil + Mancozeb 0.1% (I)* (T5), Potassium phosphonate 0.3% (T6), Copper oxy chloride 0.2% (T7), Cymoxanil + Mancozeb 0.1% (II)* (T8), Difenconazole 0.1% (T9) and control (T10) was studied in taro variety, Sree Kiran. All the treatments could significantly reduce the disease incidence (Fig. 61). The reduction of PDI over control ranged from 29.35% (Cymoxanil + Mancozeb (I) to 48.05% (Potassium phosphonate).

(*different commercial formulations)

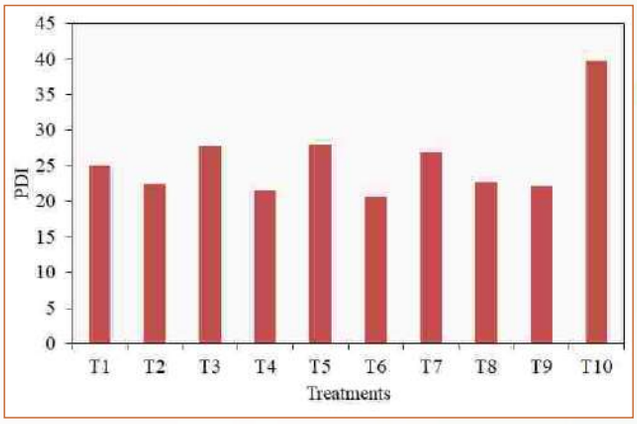


Fig. 61. Average percent disease index (PDI) calculated for various fungicides

Management of postharvest rot in elephant foot yam

Eleven treatments were evaluated for their consistency in controlling postharvest rot in elephant foot yam (Fig. 62). The treatments were cowdung slurry (T1), *Trichoderma* in cow dung slurry (T2), *Trichoderma* in rice starch water (T3), Mancozeb 0.2% (T4), Carbendazim 0.1% (T5), Mancozeb + Carbendazim 0.2% (T6), *Nanma* 0.7% (T7), Mancozeb + *Nanma* 0.7% (T8), Carbendazim 0.1% + *Nanma* 0.7% (T9), (Mancozeb + Carbendazim) 0.2% + *Nanma* 0.7% (T10) and control (T11). Apart from postharvest rot, the incidence of mealybug in stored corms was also assessed.

Fig. 62. (a) Assessment of postharvest rot after treatments (b) Assessment of mealy bug incidence in EFY

The least incidence of postharvest rot was noted with the treatment, Mancozeb + Carbendazim 0.2% (T6) followed by (Mancozeb + Carbendazim) 0.2% + *Nanma* 0.7% (T10) with 1.8% and 2.8% incidence, respectively (Fig. 63). Except the treatments, T1, T3 and T5 (cow dung slurry, *Trichoderma* in rice starch water and Carbendazim, respectively) and all other treatments could bring down both postharvest rot (PHR) and mealybug incidence to less than 10%. Based on the results obtained during last three years, treating the corms immediately after harvest with the combination fungicide, (Mancozeb + Carbendazim) 0.2% alone or in combination with *Nanma* 0.7% could keep the rotting and mealybug incidence level below 5%. The treatment, *Trichoderma* in cow dung slurry (T2) could keep postharvest rot (PHR) and mealybug incidence to less than 8% and it can be adopted in organic cultivation of elephant foot yam.

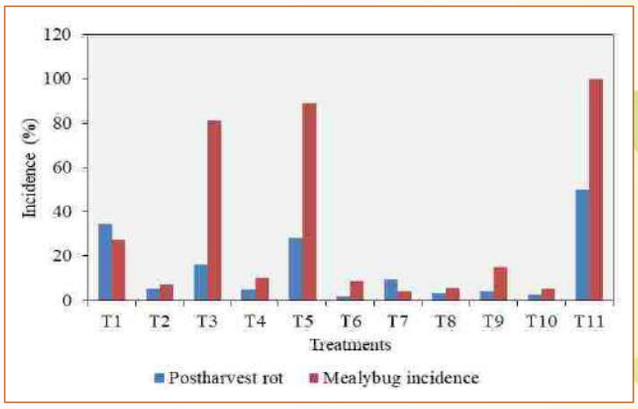


Fig. 63. Postharvest rot and mealybug incidence in EFY corms

Evaluation of bicarbonates against postharvest pathogens *(In vitro)*

Sodium, potassium and ammonium bicarbonates @ 0.5 and 1% were evaluated against 8 pathogens associated with postharvest rot in yams (Fig. 64). Ammonium bicarbonate at both concentrations resulted in 100% inhibition of mycelial growth of all the pathogens. Sodium and potassium bicarbonates showed differential antifungal activities against various pathogens. The inhibition by sodium and potassium carbonates (1%) ranged from 0.4 - 100% and 0 - 47%, respectively.

Fig. 64. Mycelial growth inhibition of 8 postharvest rot pathogens by ammonium carbonates @ 0.5 and 1%

Exploration of endophytes against *Phytophthora colocasiae* causing taro leaf blight

Endophytes are microorganisms residing inside plants and are not harmful. With an aim of identifying potential endophytes from taro against *P. colocasiae*, a total of 62 bacterial and 32 fungal endophytes were isolated from different taro plant parts. Initially, 15 bacterial endophytes were screened against the highly virulent isolate of the pathogen PCK (*P. colocasiae* kallampally) in which three were effective by inhibiting the growth in dual culture *in vitro* (Fig. 65). The remaining endophytes will be screened further.

Fig. 65. Inhibition of *Phytophthora colocasiae* by a bacterial isolate, S1 L3 from taro leaf

Fungal pathogens and disease management in cassava and yams

Field management of greater yam anthracnose

Different combination of fungicide (Carbendazim, 0.05%), bio control agent (*T. asperellum*), a cassava based bio pesticide (*Nanma*, 0.7%) and growing resistant varieties (var. Sree Keerthi) in the border were appraised against greater yam anthracnose caused by *Colletotrichum gloeosporioides*. The present package of soil and tuber treatment with *T. asperellum* along with seven sprays of Carbendazim (0.05%) resulted in lowest anthracnose intensity (55%) compared to control (97.5%), which was followed by spraying the combination of Carbendazim (0.025%) and *Nanma* (0.7%) seven times (75%) and spraying only Carbendazim (0.025%) and growing Sree Keerthi in the border (82 and 83%, respectively).

Evaluation of potential endophytes against greater yam anthracnose

In vivo assay was performed to evaluate the growth promotion activities of potential endophytes, *Bacillus amyloliquefaciens* isolated from the roots of *Phyllanthus niruri* and *Bacillus licheniformis* from the leaf of *Aloe vera.* Cowpea seeds were used for the assay by delivering the endophytes through seed treatment and spraying. Both the selected endophytes have significant contribution on growth promotion activities. The combination of seed treatment and spraying was more effective. Seed and spraying treatment combination of *Bacillus licheniformis* showed higher leaf length (13.9±0.1 cm) and plant height (28.43±0.5 cm), followed by seed treatment of *Bacillus licheniformis* (13.7±0.3 cm and 26.9 ±.52 cm), which was higher than those of control (Fig. 66).

Fig. 66. Effect of *Bacillus licheniformis* on growth promotion in cowpea. S+Sp:Seed treatment- spraying; Sp- Spraying; ST- Seed treatment; C- Control

Microscopic examination clearly manifested that the growth of *C. gloeosporioides* in PDA co-inoculated with the two potential endophytes showed profound changes in hyphal morphology and impaired and irregular mycelial growth (Fig. 67). Sporulation was very rarely seen in the endophyte treated sample when compared to control which is indicative of the antagonistic role of potential endophyte inhibiting fungal mycelial growth. Based on the field trial conducted using *Bacillus licheniformis* with different combination of seed, soil treatment and spraying, lowest anthracnose disease intensity of 47.7% was in combination treatment (soil treatment + spraying treatment). Disease intensity in fungicide treatment was 44.4%.

The expression of pathogenicity genes in *C. gloeosporioides* was studied. Kinetics of expression of selected genes was studied in the evaluated time intervals. In general, all the selected genes were up-regulated during the course of infection, especially from 4 to 24 h and then declined gradually. The normalized gene expression (control sample) increased in a narrow range from 4 to 15 h. Expression pattern in endophyte treated samples decreased after 8 h which need further validation.

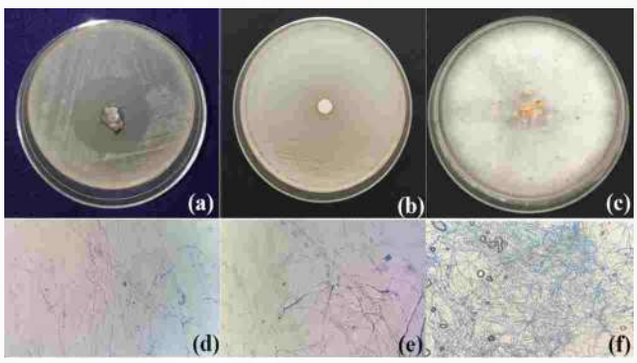


Fig. 67. Antibiosis and microscopic view of mycelial morphology of pathogen grown with endophytes. a & d: *Bacillus licheniformis,* b & e: Antibiosis by *Bacillus amyloliquefaciens,* c & f: Control

Cassava root rot

Cassava root rot infected fields in Kollam and Thiruvananthapuram districts of Kerala were visited. Unlike the tuber rot reported from Tamil Nadu, which was caused by *Phytophthora palmivora*, wilting of plants in Kerala was observed due to root rot (Fig. 68) in low land conditions and the infection occurred throughout the crop period. Analysis of samples showed the presence of *Fusarium* sp. and *Pythium* sp. (Fig. 69). The incidence varied between 50 and 80% in Kollam and 10% in Thiruvananthapuram.

In pathogenicity tests, *Pythium* sp. from Thalavoor (Kollam district) infected 30% of cassava plants and the two *Fusarium* sp. isolated from Pallichal (Thiruvananthapuram district) and Thalavoor, Kollam could infect 10% of the plants, when artificially inoculated under controlled conditions. Involvement of a greater number of pathogens and soil factors is suspected to cause severe damage, which is being explored. *In vitro* screening of fungicides showed that Carbendazim was effective up to 5 ppm against *Fusarium* sp. One of the potential *Trichoderma asperellum* (Tr 15) from ICAR-CTCRI microbial repository showed the highest inhibition of pathogen.

Fig. 68. Different symptoms of cassava root rot

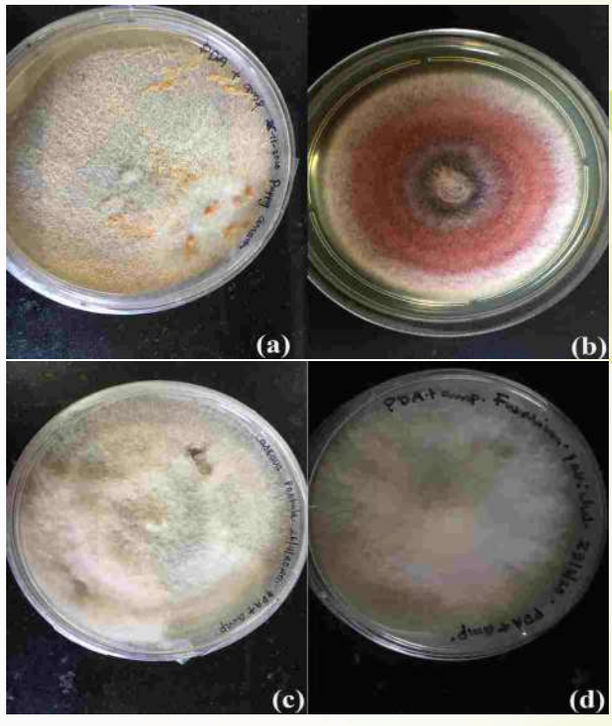


Fig. 69. *Fusarium* sp. isolated from cassava root rot samples of different locations in Kerala
(a) Kottarakara, (b) Thalavoor, (c) Thamarakudi and (d) Pallichal

Virus and Phytoplasma diseases in tropical tuber crops and their management

Cassava mosaic disease

Role of microRNA during cassava mosaic virus infection

Small RNA sequence libraries were prepared from a cassava mosaic disease (CMD) tolerant cassava variety, CMR-123 through next-generation sequencing approach. Total RNA isolated from leaf tissues of two CMD infected CMR-123 (123A and 123B) plants and an uninfected control of the same (123C) were used for the library preparation. Raw reads were subjected to sequence quality analysis and a total of 12,351,687 reads were obtained after removing the low quality reads in the sRNA library of control. In the infected samples, 123-A and 123-B, the total read counts were 14,609,032 and 12,351,687 respectively and about 97% of total data passed >= 30 phred score (Fig. 70). The adapter removed reads were aligned against different classes of small RNAs viz., siRNA (5.77%), snRNA (0.18%), snoRNA (0.18%), piRNA (17.49%), tRNAs (1.86%) and rRNA (34.59%) for contamination removal. The total reads were mapped to the host genome (*Manihot esculenta*). In the control library (123C), 55.8% of the total reads were mapped to the host genome, while 46.59% and 53.45% of the reads

were mapped to 123A and 123B libraries, respectively. The unique reads with length 17-35 bp were used for known miRNA identification of viridiplantae miRBase-22 reference mature and precursor sequences. The remaining reads were aligned with miRBase-22 precursor miRNA of viridiplantae.

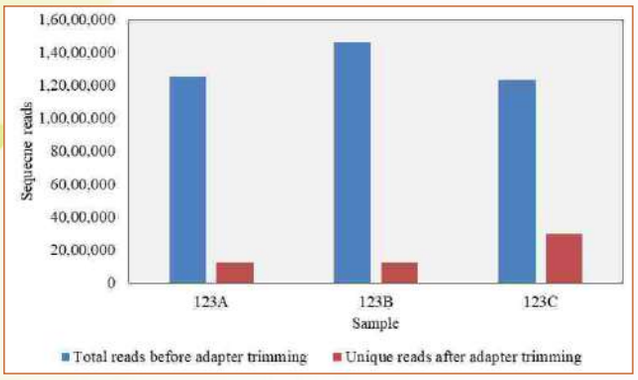


Fig. 70. Summary of sequence reads of sRNA leaf library of 123

The unaligned reads of precursor miRBase-22 were taken for alignment of reads against *Sri Lankan cassava mosaic virus* (SLCMV) genome (A: KP455486.1, B: KP455487.1). Small RNAs were then mapped to the distinct genes encoded in the SLCMV genome (Fig. 71). The unaligned reads from precursor viridiplantae miRBase-22 were taken for novel miRNA prediction, which was done using *Manihot esculenta* genome as reference using the tool miRDeep2 (version 2.0.0.8). Eight novel microRNAs were predicted from 123A library, four from 123B and 123C library using miRDeep2. Totally, 158 conserved miRNAs belonging to 22 families were identified in control leaf library of CMR123 using deep-sequencing data. Cassava microRNA mes-miR159b was the most abundant followed by mes-miR166e, mes-miR9386, mes-miR395d, mes-miR167c. Most of the aligned miRNAs were found to have targets in cassava transcripts. The cDNA library *Manihot esculenta* transcript, Phytozome 11, 305, V6.1 was used to predict the targets. Gene target prediction was done using psRNA target tool (*plantgrn.noble.org/psRNATarget*). MicroRNA families miR160, miR319, miR390, miR395, miR403, miR482, miR535 have predicted targets in immune receptors like leucine- rich repeats (LRR) and nucleotide binding site (NBS) and miR403, miR2950, miR3627 regulate resistance (R) genes and pathogenesis-related (PR) proteins and defensins. Differential expression was carried out by binomial test and the mean read count of samples, fold change and p-values were calculated. Differential expression analysis displayed significant regulation of miRNAs during cassava mosaic virus infection (Fig. 72). Sixty seven miRNAs were upregulated (Log2≥ 0.5) and 28 miRNAs were downregulated (Log2≤ 0.5) during infection.

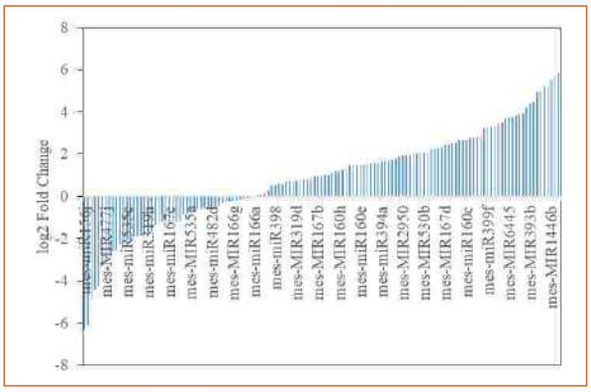


Fig. 71. sRNAs mapped to the distinct genes encoded in the SLCMV genome

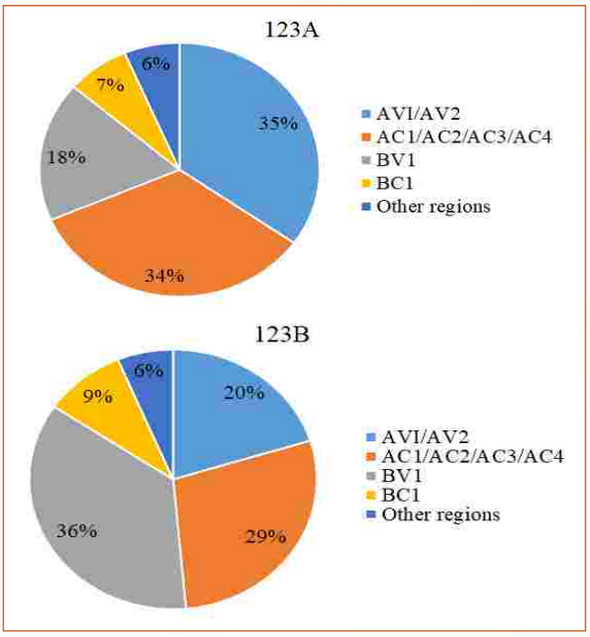


Fig. 72. Differential expression of miRNAs among the cassava 123 small RNA libraries during virus infection

Editing of cassava mosaic virus genome for developing resistance to CMD

Ac1 gene encoding replication associated protein and BV1gene encoding nuclear shuttle protein from DNA A and DNA B were selected as targets for editing of SLCMV genome using CRISPR/Cas9 and guide RNAs were designed based on various online tools. Preliminary steps for checking the efficiency, specificity and activity of gRNAs *in vitro*, using gRNA screening system were done.

Role of mixed infection in CMD

The effect of mixed infection of *Indian cassava mosaic virus* (ICMV) and SLCMV in CMD development in cassava has been studied. Cassava plants infected with single virus was confirmed through multiplex PCR analysis and selected as a source of inoculum. There was no substantial change in the symptoms when SLCMV infected plants were grafted with buds from ICMV. But severe symptoms were observed in ICMV infected plants grafted with buds from SLCMV infected plants.

Screening of cassava genotypes for cassava mosaic disease resistance

Fifteen cassava breeding lines (15S-103, 15S-409, 8S-501-2, 9S-132, 17S-143, 17S-135, 17S-241, CI-889, 17S-209, 9S-75, 15S-436, 17S-48, 17S-39, CR-54A3 and 15S-278) were screened for the resistance to cassava mosaic virus through chip bud grafting. The SLCMV infected plants, confirmed through multiplex PCR were selected as the inoculum source (scion) for grafting. Periodic observations of grafted plants were carried out by morphological (symptom appearance) as well as molecular analysis by means of ELISA and PCR, confirmed the breeding lines are resistant to cassava mosaic disease caused by SLCMV. ELISA, PCR and qPCR results revealed that the presence of SLCMV was only in control plants (susceptible *cv*. H-226) and not in the breeding lines tested. This has confirmed that all the fifteen breeding lines were resistant to SLCMV.

Dasheen mosaic disease in elephant foot yam

A field trial with five different varieties including local collections of elephant foot yam viz., Sree Athira, Peerumedu, VFPCK, Sree Padma and Gajendra, was conducted in block I of ICAR-CTCRI, Thiruvananthapuram. The incidence of *Dasheen mosaic virus* was investigated by observing disease symptoms and virus indexing was done by DAS-ELISA and Reverse transcriptase PCR. Disease severity was recorded and classified based on 1-5 symptom scale (1-mild chlorosis and mild puckering, 2-white feathering, 3-moderate chlorosis and puckering, 4-severe chlorosis and puckering, 5-stunting and severe chlorosis). Biometric parameters such as plant height, pseudostem girth and leaf spread were measured at 3 and 5 months after planting (MAP). Plant height, pseudostem girth and leaf spread were higher in non-infected plants as compared to infected plants. All the morphological variables continue to increase from 3 MAP to 5 MAP in both non-infected as well as infected plants of all varieties and then declined. There was a decrease in the leaf spread in Sree Athira variety due to infection at 5 MAP.

Cassava Mosaic Disease-Variability, Diagnostic, Vector relation and Management

Under this programme concluded in March 2020, during the past five years (2015-2020), several leads were made in the understanding of cassava mosaic disease in various angles like variability in cassava mosaic virus, disease diagnosis, molecular insight into CMD development such as the role of micro RNA in the disease, release of four CMD resistant lines and several breeding lines showing resistance in pipeline, mining of *MeNAC* genes associated with CMD, identification of two biotypes of *Bemisia tabaci* in cassava system having CMD, role of cassava genotypes on the life cycle of whitefly vector, role of endosymbionts on virus transmission, re-infection rate of cassava mosaic virus in healthy planting material, prominent role of nutrients in disease manifestation/reduction in disease intensity and successful establishment of cassava synthetic seeds for long term storage as well as easy transportation to far off places which otherwise difficult as bulky stem. Significant achievements of this project are summarised below:

Full genome of ICMV and SLCMV was sequenced and infectious clone of SLCMV was developed and infectivity was tested in *Nicotiana benthamiana.* NGS study of CMD infected plants showed higher accumulation of small RNA (sRNA) in diseased plants than in healthy ones.

Four CMD resistant lines (Sree Reksha, PDP CMR1, Sree Sakthi and Sree Suvarna) were released and several lines are in evaluation which has great potential for spread. Cassava biotype of *Bemisia tabaci* is found responsible for field level transmission and it was identified that they belong to Asia II5 and Asia I biotypes. Endosymbonts association with vector was established.

Different strategies were developed for virus free plant production with manipulation in nutrient management. The order of nutrients in suppressing the symptom was K > Si> nutrient mixture > Zn > B > herbal viricide > Ca > Mg > P. Method to produce synthetic seed of cassava has been standardized, which can be stored up to 65 days. Transgenic cassava (H-165 and TMS-6044) having RNAi constructs showed resistance to SLCMV infection.

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

Refinement of machineries for cultivation and processing of tuber crops

High quality cassava flour

High quality cassava flour was produced by static pressing method by employing response surface method with Box-Behnken design for process optimization. Cassava mash obtained by the rasping of the fresh roots without adding water (500, 750 and 1000 g) was taken in a clean muslin cloth and pressed at various pressures of 20, 40 and 60 bar for different time durations of 10, 20 and 30 sec using a hydraulic press. The dewatered mash was analyzed for moisture content and drying characteristics. The flour obtained after sun drying of the dewatered mash were analyzed for various biochemical, pasting, rheological and colour properties. When the cassava mash of different weights was pressed at different pressures and time, the maximum drying rate was 0.498 g water/min 100 g bone dry material for 750 g cassava mash at 20 bar pressure and 30 sec pressing. The minimum drying rate was 0.285 g water/min 100 g bone dry material for 1000 g sample at 60 bar pressure and 20 sec pressing. After dewatering, the moisture content of the pressed/ dewatered cassava mash varied from 38.04 to 44.96%. The starch loss in the mash due to pressing was very low and it ranged from 0.44 to 1.70%. The total colour difference was also very less, i.e., 7.48-11.06, when compared to 9.15 for the control. Maximum whiteness index was 91.95 and for the control sample, it was 90.38.

The optimum process parameters for high quality flour production were as follows (Fig. 73): pressure-60 bar, pressing time-30 sec and loading weight - 571 g of cassava mash. The resulting dewatered mash had a moisture content of 41.3% and starch loss of 0.58%. Among the colour qualities, total colour difference was 9.58 and whiteness index was 89.96. The biochemical properties were as follows: moisture content-8.45%, starch-70.76%, sugar-3.06%, fibre-0.27%, fat-0.45%, protein-1.18%, ash-2.62% and energy value-306.8 kcal. The flour had a peak viscosity of 2210 cP and break down viscosity of 1185 cP with a pasting temperature of 72.02ºC. The final and setback viscosities were 1507 cP and 4602 cP respectively. The storage modulus, loss modulus, complex viscosity and phase angle of the paste were 737.3 Pa, 1325 Pa, 25.94 Pa.s and 59.18º, respectively.

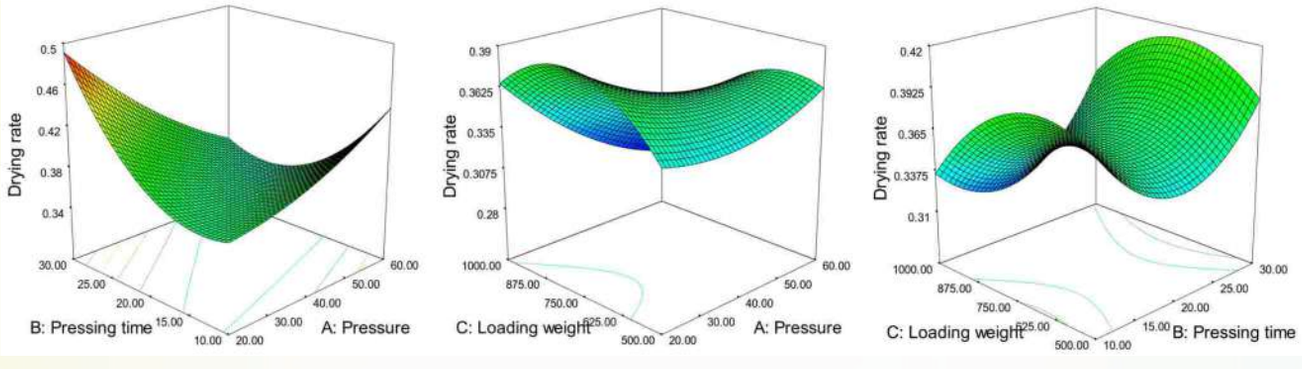


Fig. 73. Effect of process parameters on the drying rate of pressed cassava mash

Particle boards and adhesives from cassava by-products and starch

Cassava stem based particle board

Experiments were designed by Box Behnken response surface methodology for the development of particle boards (Fig. 74) from cassava stem-sugarcane bagasse using cashew nut shell liquid (CNSL) as binder. The variables were: amount of sugarcane bagasse (75 g), cassava stem (75 g), amount of CNSL (10, 15, 20%), molding pressure (150, 175, 200 bar), pressing temperature (100, 110 and 120°C). The process parameters were optimized as follows: CNSL-10%, pressure-168.24 bar and temperature-114.71 °C. At the optimized conditions, the density, moisture content and thickness of the board were 1024 kg m^{-3}, 7.35% and 0.48 cm, respectively. The water absorption by the board after 2 h soaking was 99.9% and after 24 h it was 197.5%. The colour values L, a and b were 41.26, 6.64, and 15.96, respectively and the total colour difference was 60.56. The browning index of the board was 11.74. The peak load was 19.69 N and modulus of rupture was 4.1 Nm m^{-2}. The hygroscopicity was 12.39, 20.94 and 26.3% at 75, 85 and 95% relative humidity, respectively.

Fig. 74. Cassava stem based particle board

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

The post harvest physiological deterioration (PPD) is a major constraint for cassava production and marketing. Physiological and biochemical changes in the stored cassava roots of selected cassava genotypes were studied. FT-NIR technique was developed for analyzing the quality changes in tubers under storage. The NIR spectral features were analyzed using PCA and chemometric tools to differentiate PPD category in root tissues. Surface coating of cassava after selected pre-treatment techniques was developed for increasing the shelf-life for one month or more periods for retail sale or export of cassava roots. Among the four different types of waxes viz., paraffin, carnauba, microcrystalline and candellila wax tested for their suitability for surface coating of cassava roots in twelve different cassava varieties, paraffin wax was found to be superior for shelf-life enhancement of cassava roots.

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

Effect of heat-moisture treatment on physicochemical and functional properties of cassava starch

The effect of heat-moisture treatments (HMT) on the properties of cassava starch was studied primarily to understand the effect of steaming over other heating methods for sago wafers making. The moisture range selected for the study was 10 - 40% and the heat treatments were hot air (120°C) for 3 h, microwave irradiation (900 W) for 5 min and open steaming (121°C) for 15 min. The physicochemical properties of the starch were affected by the treatments. There was a reduction in the swelling power and solubility of the treated starches (1.73 - 4.06 g/g and 0.76% - 3.3%, respectively), when compared to those of native cassava starch (9.5 g/g and 8.81%, respectively). The oil absorption index and freeze-thaw stability of heat moisture treated starches were higher than those of native starch. The percentage syneresis was highest for steam treatment and lowest for microwave treatment. There was a significant difference in pasting properties of the HM treated starch. An increase in pasting properties such as peak viscosity, trough viscosity, breakdown viscosity, final viscosity and pasting temperature were observed for the steam treatment. The loss modulus of the HM treated starch samples was higher than the storage modulus and thus starch behaved as dilute solution. Thus, HMT improved the physicochemical and functional properties of cassava starch, which serves as an important ingredient in different food and industrial applications.

Performance evaluation of the developed prototype continuous steaming machine for sago wafers/sago papad production

The developed prototype continuous steaming machine consists of chain sprocket conveyor system, steam generation system, temperature and pressure

monitoring system and electrical systems.The overall dimension of the machine is 2.83 m×0.90 m×1.10 m and the weight is 650 kg (Fig. 75). The initially developed prototype I was evaluated for its performance. Although there was sufficient steam production, considerable loss in steam was noticed over the steaming tank due to a number of slits on the surface of the steaming tank. In addition, deposition of condensate was also noticed due to the movement of steam from bottom to top direction, which affected the shape of sago globules. Thus, prototype II was fabricated by closing the steaming tank completely and made provision to supply steam from top to bottom direction. The prototype II exhibited better performance than prototype I in terms of steam efficiency. The approximate cost of the machine is ₹ 2.0 lakhs.

Fig. 75. Prototype continuous steaming machine for sago wafers/sago papad

The technology to produce sago from reconstituted dry cassava starch has been developed under this programme. Process to produce functional sago from wet cassava starch as well as reconstituted dry cassava starch incorporated with beetroot powder and sweet potato leaf powder, have been standardized. A prototype continuous steaming machine for the hygienic production of sago wafers/sago papad has also been developed.

Production of biochar from agricultural biomass and nutrient and biological enrichment

Biochar is considered as an effective method of carbon sequestration and potentially help to mitigate climate change. Biochar is found to increase fertility of acidic soils, increase agricultural productivity and provide protection against some foliar and soil-borne diseases. A cost-effective method for biochar production from cassava stem waste and other tuber crops residues was developed under this programme. The biochar was also enriched with co-composting techniques. Organic carbon and nutrient contents in the soil were positively influenced by biochar application. The application of biochar at 2% and 5% based on soil dry weight positively influenced the growth and yield of sweet potato.

Non-conventional applications of cassava starch in construction and building materials

Viscosity properties of native/modified cassava starch incorporated cement mortar

The viscosity of the starch incorporated cement mortar was measured by using Brookfield viscometer at different rpm (110, 160 and 210), concentration of starch (1, 3 and 5%) and soaking time (2, 4 and 6 min). When native starch in ungelatinized form was added as admixture in the cement, the viscosity was in the range of 9.56 to 20.43 cP under different conditions of rpm and concentration of starch. The change in viscosity was significant for the cement incorporated with starch modified with octenyl succinic anhydride (8.54-25.94 cP), acid (4.04-16.54 cP) and epichlorohydrin (10.14-25.48 cP), however, no significant change was observed for the cement incorporated with starch modified using sodium hypochlorite (11.52-20.35 cP) and propylene oxide (8.24-26.32 cP). When gelatinized starch was added to the cement, the viscosity varied from 28.15 to 39.82 cP for native starch,1.03-3.17 cP for oxidized starch, 24.54-43.54 cP for succinated starch, 26.97-47.94 cP for hydroxypropyl starch, 0.96-2.96 cP for acid modified starch and 15.24-58.18 cP for cross linked starch.

Thermoplastic starch sheets from starch-fibre composite

Thermoplastic starch sheets were prepared from cassava starch-cassava stem fibrous flour (Fig. 76). The experiments were designed using response surface methodology by employing Box-Behnken design and the variables used for the study were amount of glycerol (30, 40 and 50% based on the weight of starch), amount of cassava stem fibre (25, 50 and 75%), temperature of the die plate (120, 130 and 140ºC) and pressure of the die plate (120, 130 and 140 bar). Various physico-mechanical, hygroscopic and hydration properties of the sheets were analyzed. The optimized conditions to produce thermoplastic sheet from cassava-fibre-glycerol composite as derived from the response surface analysis were as follows: fibre-75%, glycerol-30% and temperature-120ºC and pressure-120 bar.

The sheet produced at this optimum condition had the following characteristics: density-1243 kg m^{-3}, moisture content-9%, total colour difference-29.59, yellowness index-31.80, peak load-191.84 N, percent elongation-3.96%, ultimate tensile strength-1.93 Nm m^{-2}, modulus of rupture-97.33 Nm m^{-2}, hygroscopicity at 85% RH-14.47%, hygroscopicity at 95% RH-18.67%, water activity-0.54, solubility-19.87% and expansion index after 2 h-12.76%.

Fig. 76. Thermoplastic starch sheet from cassava starch-stem fibre composite

Development and functional characterization of modified starches of cassava and lesser known tropical tuber starches for industrial application

Synthesis and characterization of cassava starch monophosphate

Starch monophosphates are modified starches synthesized by the reaction of starch with orthophosphate salts and are important ingredients in food industry. Synthetic conditions were standardized for food grade cassava starch monophosphate (Phosphorous <0.4% as per FDA regulations) using orthophosphate salts, with three levels of phosphorus content in the final product. The modified starch pastes have remarkably high clarity (98-99% transmittance), even after storage under refrigerated conditions. The starch monophosphates were low temperature gelling starches which do not require heating/minimum heating to effect gelation and have potential to be used as a substitute to the common gelling agents which require cooking and specific conditions to effect gelation in food systems. The phosphorus content of the modified starches was in the range of 0.004-0.021% and Brookfield viscosity of the 5% starch gel at 160 rpm and at 30±2ºC was 4.2-13.21 cP. The prepared cassava starch phosphates were evaluated as gelling agent in model gel candies (Fig. 77). The visco-elastic properties of the gel candies, both the fresh and stored gels (in refrigerated conditions) were measured, and it was observed that the dynamic moduli increased with increase in frequency. Storage under refrigerated conditions resulted in improved gel strength and more solid like character, which are desirable characteristics of the product. Thus, cassava starch monophosphate was found to be a suitable gelling and thickening agent in different food systems.

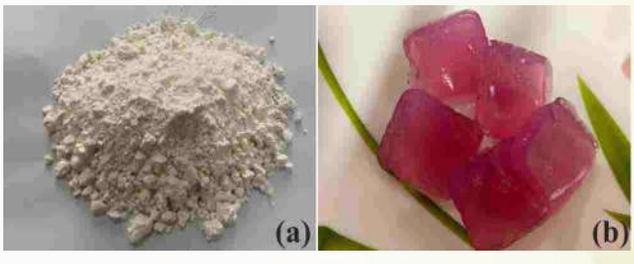


Fig. 77. (a) Cassava starch monophosphate and (b) Gel candies prepared from cassava starch phosphate

Isolation and characterization of Chinese potato starch

Starch was extracted from Chinese potato (*Plectranthus rotundifolius*) tubers and the composition and functional properties were determined to characterize the starch and explore its suitability in different applications. The extraction condition was standardized to obtain maximum starch yield without the interference of phenolic compounds. The process involved pretreatment of the tubers with aqueous sodium metabisulphite solution and the starch yield was about 17.5% on fresh weight basis. The starch possessed unique functional properties such as high peak viscosity (4326.7±114.9 cP) with extremely low breakdown (1134±58.1 cP) and setback (1156.7 ± 35.5 cP), low syneresis and good water binding capacity, which are desirable properties in food applications as thickener. The starch paste was more stable when compared to cassava starch. The different starch fractions in Chinese potato starch were as follows: rapidly digestible starch, 82.3±0.21; slowly digestible starch, 14.2±0.12% and resistant starch, 3.5±0.06%.

Development and evaluation of tuber crops based prebiotic and low calorie functional foods

Rice analogue

Rice analogue was developed from the composite flour containing cassava (60-70%), maida (20-30%) and beetroot powder (5-10%) (Fig.78) and their physico-chemical, nutritional and cooking characteristics were analyzed. The experiments were designed by response surface method by employing mixture design. In addition to the above flours, each formulation had 5% starch, gelatinized at 100ºC for 15 min in water and 10% whey protein concentrate. The process parameters optimized for the rice analogue were found to be cassava 68.16%, maida 22.13% and beetroot powder 9.71%. The physical properties of the developed product were as follows: length-5.74 mm, breadth-2.5mm, thickness-1.87 mm, arithmetic mean diameter-3.37mm, geometric mean diameter-2.98, sphericity-0.52, surface area-27.92 mm^2, volume- 8.58 mm^3, eccentricity index-2.30, flateness index-7.69, bulk density-489.61 kg m^{-3}, water activity-0.53 and total colour difference-67.37. The biochemical properties were as follows: moisture content-7.35%, starch-56.24%, sugar-8.22%, protein-9.73%, fat-4.53%, fibre-0.32%, ash-3.15%, and energy-341.76%. The product had a cooking time of 5.35 min and the swelling index and cooking loss were 2.32 and 11.30%, respectively.

Fig. 78. Rice analogue from cassava flour

Design and development of pre and post-harvest machineries/storage systems in tuber crops

Effect of varieties, size, shape and drying methods on drying characteristics of cassava chips for the production of high-quality cassava flour

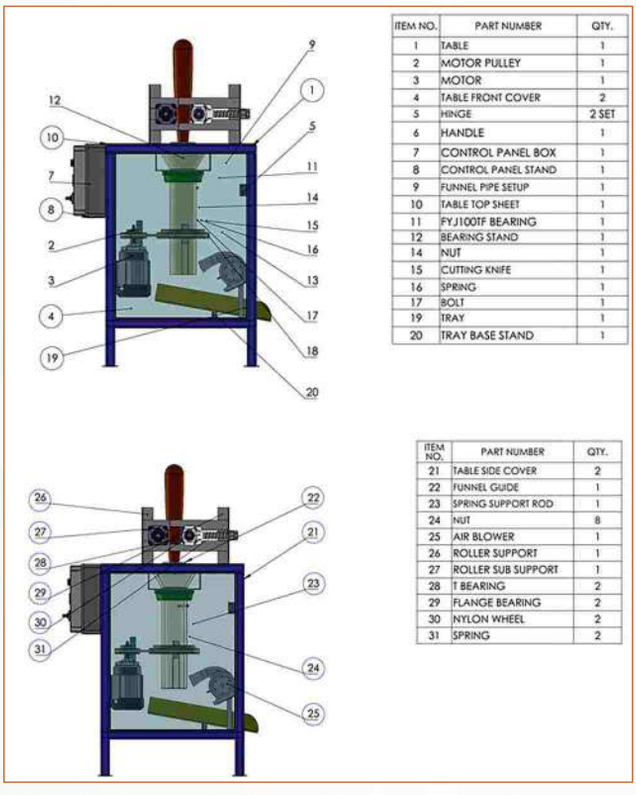
A study on the effect of different varieties (Sree Athulya, Sree Suvarna and M-4), size of the chips (1.5 mm, 2.5 mm and 3.5 mm), shape of the chips (circular, corrugated and rectangular) and drying methods (sun drying, solar drying and tray drying) on the drying characteristics of cassava chips for the production of high quality cassava flour (HQCF) was conducted. The drying characteristics such as moisture content, drying time, drying rate and the effect of weather parameters such as temperature, relative humidity and wind velocity of atmospheric air on drying were measured. The reduction in moisture content was faster in rectangular cassava chips than circular and corrugated cassava chips regardless of their size and drying method (Fig. 79), which could be due to the more available surface area for drying in the former case. The slicing of cassava chips into rectangular shapes would help to increase the moisture removal ratio in the different drying process. It was also found that cassava chips dried under tray drying had higher drying rate than those dried in solar and sun drying. There was no significant difference in terms of drying time and drying rate among the varieties. Studies on the quality parameters of the flour prepared from different chips have been initiated.

Fig. 79. Different shapes of cassava chips
(a) circular, (b) corrugated and (c) rectangular

Design and development of a continuous low cost cassava peeling machine for small scale processing

Peeling is the first unit operation in the processing of cassava for edible purposes. Cassava peeling is still largely done manually using a knife to remove the thin outer layers (skin and rind) of the tubers. Generally, women are involved in the manual peeling of cassava tubers. The capacity could be as high as 200 kg day^{-1} of

8 h operation per person. It is the most labour-intensive operation in cassava processing, involving tedious time-consuming manual labour, which invariably leads to low productivity. The production of edible grade cassava flour from peeled cassava tubers is further processed into different value added snack foods. At present there is no availability of machine for cassava peeling for small scale processing. Thus, a prototype continuous cassava peeling machine for small scale processing has been designed and fabricated (Fig. 80). The performance evaluation of the machine is being conducted.



ITEM NO.	PART NUMBER	QTY.
1	TABLE	1
2	MOTOR PULLEY	1
3	MOTOR	1
4	TABLE FRONT COVER	2
5	HINGE	2 SET
6	HANDLE	1
7	CONTROL PANEL BOX	1
8	CONTROL PANEL STAND	1
9	FUNNEL PIPE SETUP	1
10	TABLE TOP SHEET	1
11	FYJ100TF BEARING	1
12	BEARING STAND	1
14	NUT	1
15	CUTTING KNIFE	1
16	SPRING	1
17	BOLT	1
19	TRAY	1
20	TRAY BASE STAND	1

ITEM NO.	PART NUMBER	QTY.
21	TABLE SIDE COVER	2
22	FUNNEL GUIDE	1
23	SPRING SUPPORT ROD	1
24	NUT	8
25	AIR BLOWER	1
26	ROLLER SUPPORT	1
27	ROLLER SUB SUPPORT	1
28	T BEARING	2
29	FLANGE BEARING	2
30	NYLON WHEEL	2
31	SPRING	2

Fig. 80. Isometric view of the continuous low cost cassava peeling machine with detailed assembly parts

Development of convenience food and weaning food mixes from sweet potato and other tuber crops

Standardization and development of anthocyanin rich nutri-jelly from purple fleshed sweet potato

Standardization of the formulation of anthocyanin rich nutri-jelly from the extract of purple fleshed sweet potato variety Bhu Krishna was carried out with five different combinations of the ingredients (Fig. 81). Among all the combinations, the one with the composition of 1000 ml sweet potato anthocyanin extract, 600 g sugar, 0.5% citric acid and 12 g pectin was found to be the best. The moisture content, total soluble solids (TSS), titratable acidity and anthocyanin content of the nutri-jelly were 28.4%, 67.51 °Brix, 0.50%, 54.11 mg 100 g^{-1}, respectively and the overall acceptability as determined by sensory evaluation was 8.72. The storage study of the jelly (0, 30, 60 and 90 days) was conducted at ambient and refrigerated temperatures. The anthocyanin rich nutri-jelly has good storage stability at both storage conditions up to 90 days of storage.

Standardization and development of β-carotene rich nutri-jelly from orange fleshed sweet potato

The preparation of β-carotene rich nutri-jelly from the extract of orange fleshed sweet potato variety, Bhu Sona was standardized with different compositions of the ingredients (Fig. 81). The product which contained 1000 ml sweet potato extract, 650 g sugar, 0.5% citric acid and 13 g pectin was superior to other treatments. The physico-chemical properties of jelly were determined and sensory evaluation was also carried out. The nutri-jelly contained 27.29% moisture, 67.53° Brix TSS, 0.53% titratable acidity and 7.20 mg 100 g^{-1} β-carotene content. The overall acceptability as per sensory evaluation was 8.67. The β-carotene rich nutri-jelly has good storage stability at both ambient and refrigerated temperatures up to 90 days of storage.

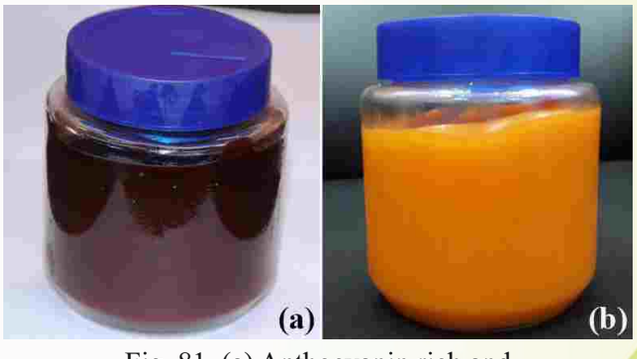


Fig. 81. (a) Anthocyanin rich and (b) β-carotene rich nutri-jelly

Standardization and development of ready-to-eat extruded puffed snacks from sweet potato

The process for ready-to-eat extruded puffed snacks was standardized with different combinations of sweet potato, cassava, maize and finger millet flours. Among all combinations, the composite of sweet potato flour (30%), cassava flour (30%), finger-millet flour (15%) and maize flour (25%) was found to be superior in the sensory and textural qualities (Fig. 83). The physicochemical properties of the puffed snack were as

follows: moisture-3.04 g, protein-10.25 g, fat-3.6 g, fibre-3.1 g, CHO-75.25 g, total ash-4.5 g 100 g^{-1}, length-2.50 cm, bulk density-0.05 g cm^{-3}, expansion ratio-4.98 and the sensory score was 8.10.

Standardization and development of nutri-sauce from orange fleshed sweet potato

The process for preparing nutri-sauce (Fig. 82) from the extract of orange fleshed sweet potato variety, Bhu Sona, was standardized. The total soluble solids (TSS) in the prepared sauce was 25º Brix.

Fig. 82. (a) Ready-to-eat extruded puffed snack from sweet potato and (b) nutri-sauce from orange fleshed sweet potato

Development of cassava starch based novel products and functional foods from other tuber crops

This flagship project was concluded in March 2020 with the following salient research achievements during the period January-March 2020.

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

Thermoplastic starch sheet

Thermoplastic sheets were also prepared from cassava starch and sorbitol (plasticizer) (Fig. 83). The variables used were the amount of sorbitol (30, 40 and 50% of the starch), temperature (120, 130 and 140°C) and pressure on the die plate (120, 130 and 140 bar). Time of pressing was fixed as 5 min and the amount of starch taken was about 150 g. The physical, mechanical, hygroscopic and hydration properties of the sheets were analyzed. The process parameters were optimized using response surface method as follows: sorbitol-30%, pressure-130 bar and temperature-129.79ºC. At these conditions, the thermoplastic starch sheets have the following physico-mechanical properties: density-1731.40 kg m^{-3}, moisture content-10.3%, total colour difference-58.0%, yellowness index-17.6, solubility-38.1%, expansion index-42.9%, water activity-0.60, peak load-55.5 N, per cent elongation at break-9.38%, modulus of rupture-89.76 Nm m^{-2}, ultimate tensile strength-1.17 N, hygroscopicity-14.80% and 22.85% at 75% and 85% relative humidity, respectively.

Fig. 83. Thermoplastic starch sheet prepared from cassava starch and sorbitol

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

Tuber starches in general, especially cassava starch is highly digestible and hence possess high glycemic index (>90). In order to reduce the digestibility and enhance the slowly digestible (SDS) and resistant starch (RS) fractions in cassava and sweet potato starches, physical as well as chemical modifications were standardized under this programme. Three types of resistant starches, viz., RS3, RS4 and RS5 were synthesized and characterized by esterification with octenyl succinic anhydride and citric acid, retrogradation and lipid complexation techniques. Cassava starch-curcumin composite with sustained release property of the incorporated bioactive compound and improved anti-proliferative activity was developed. Hydrogels of native/modified cassava starch and its composites were evaluated as sustained release matrices for incorporating therapeutic drugs.

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

The ready to use laddu mix from different combinations of sweet potato flour (25-75 g), Bengal gram flour (25-75 g), sugar (20 g) and cardamom extract (1.5 g) was standardized. Among the combinations, the sample

with 50% sweet potato flour and 50% Bengal gram flour was found to be the best. The moisture content in the laddu mix ranged from 3.48-3.92%, protein 10.75-11.52%, fat 2.38-2.86%, total ash 2.58-3.53%, fibre 2.7-3.3% and CHO 75.12 to 76.50%.

Under this programme, process has been standardized for the preparation of ready-to-cook pasta from composite flours of elephant foot yam, suji and finger millet as well as sweet potato-pseudomillet flour combinations. The recipes were standardized for instant sweet potato paratha mix, ready to use laddu mix, anthocyanin and β-carotene rich cakes and weaning food mixes.

EXTENSION AND SOCIAL SCIENCES

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

The concluded results of the different activities taken up under this project during the period 2015-2020 are reported below.

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

Technological interventions in tuber crops

The salient findings during the last five years of this study are summarized below. In Nadia and 24-Parganas districts of West Bengal, elephant foot yam varieties resembling var. Gajendra from Bihar/Andhra Pradesh were popular among the farmers. In Sangli district of Maharashtra, Sree Athulya variety of cassava produced significantly higher yield (52 t ha^{-1}). Demonstrations in Katel, Wagabandhe and Deriye in Maharashtra revealed that Da-340 of greater yam produced the maximum yield of 2.72 kg $plant^{-1}$. The frontline demonstrations on improved varieties viz., Sree Arun, Sree Kanaka, Bhu Sona and Bhu Krishna of sweet potato conducted at Belagavi, Karnataka revealed that Sree Arun produced the highest tuber yield of 36 t ha^{-1}.

Ten frontline demonstrations of improved varieties of cassava viz., Sree Jaya, Sree Vijaya, Sree Pavithra and Sree Swarna were conducted in the Kanyakumari district of Tamil Nadu during 2017-18. Sree Pavithra produced the maximum yield (36 t ha^{-1}) followed by Sree Jaya (35 t ha^{-1}). Twenty demonstrations on improved varieties of sweet potato viz., Sree Arun, Sree Nandhini and Sree Bhadra were conducted in Belagavi district of Karnataka during 2017-18. The variety, Sree Arun produced the highest yield (27 t ha^{-1}). Fifteen frontline demonstrations on improved varieties of cassava were conducted in Kanyakumari, Salem and Namakkal districts of Tamil Nadu during 2018-19. The yield of improved varieties of cassava was 15.45% higher than that of the local varieties.

Demonstrations on improved variety of Chinese potato viz., Sree Dhara conducted in Tirunelveli district, Tamil Nadu during 2018-19 indicated that yield of Sree Dhara (26.7 t ha^{-1}) was higher by 16.6% than the local varieties (22.9 t ha^{-1}). The FLDs on fertilizer best management practices in elephant foot yam var. Gajendra were conducted during 2019 in East Godavari and West Godavari districts of Andhra Pradesh. About 8.21% yield increase was observed in fertilizer best management practices over farmers' practices. The gross income and net income obtained from fertilizer best management practices were 8.21% and 8.73% higher in comparison to farmers' practices.

Tuber crops consumption and strategic market analysis

Sixty per cent respondents consumed short macroni pasta once or twice in a month. Taste (93%), aroma (82%) and chewiness (78%) were the most recommended attributes. In Nayagarh and Khorda districts of Odisha, the per capita consumption of taro was estimated as over 10 kg. The urban pasta consumers preferred cassava pasta relative to commercial pasta product due to its aroma (mean = 6.06) and taste (mean = 6.10). The willingness-to-pay increased from ₹146.50 to ₹188.00 (+ 28%) when crop information was given, and it was ₹191 with health benefits information. Consumption of tuber crops among farmers in Kanyakumari district revealed that per capita consumption (kg $month^{-1}$) 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).

Entrepreneurship and commercialization in tuber crops

A model for creating seed entrepreneurs through variety licensing system and seed entrepreneurship was developed and currently implemented through ABI.

Agricultural Business Plan Training Module was developed for sharpening critical business skills of farmers and other stakeholders. Since 2016, a total of 490 students, 400 farmers and 120 extension workers were trained by using this module. A survey indicated the presence of five categories of agri start-ups in India viz., upstream (input) marketplace start-ups, downstream (output) farm-to-fork supply chain start-ups, IoT and big data led innovation start-ups, engineering-led innovation start-ups and farming as a service (FaaS) start-ups.

A conceptual framework for assessing the commercialization success of agricultural technologies (varieties, mineral nutrient mixture, eco-friendly pesticides, novel foods and industrial products) was developed. The tuber crops entrepreneurial ecosystem involving stakeholders like extension agents, entrepreneurs, and farmers was assessed in the dimensions of human capital, culture, finance, policy and markets. A scale for assessing the perceptions of the stakeholders on the dimensions of tuber crops entrepreneurial ecosystem was developed.

Value chain analysis in sweet potato

Value chain analysis of sweet potato was conducted during 2017-18 in Belagavi district of Karnataka with a sample size of 137 covering 112 farmers, 10 commission agents of APMC market in Belagavi, five wholesalers from Delhi, Maharashtra, Punjab and Gujarat and 10 retailers in Belagavi town. Multiple regression was employed for assessing the farm harvest prices of sweet potato. The results of regression indicated that greater price realization was in September, October and November.

The value chain of sweet potato in Belagavi district representing various actors at the upstream, midstream and downstream levels, along with their functions and interrelationships is displayed in Fig. 84.

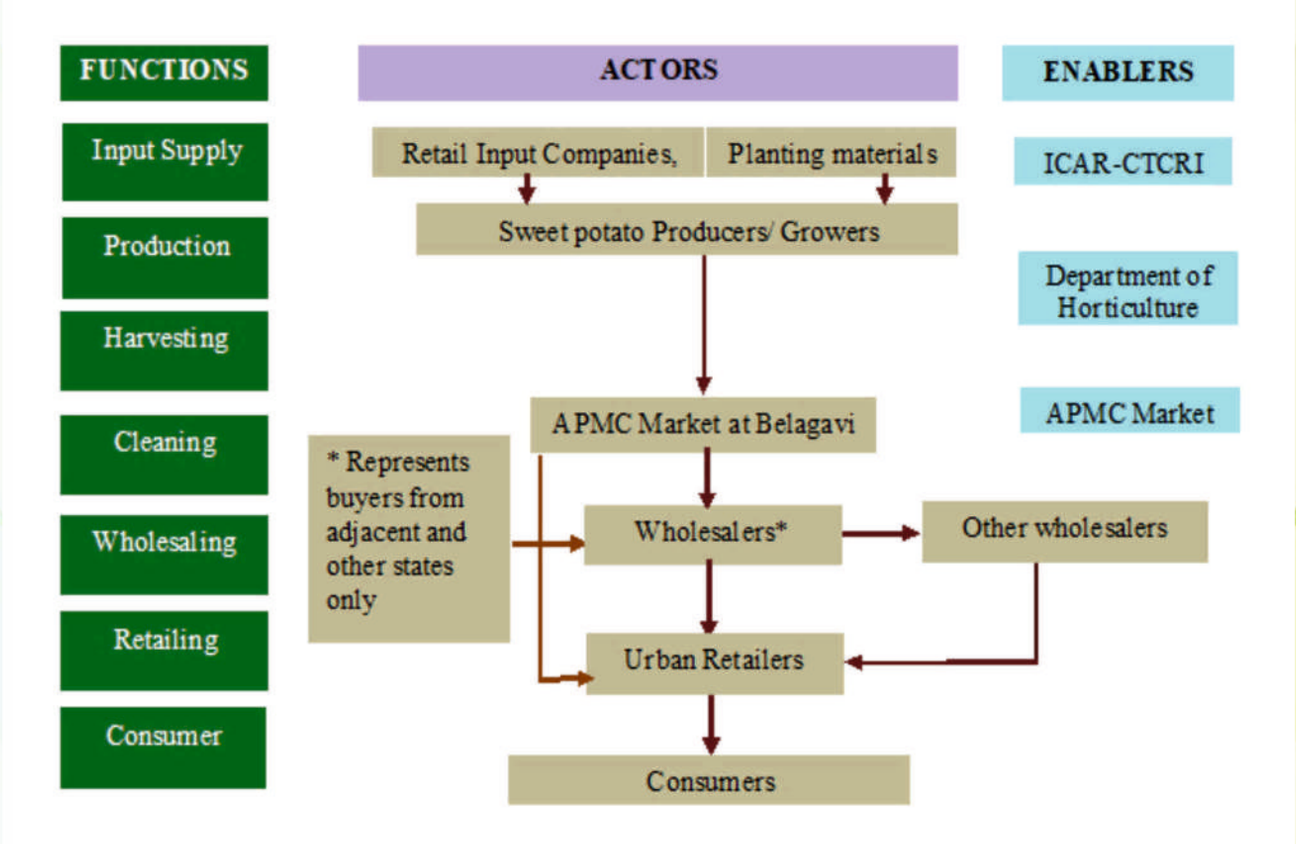


Fig. 84. Sweet potato value chain map in Belagavi district of Karnataka

The total cost for cultivating sweet potato was estimated to be ₹24,262 ha^{-1}. Human labour and chemical fertilizers along with farm yard manure were the major expenditure accounting to 32% and 26%, respectively. The average yield of sweet potato was 9.83 t ha^{-1} and it was sold at a rate of ₹599 $quintal^{-1}$. The major problem faced were incidence of pests and diseases, low price and high commission fee (7-8%). The major constraints faced by the commission agents were lack of cold storage facilities, price fluctuations and delay in payments from buyers, whereas the constraints faced by the wholesalers and retailers were price fluctuations, high transportation cost and lack of cold storage facilities.

Time series data were used for forecasting the consumption of cassava and starches in India using ARIMA model. The total volume of consumption of cassava tubers are expected to reach 1.45 million tons by 2021 from 0.94 million tons in 2016 growing at a compound annual growth rate of 9% during 2016-2021. Similarly, demand for cassava starches and starch products in India are expected to increase 1.7% by 2021 from 1.5% in 2016.

Sustainable livelihood analysis of tuber crops

The Rural Sustainable Livelihood Index (RSLI) analysis of tuber crops farmers and non-tuber crops farmers were conducted in Kerala (60), Tamil Nadu (120), Karnataka (120), Andhra Pradesh (120) and Odisha (100) with a total sample size of 520 farmers. Tuber crops viz., cassava, sweet potato, elephant foot yam and taro and non-tuber crops viz., paddy and banana were covered for the analysis using DFID methodology.

The RSLI was 67 for tuber crops farmers in Pathanamthitta and 70 for Thiruvananthapuram district. The RSLI for paddy growers was more (63) than cassava farmers (52) in Tirunelveli and Kanyakumari districts of Tamil Nadu. The RSLI was marginally more for paddy growers (57.97) than sweet potato growers (56.02) in Belagavi district of Karnataka. The RSLI for banana growers was slightly higher (69) than that of the elephant foot yam growers (66) in East Godavari and West Godavari districts of Andhra Pradesh. The RSLI was marginally more for paddy growers (60) than taro growers (59) in Nayagarh district of Odisha.

ICT applications for technology transfer of tuber crops

IoT device called Electronic crop (eCrop) was developed as an one point solution for smart farming to reduce yield gap, and to develop and implement models on crop growth, pest and disease development etc. using the real time data collected from the field. It was validated with sweet potato growth and showed an accuracy of 93.25% between predicted and observed yield. User friendly web interface for doing smart farming using Electronic Crop (eCrop) was also developed. Using this facility, smart farming can be taken up for any crop under any weather, soil and management condition and in any location. Testing the performance of the crop under any simulated condition is also possible through this interface. It is available at URL www.ctcri.org/eCrop. A model digital farm of tuber crops is being set up at ICAR-CTCRI through this system.

Two mobile apps, VFT: cassava and VFT: taro, were developed for identifying varieties of cassava and taro, respectively from the images of leaves. These apps use the Convolutional Neural Network (CNN) image classification model using deep learning algorithm of artificial intelligence for classifying the images. The CNN image classification model for cassava was developed using the pictures of emerging leaves (Top view) of four cassava varieties 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.

A self learning cassava and sweet potato crop growth model was developed using artificial intelligence algorithm. The code for developing the model was written in python and Tensor Flow libraries were used. The accuracy of the model was tested against the observed values. It was found that the accuracy of prediction increases regularly when more and more missing. Developed an online platform, HOMS (Horticulture Crops Online Marketing System) to help marketing of fruits, vegetables and tuber crops. Its

android mobile app version HOMS app can be downloaded from Google Playstore. Tuber Crops Online Marketing System (TOMS), i.e., the online marketing system exclusively for tuber crops and its android mobile app TOMS App were developed.

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

Interactive visualization tools for high dimensional data of area production statistics of tuber crops were developed in R using the package Plotly. A comparative analysis of different scoring methods for construction of Soil Quality Index (SQI) was carried out. An R package was developed for the computation of SQI by integrating ANOVA and Principal Component Analysis.

Different machine learning methods were compared for the classification of soils based on properties. The data for the study 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. The regression models viz., Cubist regression tree and Partial Least Square Regression (PLSR) were applied for the prediction of soil properties such as OC, CEC, pH and clay using spectral data. Cubist and PLSR models were implemented in R using the packages cubist and pls.

Bayesian Interval Mapping for non-normal traits has been applied for mapping of SSR markers of cassava mosaic disease, where the response variable was the disease score which was non normal and categorical. The data on 112 SSR markers on varieties/accessions, viz., MNGA and CI-732, which are highly contrasting in the trait of interest and its progenies were selected. Thirteen marker alleles (SSRY28^{a}, SSRY28^{b}, SSRY324^{d}, SSRY59^{a}, SSRY59^{b}, SSRY43^{d}, SSRY32^{c}, SSRY32^{d}, SSRY10^{b}, SSRY30^{c}, NS97^{c}, NS185^{a} and Ns185^{b}) were identified by Single Marker Analysis and 2 QTLs were identified by Composite interval mapping. The first QTL was associated with markers NS97^{a} and SSR38^{a}, but with a low phenotypic variance. The second QTL was strongly associated with NS97^{c} flanked by SSRY30^{c} and this QTL on chromosome 22 was found to be the major QTL which was responsible for the phenotypic variation in CMD. Three QTLs were identified by Multiple Interval Mapping, one in chromosome 6 at a position 6 cM and the other two QTLs in chromosome 7 at 0.1 cM and 60.4 cM positions. The two main QTLs identified by refined model were located in chromosome 7 at two different positions. To apply the Bayesian method of QTL mapping, disease score was modelled by Poisson distribution and the expectation was connected to QTL effects through a log link function. The MCMC procedure in SAS designed for Bayesian analysis using Markov Chain Monte Carlo algorithm was used for computations.

Meta-analysis of 61 QTLs associated with CMD and CBSD was carried out and fifty eight QTLs were projected in the consensus map. Eleven Meta QTLs for CMD resistance and 10 Meta QTLs for CBSD resistance were predicted. A total of 73 candidate genes were identified for QTLs associated with CMD resistance and 51 were found associated with QTL for CBSD-RN resistance. Various defence related proteins were found to be associated with these candidate genes.

The quantitative structure activity relationship (QSAR) of anthocyanins in greater yam (Acc. Da-340) and sweet potato (var. Bhu Krishna) was studied. The polyphenolic compounds were docked against enzyme molecules, Acetylcholinesterase and Angiotensin Converting Enzyme (ACE) and the overall drug likeness were tested *in silico*. Polyphenolic compounds of greater yam and Chinese potato, viz., Kaemferol and Rosmarinic acid exhibited inhibitory activity of ACE. Pelargonidin and peonidin, the anthocynidins present in sweet potato, could inhibit Acetylcholinesterase and Angiotensin converting enzyme.

Machine learning method was applied for the identification of miRNAs in cassava (*Manihot esculenta*) and 41,381 transcript sequences downloaded from Phytozome database were used for the study. The miRNAs of cassava available in MIRBASE was used as positive dataset and 28 pre-miRNAs were predicted. In sweet potato, 7,71,963 SNPs were predicted using SNP-MLer, a tool for learning Neural Network models and the prediction tool SNP-ML for SNP detection.

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

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

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

Technological interventions and documentation of farmers' innovations including ITKs in tropical tuber crops

Following new activities were initiated under this project in April 2020.

FLD on Fertilizer best management practices in greater yam

Five FLDs on Fertilizer Best Management Practices (FBMP) in greater yam (Local cultivar: Bombay yam) with 50 cents each intercropped with coconut and turmeric were conducted during June 2019 to March 2020 crop season at Utchili and Vaddiparru villages of Atreyapuram mandal in East Godavari district of Andhra Pradesh (Fig. 85). Secondary and micro nutrient-inclusive customized fertilizer formulation developed based on site specific nutrient management (SSNM) technology for greater yam was applied for enhancing the productivity and profitability of greater yam. The foliar liquid micronutrient formulation developed by ICAR-CTCRI was also applied as foliar spray as per recommendations.

The average yield of greater yam in FBMP treatment was 14.25 t ha^{-1}, which was 10.81% more than the yield obtained from farmers' practices (12.86 t ha^{-1}) in East Godavari district. Similar trend was observed in FBMP treatment for gross income (10.81%) and net income (40.13%) in comparison to farmers' practices. Total cost of cultivation was less for FBMP fields (₹1.11 lakhs ha^{-1}) than the farmers' practices (₹1.19 lakhs ha^{-1}) and the difference was 7.05%. Farmers opined that FBMP treatment resulted in robust vegetative growth, absence of nutrient deficiencies, higher yield, good shape and size of tuber and increase in the weight of tuber.

Soil health cards were distributed to these five FLD farmers of East Godavari for managing the soil fertility for sustainable production of greater yam and other crops. The productivity and profitability of greater yam farming with FBMP increased significantly over the farmers' practices. Partnership with agricultural input dealers/fertilizer firms to ensure timely and continuous supply of customized fertilizers and micronol, issuing soil health cards, promotion of participatory research and extension and strengthening the linkages with other stakeholders will ensure sustainability of greater yam farming.

Fig. 85. FLD on fertilizer best management in greater yam - a view of farmers' fields in East Godavari district of Andhra Pradesh

FLD on improved varieties of sweet potato

Five FLDs on improved varieties of sweet potato viz., Sree Arun, Sree Varun, Sree Kanaka and Bhu Krishna with 50 cents each were conducted during February-June 2020 in Kilimanoor panchayat of Thiruvananthapuram district of Kerala. The sweet potato variety, Sree Arun produced the maximum yield (22.30 t ha^{-1}) followed by Sree Varun (21.70 t ha^{-1}), Sree Kanaka (17.80 t ha^{-1}) and Bhu Krishna (15.40 t ha^{-1}) under irrigated lowland conditions. Average yield of improved varieties of sweet potato was found to be 19.30 t ha^{-1} which was 9.66% greater than the yield of local varieties (17.60 t ha^{-1}). Gross income realized from improved and local varieties of sweet potato were, ₹2.89 and ₹2.64 lakhs ha^{-1} respectively. The productivity and profitability of sweet potato with improved varieties increased significantly over the existing local varieties. After the harvest, the planting materials of sweet potato varieties viz., Sree Arun, Sree Varun, Sree Kanaka and Bhu Krishna were distributed to neighbouring villages and panchayats viz., Manampur and Ottoor in Thiruvananthapuram district for establishing seed villages for meeting the demands of planting materials of improved varieties with high yielding potential and nutritional qualities.

FLD on improved varieties of elephant foot yam

Five FLDs on improved varieties of elephant foot yam viz., Gajendra and Sree Padma with 50 cents each were conducted during March-December 2020 in Keelapuliyur village of Tenkasi district of Tamil Nadu (Fig. 86). Gajendra produced the maximum yield (39.6 t ha^{-1}) followed by Sree Padma (37.5 t ha^{-1}). Average yield of improved varieties of elephant foot yam was found to be 38.55 t ha^{-1} which was (7.86%) greater than the yield of local varieties (35.74 t ha^{-1}).

Fig. 86. View of demonstration plots of improved varieties of elephant foot yam

Net income realized from improved and local varieties of elephant foot yam were, ₹2.58 and ₹1.99 lakhs ha^{-1}, respectively. The benefit cost ratio of the improved varieties was 1.81 which was greater than (14.6%) the local varieties (1.58). The productivity and profitability of elephant foot yam with improved varieties increased significantly over the existing local varieties. Establishment of seed villages to ensure timely and continuous supply of improved varieties, promotion of participatory research and extension, organized marketing system and strengthening the linkages with other stakeholders of tuber crops will ensure sustainability of farming in the long run.

FLD on improved variety of Chinese potato

Fifteen FLDs on improved variety of Chinese potato viz., Sree Dhara with 50 cents each were established during August-September 2020 at Pallakkal Pothukudi in Tirunelveli district and Kuthapanjan in Tenkasi district of Tamil Nadu in collaboration with Department of Horticulture, Government of Tamil Nadu (Fig. 87). Recommended package of practices was adopted by the farmers as per the guidance and supervision of scientists of ICAR-CTCRI. Farming practices, socioeconomic characteristics, pest and disease incidence, growth and yield parameters of the crop in fifteen demonstrations are being recorded.

Fig. 87. Demonstration plots with Chinese potato (var. Sree Dhara)

Documentation of Farmers innovations and ITKs in tropical tuber crops

Detailed review of literature was done for preparing the interview schedule and other data collection instruments for documenting the farmers' innovations and ITKs in tropical tuber crops in Kerala. Farmers' innovations and ITKs pertaining to varieties, agronomic practices, nutrient management, pest and disease management, mechanization, pre- and post-harvest processing, value addition, storage of planting materials and tubers etc. are being documented from tuber crops growers of Wayanad, Malappuram, Ernakulam and Thiruvananthapuram districts of Kerala.

Upscaling tuber crops technologies for promoting food and nutritional security

Per capita consumption of sweet potato

To estimate Sweet potato Biofortification Priority Index (BPI), the per capita consumption of sweet potato from various states were collected from secondary sources. Results revealed that in 2016, Arunachal Pradesh had highest annual per capita consumption of sweet potato (6.31 kg) followed by Mizoram (2.26 kg) and Meghalaya (1.25 kg) (Fig. 88). Since the North-Eastern states consumed more sweet potatoes than other parts of India, it is essential to promote sweet potato varieties and other food products in these states.

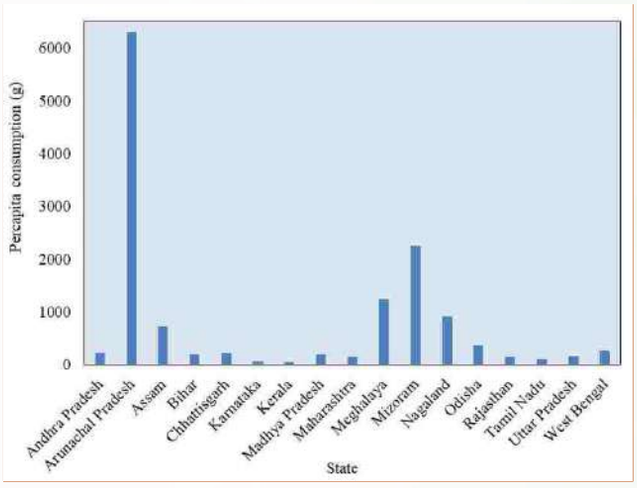


Fig. 88. State-wise annual per capita consumption of sweet potato (Source: NSS Household Consumer Expenditure Surveys)

Development of Biofortification Priority Index

A Biofortification Priority Index (BPI) was developed to identify the Indian states which require field interventions to promote biofortified varieties of sweet potato. The BPI developed by Harvest Plus was modified to identify priority states using the production and consumption of sweet potato along with Vitamin A and Zinc micronutrient deficiency status in each state. Results indicated that Meghalaya (36.62%), Odisha (27.86%), Mizoram (25.58%), Assam (19.25%) and Arunachal Pradesh (13.75%) were prioritized states for promoting biofortified varieties of sweet potato.

Promoting biofortified varieties of sweet potato in Anganwadis

A field intervention for promoting biofortified varieties of sweet potato in Anganwadis was implemented in 10 schools in Tenkasi district, Tamil Nadu. About 2,500 vine cuttings of biofortified sweet potato varieties, viz., Bhu Sona and Bhu Krishna were distributed and 10 FLDs were laid out in Anganwadis (Fig. 89). To equip the Anaganwadi workers in producing biofortified sweet potato varieties, two capacity building programmes were conducted in which 100 Anaganwadi workers participated.

Fig. 89. FLD on biofortified sweet potato in Anganwadi, Tenkasi, Tamil Nadu

Mapping of women's empowerment in tuber crops cultivation for engendering research and development

Women play an important role in cassava cultivation and hence a study was conducted to map the women empowerment in cassava cultivation in Thiruvananthapuram and Pathanamthitta districts of Kerala as these areas are having sizeable area under cassava cultivation. A total of 100 respondents were selected using simple random sampling from both the districts which included 65 women and 35 men respondents for the analysis.

Profile characteristics of the women respondents

The study revealed that nearly 90% of the women belonged to middle age (35-60 years). About 45% of the women had education upto high school level and 25% was graduates. Majority (65.63%) of them had agriculture as their primary occupation. Family size indicated that only 24.62% had small family (<4 members) and majority (75.38%) had big family with 4 to 6 members. One third of the respondents (33.84%) have experience of more than 20 years in agriculture and 29.23% were with 10 to 20 years which reveals that they are doing agriculture traditionally. More than half of the respondents (55.39%) had more than 10 years of experience in cassava cultivation. Majority of the women were marginal farmers having an area of below 2.5 acres. Mostly women were involved in agriculture at household farm level and not in commercial farming. The mean area of cassava cultivation was 0.48 acres as they belonged to marginal and small category. Nearly half of the respondents (49.23%) had livestock component. Less than one fifth of the respondents (18.46%) only had availed credit from banks and other financial sources for agriculture purposes. Majority of the women had medium level of aspiration (72.30%) and innovativeness (50.76%) in cassava cultivation.

Extent of participation in cassava cultivation

The extent of participation of farm women and men in cassava cultivation were estimated and the respondents were classified into three categories viz., low, medium and high using mean and SD. It was observed that majority of the women respondents (61.53%) and men respondents (68.57%) had medium level of participation in cassava cultivation. This may be due to the fact that cassava is mostly grown in homestead system of cultivation.

Practice wise extent of participation in cassava cultivation

The participation of women and men respondents in cassava cultivation was estimated using mean participation score. The overall participation score was more for men (2.43) than women (2.16) in cassava cultivation which was significant at 1% level. The difference in the level of participation of women and men in the practices viz., land preparation, identification of pests and their management and value addition, which were significant at 1% level. It was revealed that the participation score for the value addition was more for women (1.95) than men (1.65) as many women have undergone training at ICAR-CTCRI and started tuber crops-based agribusinesses. Significant differences in the level of

participation were observed between women and men respondents for the practices viz., identification of diseases and their management and grading and marketing. Non-significant differences were observed for the practices like sett treatment, application of organic inputs, irrigation, intercultural operations and storage of planting materials.

Women Empowerment index in cassava

Women's Empowerment Index in Agriculture is a composite index developed by International Food Policy Research Institute (IFPRI) and USAID's Feed the Future in February 2012. This comprehensive index comprises of sub indicators to measure the inclusion levels of women in agriculture. The modified methodology was used for women empowerment index in cassava. Women Empowerment Index in Cassava (WEIC) consists of five domains viz., production decision-making, access to productive resources, control over use of income, community leadership and time allocation and each domain has sub indicators of empowerment.

The mean empowerment index of men was more than women in all aspects except group membership, which could be due to the formation of self-help groups at the village level and mostly women are members in the groups. Women have a lot of opportunity to work in groups because of the implementation of schemes and projects at the village level. Access to and decisions on credit and speaking in public are non-significant. The overall empowerment index between men and women were significant at 5% level. Women empowerment index in cassava was estimated to be 0.78 and empowerment index for men was 0.86. Men were dominating in all the indicators except group membership hence, suitable interventions are required to improve the conditions of farm women and empower them in all aspects.

Needs of farm women in cassava cultivation

The needs of the farm women were assessed to identify the gaps in their occupation and also for building their capacities. Training on improved technologies of cassava cultivation was the first need of the farm women with a mean score of 2.83 out of maximum score of 3. The other needs in the order of importance were credit/loan facilities (2.82), training on value addition in cassava (2.78), demonstrations on improved varieties/technologies of cassava (2.77), crop insurance scheme (2.76), quality planting materials of improved varieties of cassava (2.74), marketing facilities (2.72), Self Help Group for cassava based agribusinesses (2.70), subsidies/critical inputs for cassava cultivation (2.68) and pre and post harvest machineries to reduce drudgery (2.31).

Preferences in cassava cultivation

The first preference given by the farm women was for good cooking quality of the tubers with a mean score of 2.91 out of maximum score of 3, as in Kerala the cassava is cultivated for table purpose rather than commercial. The second preference was for high yield potential (2.83) and other preferences in the order of importance were short duration varieties (2.65), good keeping quality (2.63), suitable for organic farming (2.60), climate resilient/drought resistant varieties (2.46), pest and disease resistant varieties (2.35) and suitable for cropping system (2.34).

Opportunities in cassava cultivation

Regarding opportunities in cassava cultivation as perceived by women it was observed that women gave first rank (2.88 mean score) to cassava cultivation as it is suitable for homestead farming, cropping systems and integrated farming systems. The other opportunities as perceived by farm women in the order of importance were scope for value addition (2.75), linking crop insurance scheme (2.71), enhancing yield by adoption of improved technologies (2.60) and suitable for different agroclimatic and edaphic conditions (2.51) and source of food for farm animals (1.91).

Constraints in cassava cultivation

The constraints in cassava cultivation as perceived by farm women were collected on a three point continuum. The constraints were ranked based on the mean score. The first problem reported by the women was wild animals' attack (2.69). The other major constraints in the order of importance were high labour cost (2.57), price fluctuation (2.52), erratic rainfall and climatic conditions (2.34) and poor shelf life of tubers (2.18), lack of knowledge and access to crop loans/subsidies

(2.12), non-availability of good quality planting materials (2.08) and lack of marketing facilities (2.03). The labour cost was also high and nearly 40 % of cost of cultivation was spent towards labour charges. Price fluctuation was also expressed by the women as the farm gate price was very low. Poor shelf life of tubers is also a constraint and hence they are not able to store them for long time which affects their marketing.

Impact assessment of technologies of tropical tuber crops

Different tuber crops technologies viz., varieties, production, protection and value addition technologies have been developed and implemented in farmer's field by ICAR-CTCRI. These technologies were compiled from 2005 onwards for assessing the impact. In-depth review of literature related to adoption and impact studies was done to understand the various impact assessment methodologies. Based on this, an interview schedule was prepared for data collection.

Framework for socio economic impact assessment

The socio-economic impact assessment broadly classified into *ex-ante* and *ex-post* assessment. The *ex-ante* assessment is done before the introduction of technology while, *ex-post* is done after the introduction of technology. The socio-economic impact assessment was further classified into micro and macro level. Micro level studies were done at farm level and macro level studies were done at region and or at country level.

Adoption and impact

Adoption and diffusion of tuber crops technologies was assessed to understand its scope and end users. *Ex-ante* adoption studies are done at micro and macro level for the crops which are not currently cultivated. *Ex-post* adoption studies were done at both micro level and macro level for the crops which are already in cultivation. For micro level *ex-ante* adoption studies, simulation was used, while for *ex-post* adoption studies, logit/probit, tobit, heckman and double hurdle models were used. For micro level *ex-ante* impact studies, simulation and economic surplus model are most widely used, while for *ex-post* impact studies Partial budget analysis (PBA), Propensity score matching (PSM), Randomized controlled trials (RCTs), Economics surplus model (ESM), Instrumental variable (IV), Difference in difference (DID) and Regression adjustment are mostly used.

Status of tuber crops cultivation

Area, production and productivity of root and tuber crops for the year 2018 were collected from the Food and Agriculture Organization of the United Nations website (http://www.fao.org). The area, production and productivity of cassava and sweet potato in India for the period of 2001-02 to 2017-18 and state wise area, production and productivity of cassava and sweet potato for 2017-18 were collected from the Department of Agriculture, Cooperation and Farmers Welfare website (http://agricoop.nic.in). Information regarding the country-wise export of cassava during 2016-17 to 2018-19 and sweet potato during 2011-12 to 2018-19 from India was collected from APEDA website (https://agriexchange.apeda.gov.in). Simple descriptive statistics and compound annual growth rate were determined. The growth rate was interpreted in terms of percentage.

It was estimated that the tuber crops were grown in an area of 62 million ha with a production of 832 million tons with an average productivity of 11 t ha^{-1}. Among the tuber crops, cassava is the most important tropical tuber crop and a staple food crop in many of the African countries. Potato accounted for about 44% of the overall root and tuber crop production in the world, followed by cassava (33.39%), sweet potato (11.05%), yams (8.72%) and aroids (2.6%). Though potato leads in the production among the tuber crops, cassava holds the top spot in area under cultivation. Besides area and production, potato (20.94 t ha^{-1}) and sweet potato (11.40 t ha^{-1}) witnessed the highest productivity among the tuber crops.

The compound annual growth rate of area under cassava (-1.38%) and sweet potato (-0.70%) cultivation have shown a negative trend over the years from 2001-02 to 2017-18. Though the area under sweet potato cultivation has shown a negative trend, an increase in its productivity has increased its growth in production (1.40%) over the years. On the contrary, in cassava, there was reduction in the area as well as productivity, there was also a decline in the growth of production of cassava over the years.

The area (0.09 million ha) and production (2.86 million tons) of cassava is highest in Tamil Nadu followed by Kerala (0.05 million ha and 1.73 million tons). Tamil Nadu alone contributes nearly 58% of the total cassava produced in the country. Productivity of cassava is also highest in Tamil Nadu (31.94 t ha^{-1}) which is more than the national average (28.64 t ha^{-1}). Apart from south Indian states, some of the north-eastern states such as Nagaland (1.60%), Assam (0.58%), and Meghalaya (0.73%) also provide a considerable share in total cassava production during 2017-18.

Total area under sweet potato cultivation in India was about 0.13 million ha during 2017-18 with a production of about 1.50 million tons. Among the states, Odisha had the highest share of area under sweet potato (30.94%), followed by Kerala (15.98%), West Bengal (15.62%) and Uttar Pradesh (13.25%). Though the area under cultivation of sweet potato in Kerala is less than half of that in Odisha, it produces nearly 23% of the total sweet potato produced in the country, whereas Odisha contributes only 25% to the total production.

Asia-Pacific (APAC) is the largest market and second largest producer of cassava products. China is the world largest importer of cassava products, mainly cassava chips and cassava flour. Thailand and Vietnam are the largest exporters of cassava globally. It was estimated that the production of cassava in Asia increased by 12.8% compared to the production in 2013 (Global tapioca market, 2017-2021). India is also one of the importers and producers of cassava. Cassava is mainly used as a raw material for starch and sago factories and used for culinary purpose. About 24% per cent of cassava was exported to United Arab Emirates followed by USA (13%) and Oman (12%) during 2016-17 to 2018-19.

Sweet potato is mostly consumed as snacks in boiled or baked form, and also used for vegetables. About 80% was sold through retail markets in India during 2011-16 and the rest is exported to other countries. About 73% of sweet potato was exported to Nepal followed by United Arab Emirates (15%) and Maldives (10%) mostly as fresh tubers during 2018-2019.

Price analysis and forecasting of cassava and sweet potato

Time series data on monthly wholesale prices of cassava and sweet potato from January 2010 to December 2020 for six selected states in India were collected from the AGMARKNET price portal (https://agmarknet.gov.in). District wise farm gate price of cassava for Kerala for the period of 1998-99 to 2016-17 were collected from Directorate of Economics and Statistics website (https://eands.dacnet.nic.in). Simple descriptive statistics and analytical methods such as Exponential Smoothing Models (ESM), Auto Regressive Integrated Moving Average (ARIMA) and Artificial Neural Network (ANN) were employed for price forecasting.

Development of intelligent smart technologies for tropical tuber crops

Mobile Apps for Online Marketing

Two online marketing platforms, HOMS (Horticulture-crops Online Marketing System) for horticultural crops and TOMS (Tuber Crops Online Marketing System) exclusively for tuber crops, were developed (Fig. 90 and 91). The android mobile apps of both are available in Google Playstore. These platforms can be operated using Malayalam or English. Registration is simple and free and a mobile number is essential for registration. Buyers and Sellers of the items can post messages in the market platform in simple steps. Seller can give the quantity available for sale, items to be sold, place etc. online. Buyer also can give the details in the similar way. All such posted messages will be displayed in the market platform and everybody can see it. After seeing the message of interest, both buyers and sellers can negotiate and can have a deal. ICAR-CTCRI has no liability in price fixation or delivery of the items, or any other issues related with transactions. These terms should be agreed for becoming a member of the marketing system and for posting messages in it. For posting messages, membership is not essential. But the new facilities which are expected to be added in the market like SMS alerts, will be given only to the members. Apart from connecting Buyers and Sellers, this system also links producers with procurement agencies, distributors, input suppliers as well as logistics service providers. The HOMS market is available at http://www.ctcritools.in/homs and TOMS at http://www.ctcritools.in/toms.

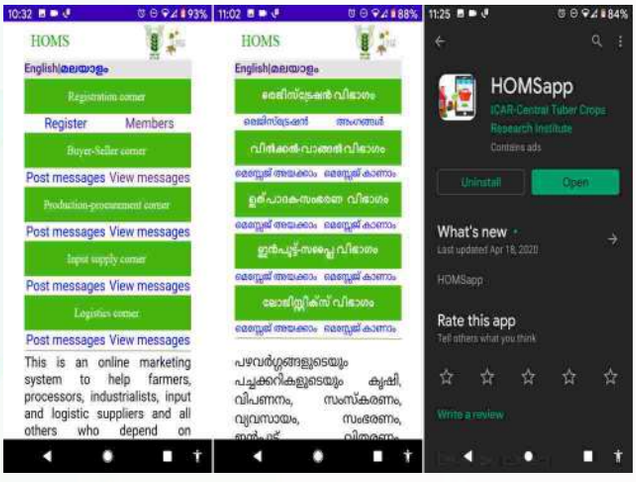


Fig. 90. View of HOMS app

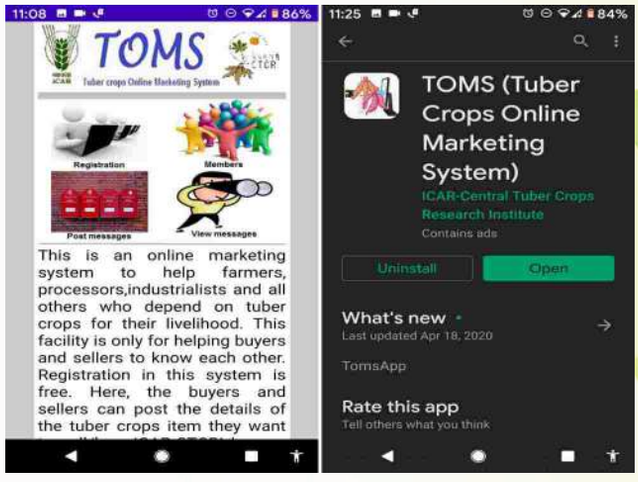


Fig. 91. View of TOMS app

Smart farming using eCrop

An eCrop based smart farming system was developed and installed in the field (Fig. 92). The eCrop, automatically acquires weather parameters at specific intervals and this data is updated in the ICAR-CTCRI website. Advisory for precision farming is generated using this data everyday by the crop simulation models in the back end. For sweet potato, SPOTCOMS model generates advisory for precision farming. The advisory includes the quantity of water, N, P and K values that should be provided to the crop at daily/weekly interval or total for the remaining crop period in one dose. The advisory is received by the control unit at a fixed time and the fertigation unit is triggered automatically, by which the fertilizers and water as per the advisory is applied to the crop.

Fig. 92.(a) Smart farming system and (b) Control unit of smart farming system

Self Learning Cassava Model

Self learning cassava model was developed to add learning capability to the IoT device eCrop. Extreme gradient boost algorithm (XGBoost) of artificial intelligence was used for developing the model. Data on cassava growth for the varieties, Sree Visakham, Sree Sahya and M-4 during the crop seasons 1999-2000, 2000-2001 and 2001-2002 were used for the study. An increase in the accuracy of the model was observed for predicting height, tuber weight and leaf area. Coding was done using Python with Tensorflow library.

Generation and application of statistical and bioinformatics tools for tropical tuber crops research and development

Machine learning tool to predict protein-protein interaction and host pathogen interaction between plants and *Phytophthora* sp.

A computational approach was developed for the prediction of plant host proteins with *Phytophthora*, using the protein sequence information on plant and pathogen. Experimentally validated protein sequences from five *Phytophthora* species that interacts with

proteins from 5 hosts (*Solanum lycopersicum*, *Glycine max*, *Nicotiana benthamiana*, *Arabidopsis thaliana* and *Solanum tuberosum*) were downloaded from Uniprot database and used as the positive interacting dataset and generated negative datasets (non-interacting host and virus protein sets) by randomizing the interacting protein sequences using Randomized algorithm in R and recombining the sequence features in such a way that they differ entirely from the interacting pairs. The protein features were extracted using the R package, protr and different machine learning tools were applied to develop prediction models to test whether the pair of proteins interact or not. The protein features extracted include amino acid composition, dipeptide composition, normalized Moreau-Broto autocorrelation, CTD composition and pseudo-amino acid composition. The data were split into training and test datasets and machine learning methods such as support vector machines, random forest and ensemble methods were applied to evaluate the method's accuracy, specificity and sensitivity. In SVM based prediction, the highest accuracy of 75% was obtained for Radial Basis Function Kernel. The SVM based on dipeptide composition features also performed with an accuracy of 75%. Overall, the model achieved a maximum accuracy of 86% using Random Forest.

An interactive web application for prediction of interacting proteins using RShiny was developed to select the protein features and the methods for prediction (Fig. 93).

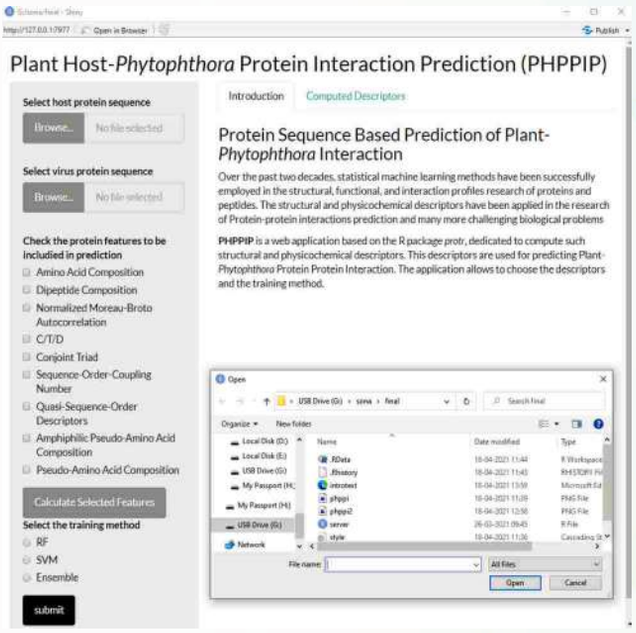


Fig. 93. Front end of the web application to predict plant-pathogen interaction

NEH, TSP AND SCSP PROGRAMMES

Scaling up of biofortified tuber crops through 'Rainbow Diet Approach' in the North Eastern Hill Region: ICAR-CTCRI NEH programme (Nodal Officer: Dr. Sheela Immanuel; PI: Dr. P. S. Sivakumar; Co-PIs: Drs. M. Nedunchezhiyan, K. Laxminarayana, V. B. S. Chauhan, M. S. Sajeev, P. Murugesan, H. Kesava Kumar, T. Krishnakumar and P. Prakash)

In this approach, a mixed methods approach involving campaigns, public rallies (Fig. 95), frontline demonstrations, school gardens, entrepreneurship development programmes are organized in four states - Arunachal Pradesh, Mizoram, Meghalaya and Tripura. Two public rallies, 30 frontline demonstrations (Fig. 96) involving antioxidant rich sweet potato varieties, four entrepreneurship programmes, four campaigns involving 820 farmers and 260 school and college students were conducted. A training programme on

Raw and boiled form

Processed form

Fig. 94. Tuber crops rainbow diet

Rainbow Diet Campaign

Rainbow Diet Campaign is the 'Campaign' approach initiated in the North Eastern states to address the micronutrient deficiencies especially Vitamin A deficiency. Since two North Eastern states i.e., Mizoram and Tripura have high prevalence of Vitamin A deficiency among 10-16 age group, a tuber crops based 'Rainbow Diet' using antioxidant rich sweet potato varieties (β-carotene and anthocyanin rich) (Fig. 94) is promoted.

'Promoting tuber crops based rainbow diet for food and nutritional security' was jointly organized by ICAR-CTCRI and ICAR-RC NEH, Kolasib, Mizoram, during 21-22 February 2020.

A Workshop cum Training on Promoting Rainbow Diet 'Achieving food, nutritional and health security through tuber crops' was organized in collaboration with ICAR Research Complex for NEH Region, Tripura Centre, Lembucherra, Agartala on 24 February 2020. Around 300 farmers and farm women

representing various SHGs, FPOs, Farmers' Clubs from different districts of Tripura attended the workshop with their local germplasm of tuber crops and its recipes. A Stakeholders cum Interface Meet (Entrepreneurship Development Programme) on 'Promoting tuber crops based Rainbow diet for food, nutrition and health security' was jointly organized by ICAR-CTCRI and College of Fisheries, Central Agricultural University (I), Tripura on 25 February 2020.

Fig. 95. Public rallies conducted in Khupa (Anjaw, Arunachal Pradesh) and Tura town (Meghalaya)

Fig. 96. Workshop cum training on promoting Rainbow diet and distribution of planting materials for FLD in Tripura

Seed Entrepreneurship and Seed Village development

Two seed villages were established in Anjaw (Arunachal Pradesh) and Sepaijala (Tripura) districts. Fifty farmers were trained in quality planting material production of biofortified varieties of tuber crops. Thirty seven Frontline Demonstrations (FLD) of biofortified varieties of sweet potato (var. Bhu Sona and Bhu Krishna) were conducted in Anjaw district, Arunachal Pradesh and Tura, Meghalaya. About 200 stems of CMD resistant cassava varieties were distributed for FLD on Eri Silkworm production for

promotion in NEH (Fig. 97). About 11,000 vine cuttings of sweet potato were distributed to Tura (Meghalaya) and Anjaw (Arunachal Pradesh) for laying out FLDs in seed villages benefitting 140 farmers.

Ethnic food festivals for documentation of traditional foods

Three ethnic food festivals were conducted in Arunachal Pradesh (Fig. 98), Mizoram and Tripura. During these festivals, 30 farmers displayed 123 food products developed from tuber crops. Fifty recipes from tuber crops from Tripura were documented.

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

During the year 2020, 47 tribal households were adopted from Phalsipadar, Bujilimendi, Budhapadara, Nediguda, Kantiadhia and Jharkedi villages of Chakapada (Block), Kandhamal (District) for demonstrating tuber crops based farming system (0.4 ha model) (Fig. 99). Planting materials of sweet potato (2,25,000 vine cuttings), greater yam tubers (3,000 kg), elephant foot yam (3,000 kg), taro (500 kg), cassava (3,000 stems), yam bean seeds (25 kg), maize seeds (20 kg), red gram (10 kg), vegetable seed kits (125 nos.) and back yard poultry birds (Vanaraja, 1000 nos.) were distributed to the tribal farmers. Vegetable kits contained *Amaranthus*, bhendi, chilly, onion, cowpea, French bean, *Dolichos* and bottle gourd seeds. Regular monitoring was done to address the problem faced by the tribal farmers. For capacity building of the tribal farmers, four on-farm trainings on 'Production and value addition in tropical tuber crops' were organized at Falsipadar village, Tikabali block, Kandhamal district, Odisha on 23 December 2020 and at Chakrakiari village, Chakapada block, Kandhamal district, Odisha on 24 December 2020.

Fig. 97. CMD resistant cassava varieties FLD on Eri Silk worm production in collaboration with Central Silk Board

Fig. 98. Tuber crops ethnic food festival in Anjaw, Arunachal Pradesh

In tribal farmers' field, the average yields of different crops were as follows: sweet potato- 16 t ha^{-1}, yam bean -20 t ha^{-1}, taro- 16.5 t ha^{-1}, elephant foot yam-34 t ha^{-1}, maize - 3,550 kg ha^{-1} and ragi- 1,140 kg ha^{-1} and other crops are yet to be harvested. Each tribal household produced sufficient tubers, rice, ragi, maize etc. for consumption (food and nutritional security) and surplus for selling (cash income).

Fig. 99. Tuber crops cultivation in tribal farmers' fields

Empowerment of farmers through tuber crops based technological interventions: ICAR-CTCRI SCSP programme (Nodal Officer: Dr. Sheela Immanuel; PI: Dr. D. Jaganathan, Co-PIs: Drs. G. Byju, K. Susan John, K. Sunilkumar, V. Ramesh, R. Muthuraj, M. S. Sajeev, T. Krishnakumar, A. V. V. Koundinya, B. G. Sangeetha and E. R. Harish)

Technologies of tropical tuber crops viz., improved varieties, nutrient use efficient varieties, site specific nutrient management, integrated nutrient management, pest and disease management, post harvest processing and value addition were disseminated through frontline extension programmes such as on-farm demonstrations, training programmes, farm advisory visits, field days, and exhibitions (Fig. 100).

Frontline demonstrations

A total of 64 FLDs were conducted in Kerala and Tamil Nadu for the benefit of 64 SC farmers. The details of the demonstrations are given below:

Ten on farm demonstrations on site specific nutrient management (customized fertilizers and micronol) in cassava were conducted in Thiruvananthapuram district of Kerala covering an area of 5 acres with ten progressive farmers. Twenty on farm demonstrations on site specific nutrient management (customized fertilizers and micronol) in elephant foot yam and taro were conducted in Ernakulam district covering an area of 10 acres with twenty progressive farmers.

Nine on farm demonstrations on the use of lime in cassava, popularization of the variety, Sree Pavithra and soil test-based application of Mg, Zn and B in cassava were conducted in Kollam, Alappuzha and Pathanamthitta districts of Kerala covering an area of 4.5 acres with nine farmers.

Site specific nutrient management in cassava (Thriruvananthapuram district)

Improved variety of elephant yam

Improved variety of Chinese potato

Supply of critical inputs in Malappuram district

Supply of planting materials of Chinese potato in Tirunelveli district

Fig. 100. FLDs on improved varieties/technologies of tuber crops under SCSP programme

Fifteen demonstrations on the improved variety of Chinese potato viz., Sree Dhara were conducted in Tenkasi and Tirunelveli districts of Tamil Nadu covering an area of 7.5 acres with fifteen farmers. Five demonstrations on improved varieties of elephant foot yam viz., Gajendra and Sree Padma were conducted in Tenkasi district of Tamil Nadu in an area of 2.5 acres with five farmers.

Five demonstrations on improved varieties of sweet potato viz., Sree Arun, Sree Varun, Sree Kanaka and Bhu Krishna were conducted in Thiruvananthapuram district of Kerala in an area of 3 acres with five farmers.

Critical inputs viz., planting materials, customized fertilizers, microfood, farm implements, and tools were distributed to the SC farmers for enhancing productivity and farm income from improved technologies of tuber crops.

Outreach programmes

Training programmes, field days, farm advisory visits and exhibitions were conducted in Thiruvananthapuram, Alappuzha, Kollam, Pathanamthitta, Ernakulam and Malappuram districts of Kerala and Tenkasi and Tirunelveli districts of Tamil Nadu for the benefit of 514 SC farmers and other stakeholders (Fig. 101). Publications on technologies of tropical tuber crops and training kits were given to them during training programmes. The important programmes organized during the year are given below.

- Training programmess on improved technologies of tuber crops cultivation on 16 January 2020 at Vadakkekara, North Paravoor, Ernakulam for the benefit of 91 farmers and on 17 January 2020 at Thiruvankulam, Ernakulam for the benefit of 115 farmers.
- Field day and establishment of demonstrations on 25 February 2020 at Thiruvankulam, Ernakulam for the benefit of 25 farmers and on 26 February 2020 at Vadakkekara, Ernakulam for the benefit of 34 farmers.
- Training on Improved technologies of tuber crops for enhancing farm income on 18 December 2020 at Chenkal, Thiruvananthapuram for the benefit of 65 farmers.
- Wide coverage was given in leading newspapers for dissemination of technologies of tuber crops for the benefit of farming community.

Training at Vadakkekkara, Ernakulam


Training at Thiruvankulam, Ernakulam


Field day at Vadakkekkara, Ernakulam

Training at Chenkal, Thiruvananthapuram

Fig. 101. Outreach programmes on tuber crops under SCSP programme

EXTERNALLY AIDED PROJECTS

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: Dr. C.Visalakshi Chandra)

Under this work plan, CIP has supplied a total of approximately 20,000 hybrid seeds obtained from controlled crosses to ICAR-CTCRI through NBPGR. The activity started in June 2018. The seeds were germinated in a phased manner with 3,000 - 4,000 seeds each in four batches. The methodology for germination of seeds was standardized initially and treatment with concentrated sulphuric acid for 40 min was found as ideal time for scarification and obtaining maximum germination. From the first three batches of around 10,000 seeds, 480 hybrids were selected based on flesh colour (orange) and dry matter and the clones were maintained in polybags. A set of 4,000 seeds were germinated in the glass house during March 2020, of which 3,500 seedlings were established. One hundred and sixty hybrids were selected based on good tuberization, flesh colour and dry matter (based on texture while cutting and mouth feel). Poor tuberization like formation of pencil roots (Fig. 102), irregular tuber shape like horizontal constrictions, woody roots etc were observed in almost 50% of the seedlings. The vine cuttings of selected seedlings were potted for clonal multiplication. The selected clones were replanted as duplicates and pruned and maintained in an open fenced field with regular irrigation and insecticide application. A preliminary trial was laid out with 240 high starch orange fleshed clones for evaluation in the upland during February 2020 and harvested in June 2020. The experiment was laid out in augmented design with three controls, viz., Sree Retna, Sree Kanaka and Bhu Sona in 8 blocks. There was tuberization in 81.6% of the accessions. Majority of the hybrids (152) had per plant yield less than 100 g, while 10 hybrids had per plant yield between 250-500 g (Fig. 103). A high dry matter content ranging between 25-31.2% was recorded in 39.3% of the hybrids.

Fig. 102. (a) Flesh colour variation and (b) poor tuberization in hybrid plants

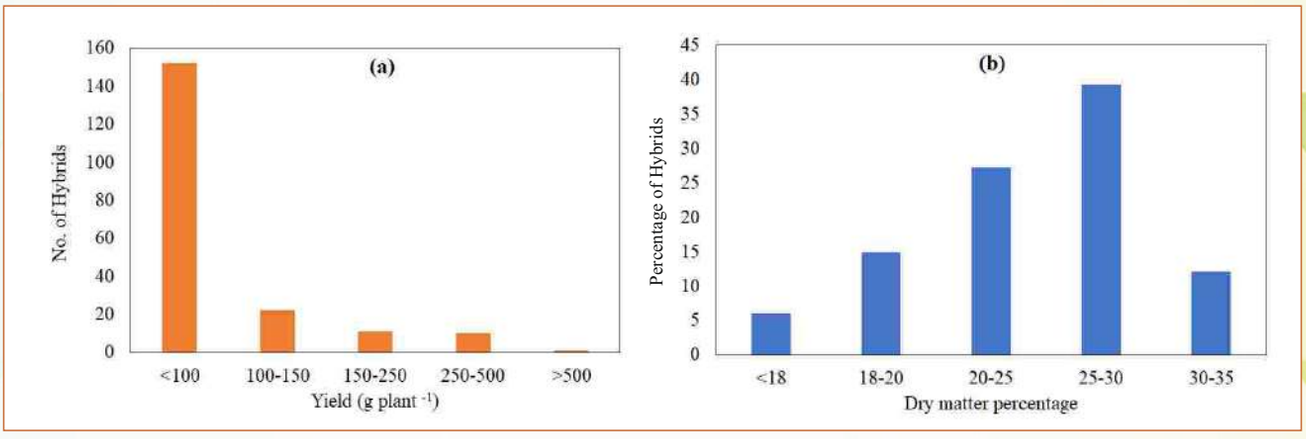


Fig. 103. (a) Yield and (b) Dry matter of sweet potato hybrids

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.K. I. Asha, A. Asha Devi, Shirly Raichal Anil, Kalidas Pati and N. Krishna Radhika)

The gene bank of reference varieties of cassava (55) and sweet potato (52) are being conserved in the field (Fig. 104). The DUS testing guidelines of both cassava and sweet potato were standardized. The DUS testing guidelines included thirty characteristics for cassava, of which six traits, viz., pubescence on apical leaves, predominant shape of central leaf lobe, petiole colour and colour of the mature stem: exterior, tuber rind colour and tuber flesh colour were selected as grouping traits. In the case of sweet potato, the guidelines included 25 characteristics including six grouping traits viz., plant growth habit, vine pigmentation, mature leaf shape, tuber shape, predominant skin colour and tuber flesh colour. All the reference varieties were harvested and replanted. Farmers were sensitized to start registration of cassava and sweet potato varieties. One farmer, Shri. John from Kozhikode, Kerala sent the planting material of one promising farmers' variety of cassava named *Manna* for registration and it was planted in the field for characterization and registration.

Forty three sweet potato and 14 cassava lines were maintained in the field gene bank at RS ICAR-CTCRI, Bhubaneswar.The leaf morphology database of sweet potato has been updated.

Fig.104. Cassava gene bank under DUS

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. M.N. Sheela (Lead Centre) and Dr. Kalidas Pati (Collaborating Centre); Co-PIs: Drs. J.Sreekumar, Vivek Hegde, M. Nedunchezhiyan, P.P. Singh (RAU, Dholi) and Ashish Narayan (DRPCAU, Dholi)]

The gene bank of reference varieties of greater yam (461) and yam bean (24) are being conserved in the field. The DUS testing guidelines of both greater yam and yam bean were standardized. For the DUS testing of greater yam, 20 characteristics were selected, of which five characteristics viz., petiole colour, leaf shape, tuber shape, tuber cortex colour and tuber flesh colour were identified as grouping traits.

Yam bean DUS test guidelines included 17 characteristics. Four characteristics viz., flower colour, pod length, tuber shape and seed shape were selected as

grouping traits. Seven greater yam and 10 yam bean lines were maintained in the field gene bank at Regional Station (Fig. 105). Three greater yam lines were collected from Odisha and planted in the field for characterization based on the DUS guidelines. Forms for the registration of 4 varieties of greater yam and 5 varieties of yam bean were prepared and submitted under extant variety category. The DUS testing guidelines have been developed and published in the PPV & FRA website.

Fig. 105. Distinctive characteristics of Tikabali Yam-1

Development of Standards of DUS testing for varietal gene bank in Elephant Foot Yam and Taro (PPV & FRA, New Delhi; PI: Dr. Kalidas Pati; Co-PIs: Drs. J. Sreekumar and J. Tarafdar (BCKV, Kalyani)

The DUS testing guidelines of twenty one taro and 18 EFY lines were maintained in the field gene bank (Fig. 106 and Fig. 107). All the reference varieties were replanted. Two lines received from PPV&FRA for varietal testing were planted and characterization is in progress. Three new taro and 2 EFY lines were collected from Odisha and planted for characterization based on DUS characters such as plant height, growth habit, plant type, leaf number, leaf length leaf vain pattern, petiole colour, sheath length etc.

Fig. 106. Distinctive characteristics of Tikabali Taro-2

Fig. 107. Distinctive characteristics of Tikabali EFY-3

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)

Gamma irradiation to induce sprouting in cassava and generate mutants

The LD_{50} dose of Gamma irradiation of stem cuttings was found as 15.9 Gy for the cultivar Sree Jaya and 20.99 Gy for the cultivar H-226. Sprouting was reduced to 73.01% in H-226 when the stem cuttings were treated with 15 Gy of gamma irradiation. In Sree Jaya also, sprouting of 64.4% was recorded at 15 Gy of gamma irradiation when compared with higher radiation doses (30, 45 and 60 Gy). However, the percentage of sprouting was low at all radiation doses when compared with controls viz., Sree Jaya (90%) and H-226 (100%).

A greater variation was observed for the colour of apical leaves, petiole and pigmentation on shoot among the mutants of Sree Jaya. Purple, greenish purple and green colour apical leaves were observed in 46, 1 and 3 mutants, respectively. Eighteen genotypes had purple colour petiole analogous to their parent Sree Jaya and the rest had dark purple petiole (3), purple colour petiole with light purple basal colour (11), with green basal colour (8), with greenish purple basal colour (10).

Thirty five mutants had green colour shoot similar to the untreated parent Sree Jaya while 16 mutants had purple pigmentation on the shoot. Such variation in colour was not found among the mutants of H-226. One large leaf mutant (SJ 30-4) of Sree Jaya with an average single leaf area of 602.47 cm^2 was found. It was having an average leaf length and width of 22.4 and 6.2 cm, respectively.

All the cassava mutants along with control plants were screened for CMD resistance at 45, 75 and 135 days after planting (DAP). Two mutants SJ 15-2 (20) and SJ 15-13 (21.4) of Sree Jaya had low Percent Disease Index (PDI) at 45 DAP, but eventually lost the resistance later. One mutant of H-226 viz., H-226 30-14 (PDI: 20 at 135 DAP) had CMD resistance but had lower plant height and tuber yield (655 g $plant^{-1}$). The highest tuber yield was recorded in the mutant SJ 30-14 (9.7 kg $plant^{-1}$) followed by SJ 15-34 (8.46 kg $plant^{-1}$) which was 82 and 58.6% improvement over the control, Sree Jaya (5.3 kg $plant^{-1}$), respectively. None of the mutants of H-226 had outperformed the untreated H-226 in terms of tuber yield. Only one mutant of Sree Jaya SJ 30-14 had a greater number of tubers (12) than control (10). One mutant of H-226 viz., H-226 15-36 had number of tubers (10) on par with the control (9.67) while other mutants had a smaller number of tubers. Maximum root length seemed to be increased than control in majority of the mutants of both Sree Jaya and H-226. About 110% increase in maximum root length was observed in SJ 15-1 and SJ 15-34 over that of control, Sree Jaya. Similarly, H-226 15-18 had 138% increased maximum root length over that of control, H-226.

Except a few mutants of Sree Jaya, all others had increased tuber dry-matter content over that of control, Sree Jaya. The mutants SJ 15-14 (41.17%) and SJ 15-27 (40.03%) had more dry matter than control, Sree Jaya (26.76%). In the case of H-226 also, few mutants had more dry matter content than control (34.72%). Among these, H-226 15-17 (42.51%) and H-226 15-19 (38.98%) had maximum dry matter. A huge variation was observed for tuber rind colour and flesh colour among the mutants of Sree Jaya. Tuber rind colour changed to cream (10 mutants) and yellow (10 mutants) from original pink colour (Fig.108a). Dark cream or yellow colour flesh was found in 8 mutants and the remaining had creamish-white colour flesh like the parent, Sree Jaya (Fig.108b). The yellow colour is known to be associated with β-carotene, the precursor of Vitamin A. Hence, these mutants were expected to have more β-carotene content than the parent. Such changes in colour were not observed in H-226. Post-harvest physiological deterioration (PPD) was observed to be slow in the mutants than the control when measured at 4 days after harvest.

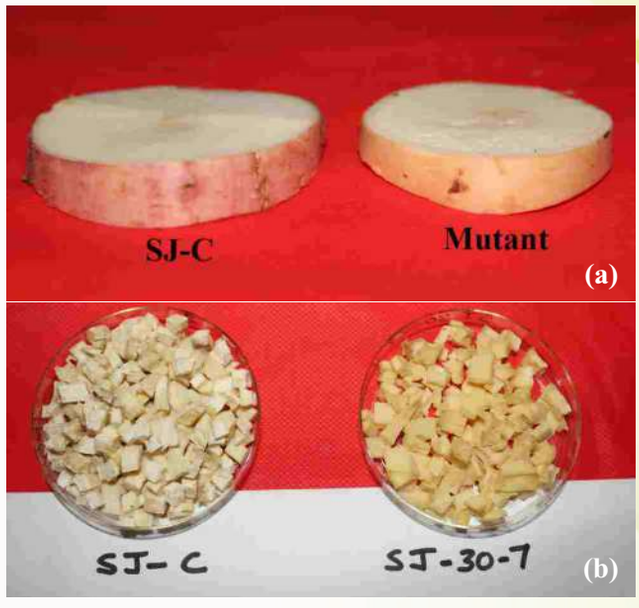


Fig. 108. (a) Change in rind colour from pink (control, Sree Jaya) to cream (mutant) and (b) Change in flesh colour from creamish white (Sree Jaya) to yellow (mutant)

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 (DBT Twinning Programme-2017; PI: Dr.Vivek Hegde; Co-PI: Dr. P. S. Sivakumar)

An efficient transformation protocol was optimized for taro (*Colocasia esculenta* L. Schott) variety Muktakeshi using *Agrobacterium* strain LBA4404 carrying β-*glucoronidase* (GUS) reporter gene on vector PBI 121. Actively growing buds from *in vitro* grown plants were used for *Agrobacterium*-mediated genetic transformation. Growing portion of the explants were exposed by cutting them longitudinally and submerged in *Agrobacterium* suspension for 15 minutes with continuous shaking. The infected explants were co-cultivated on MS basal medium for 72 h at 28°C in dark. After the co-cultivation, the explants were washed with liquid MS basal medium

containing Carbenicillin (1ml l^{-1}) for three to four times and cultured on basal MS medium. After three weeks, proliferating explants were sub-cultured onto regeneration medium supplemented with 4.0 mg l^{-1} BAP along with 1.0 mg l^{-1} NAA. A total of 42.86% of explants regenerated on regeneration medium (Fig. 109). The GUS histochemical assay was performed using stem and leaf cuttings of the transformed plants and 7.14% transformation frequency was observed (Fig. 109).

Fig. 109. (a) Regeneration of transformed taro corm bud (b) Histochemical GUS assay of the leaf and petioles of the transgenic line one (T) and non-transformed control (NT)

In vitro quality planting material production of tuber crops to meet the demand of Odisha (RKVY, Department of Agriculture & Farmers Welfare, Government of Odisha; PI: Dr. V. B. S. Chauhan; Co-PIs: Dr.Kalidas Pati, Mr. Hanume Gowda K., Mr. V. V. Bansode and Dr. M. Nedunchezhiyan)

Development of *in vitro* plant regeneration protocol of yam var. Orissa Elite

Greater yam var. Orissa Elite plant was selected, and young stems were collected from the field, cleaned under running tap water and subsequently leaf was excised and cut into small segments with each twig segment having one nodal region. Nodal explants were washed in liquid detergent followed by fungicide (Bavistin) and surface sterilized by $HgCl_2$ and washed with autoclaved distilled water. The nodal segments were inoculated on Murashige and Skoog's (MS) (1962) basal medium supplemented with activated charcoal and different concentrations and combinations of N^6- Benzyl adenine (BA) (1.0 - 5.0 mg l^{-1}), Kinetin (KIN) (1.0 - 5.0 mg l^{-1}), meta Topolin (mT) (1.0 – 5.0 mg l^{-1}) and Zeatin (Z) (1.0 – 5.0 mg l^{-1}). The culture medium was added with 3% (w/v) sucrose and gelled with 0.2% (w/v) Cleri Gel™ Ultra. The pH of the medium was adjusted to 5.8±0.1 prior to autoclave. Shoots were initiated from all explants within one week of inoculation and the response of explants for regeneration of shoot initiation and proliferation varied in the entire tested medium (Fig. 110). Maximum number of shoots were regenerated from nodal segments on MS basal medium supplemented with 2.0 mg l^{-1} mT and 0.5 mg l^{-1} Z after five weeks of culture. An interesting feature observed during multiple shoot proliferation node explants was that roots were developed simultaneously in all cultures in all tested medium. *In vitro* regenerated shoots were rooted on 1/2 MS medium supplemented with 1.0 mg l^{-1} IBA. After rooting of *in vitro* regenerated shoots, *in vitro* plantlets were taken out from the culture tube and washed thoroughly to remove agar medium and subsequently planted in small paper glass containing sand, soil, and cocopeat (1:1:1). Then it was covered with polyethylene bag to maintain humidity. Acclimatized plantlets were watered as per the requirement. After two weeks of acclimatization, the polyethylene bag was pouched to reduce humidity and finally polyethylene bag was completely removed. Acclimatized plants were transferred to clay pot and kept in shade house for one week prior to transferring under full sun for two weeks. All plants were established successfully. These plants were transferred in net house for maintenance/ production of mini tuber and further multiplication in field.

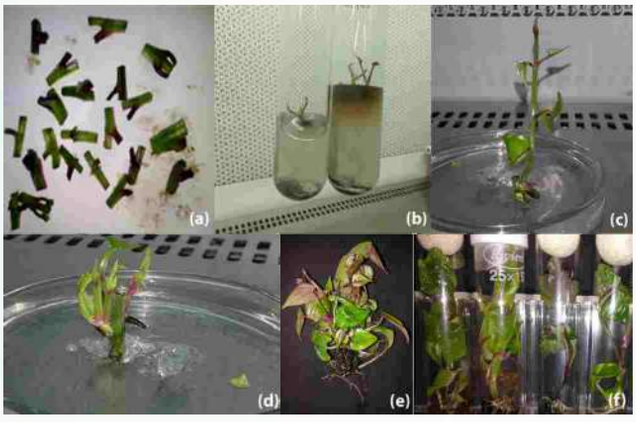


Fig. 110. Micropropagation of yam var. Orissa Elite: (a) Nodal explants of yam, (b) Shoot initiation from node explants within one week, (c) Single shoot initiation and elongation in MS medium, (d) Shoot bud initiation from nodal segment in MS + 2.0 mg l^{-1} mT and 0.5 mg l^{-1} Z, (e) Multiple shoot proliferation and elongation in MS + 2.0 mg l^{-1} mT and 0.5 mg l^{-1} Z, (f) Rooting of *in vitro* regenerated shoot in 1/2 MS medium supplemented with 1.0 mg l^{-1} IBA

Development of *in vitro* plant regeneration protocol for cassava var. Sree Jaya

Cassava (var. Sree Jaya) plant was selected, and young stems were collected from the field. The leaf was excised from stem and cut into small segments i.e., each stem segment having one nodal region. Nodal explants were washed in liquid detergent followed by fungicide (Bavistin). Then, the explants were surface sterilized by using $HgCl_2$ and washed with autoclaved distilled water. Surface sterilized stem segments were inoculated on Murashige and Skoog's (MS) (1962) basal medium supplemented with activated charcoal and different concentrations and combinations of N^6-Benzyl adenine (BA) (1.0 - 5.0 mg l^{-1}), meta Topolin (mT) (1.0 - 5.0 mg l^{-1}) and Zeatin (Z) (1.0 - 5.0 mg l^{-1}). Shoots were initiated from all explants within one week of inoculation and the response of explants for regeneration of shoot initiation and proliferation varied in the tested medium (Fig. 111). Maximum number of shoots were regenerated from nodal segments on MS basal medium supplemented with 2.0 mg l^{-1}mT after four weeks of culture. *In vitro* regenerated shoots were rooted on 1/2 MS medium supplemented with 0.5 mg l^{-1} IBA. After rooting, plantlets were acclimatized in shade then transferred in net house for maintenance and further multiplication in field.

Fig. 111. (a & b) Shoot bud initiation from stem segment on MS medium, (c & d) Multiple shoot proliferation on MS medium supplemented with 1.0 mg l^{-1} mT, (e) Rooting on 1/2 MS + 0.5 mg l^{-1} IBA

Quality Planting Material Production

Tissue cultured true to type disease free plants of sweet potato varieties, Bhu Krishna, Bhu Sona, Kisan and cassava variety Sree Jaya were produced and after hardening, the tissue cultured plants were planted in field for multiplication in area of 1,000 square meters at RS ICAR-CTCRI (Fig. 112). Disease free planting material of sweet potato (2.5 lakhs vine cuttings) and cassava (10 thousand stem cuttings) were produced in field nursery and given to the farmers for cultivation. Tissue culture plants of other tuber crops such as taro, elephant foot yam and greater yam were maintained in net house for further multiplication in field for distribution to the farmers.

Fig. 112. *In vitro* produced sweet potato plantlets grown in nursery for multiplication

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 and 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, geo-referenced on-farm characterization of organic growers. Besides, cluster based demonstration of organic package under SCSP and on-station and farmer participatory evaluation of natural farming in cassava based cropping systems are ongoing.

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

Four cropping systems, cassava-vegetable cowpea, cassava-groundnut, taro-green gram and taro-black gram, were evaluated in ICAR-CTCRI, Thiruvananthapuram, 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 × 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 for the fourth consecutive season. Economic analysis of the system indicated that of the four systems, cassava-groundnut was the most remunerative. In cassava-groundnut, 75% organic was the most profitable with and without premium price. In cassava-vegetable cowpea system, state POP was the most profitable, with and without premium price. With premium price, 75% organic performed second best to state POP. In this system, the highest equivalent energy and production efficiency was also observed in state POP. In cassava-groundnut, taro-green gram and taro-black gram systems, 75% organic + innovative practices resulted in the highest equivalent energy and production efficiency.

Combined analysis over four years (2015-19) indicated that the cropping systems differed significantly for tuber yield, grain yield and tuber equivalent yield (TEY). Cassava-groundnut and cassava-vegetable cowpea performed equally with respect to tuber yield, grain yield and TEY. Management options were significant for grain yield and TEY. Tuber yield under different management options was not significantly different. The treatments, 100% organic and 75% organic proved superior for grain yield. TEY of all management options, except POP, was similar. The effect of cropping system×management option interaction was not significant for tuber yield and TEY. Groundnut performed well in all the management practices, except POP.

Evaluation of response of different varieties of cassava to organic farming

The fourth year (2019-20) results indicated that of the 12 varieties tested, Sree Reksha (CR-24-4) produced significantly higher yield (36.97 t ha^{-1}). Second highest yield was obtained from Sree Vijaya (26.94 t ha^{-1}). Sree Reksha generated higher profit (₹6,87,275 ha^{-1}) and B:C ratio (3.90) followed by Sree Vijaya (₹4,36,345 ha^{-1} profit and 2.84 B:C ratio) under organic mode. Combined analysis of yield over four years indicated that the varieties varied significantly under organic management. Sree Reksha produced stable and highest yield (36.67 t ha^{-1}) followed by Sree Pavithra (25.43 t ha^{-1}).

Geo-referenced on-farm characterization of organic growers

Geo-referenced survey of 30 farmers practicing organic farming on major crops including all tuber crops in Thiruvananthapuram, Kollam and Pathanamthitta districts of Kerala was conducted (Fig. 113). The survey was carried out in Kazhakoottam and Kilimanoor blocks, Thiruvananthapuram, Ochira, Chavara and Chittumala blocks, Kollam and Koipuram, Elanthoor and Mallappally blocks, Pathanamthitta (Fig. 113). Eighty three per cent of the farmers belonged to the small and marginal group with a land holding size <2 ha. Average land holding size was 1.12 ha. Most of the farming situation surveyed was rainfed (80%), some were irrigated. 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 86.67% of the farmers. The soil type was laterite (100%). About 46.67% of the surveyed farmers owned cow, 23.33% had goat,

53.33% had poultry (hen and duck), 36.66 % had fish and 10% had apiary as an integral part of organic farming. Animal wastes were converted to excellent manures using biogas (6.67%) and vermicompost units (20% farms) (with an average capacity to produce nearly 200 kg compost/annum).

Nutrient sources for organic farming constituted cow dung slurry/FYM (100%), poultry manure (50%), goat manure (30%), kitchen waste compost (20%), vermicompost (40%), biogas slurry (6.7%), neem cake (56.67%), groundnut cake (13.33%), bio-formulations like *Panchagavya* (16.67%), *Jeevamrutham* (26.67%), *Hridayamrith* (20%) and green leaf manuring (23.33%). Apart from these, ash (66.67%) and bone meal (50%) were also used. Majority of farmers conducted soil testing before raising the crop. Pest and disease management was done through application of neem oil-garlic emulsion (36.67%), neem oil (30%), fish amino acid (36.67%), egg amino acid (223.33%), *Kanthari* emulsion (50%), neem soap (30%), *Beauveria* (53.33%), *Trichoderma* (53.33%), *Pseudomonas* (60%) and pheromone trap (50%). Apart from these, cultural methods, intercropping, trap crops on field bunds and some indigenous methods were also practiced.

Fig. 113. Glimpses of geo-referenced survey of organic growers

(IOFS) model

Net returns of ₹54,862 could be obtained from cassava based cropping system (with animal components for 4 months started during April 2020) from an area of 75 cents (Fig. 114). The marketable equivalent yield (MEY) from the system was 9,108 kg and the IOFS could generate 107 mandays.

Fig. 114. IOFS components

Cluster based demonstration of organic farming package under SCSP

Ten SC farmers were selected in Kariyil colony, Kazhakoottam, Thiruvananthapuram, Kerala based on their interests in organic cultivation practices. Organic cassava production, homestead and terrace cultivation of organic vegetables were taken up by the farmers. Critical agricultural inputs like knapsack sprayer (15 lit capacity), garden hose, hand hoe, hand rake, rose can, grow bags (50 nos.), vegetable seeds (amaranth, bhindi, brinjal, vegetable cowpea and chilli), cassava stems and organic inputs (neem cake, vermicompost, biofertilizers, *Panchagavya*, vermiwash, *Jeevamrutham, Beejamrutham* and *Ghanajeevamrutham*) were supplied (Fig. 115). In addition, awareness lecture on organic farming of cassava, hands on experience on planting, monitoring crop growth, evaluation of pest and disease infestation and its management, training on preparation and application of liquid organic manures were carried out.

Fig. 115. Glimpses of SCSP scheme under AI-NPOF: Supply of critical agricultural inputs, organic cassava production and homestead and terrace cultivation of organic vegetables

Evaluation of natural farming in cassava (on-station and farmer participatory)

Both on-station and on-farm experiments have been initiated during August and October 2020, respectively.

Enhancing the economic viability of coconut based cropping systems for land use planning in Kerala (Kerala State Planning Board; PI: Dr. K. Susan John; Co-PIs: Drs. S. Sunitha and S.S. Veena)

The project was started in November 2014 and ended in June 2020 with the objectives of developing Best Management Practices (BMP) for cassava and elephant foot yam under intercropping in coconut, developing customized fertilizer formulations for EFY and their evaluation and onfarm validation. Based on the experiments conducted for three years in cassava and EFY in the two AEUs, viz., AEU 3 (Onattukara Sandy loam) and AEU 9 (Southern laterites), no superiority of BMP was observed over the existing PoP and farmers practice in terms of tuber yield as well as in the improvement of soil chemical properties.

For elephant foot yam under intercropping in coconut, three grades viz., N, P_2O_5, K_2O, Mg, Zn, B @ 8:11:21:3.5:1:0.3 (CF1), 7:12:24:2.5:1.25:0.4 (CF2) and 7:3:25:3:1.25:0.4 (CF3) were developed based on STCR and response curve approach. Application of CF2 @ 625 kg ha^{-1} was found best for EFY with a BC ratio of 5.44 and CF3 @ 500 kg ha^{-1} for cassava. The practices were demonstrated and popularized through KVKs of Kollam, Idukki and Alappuzha districts of Kerala, where there was an increase in tuber yield in elephant foot yam up to 15-20% over PoP and farmers practice and BC ratio ranged from 1.56-2.00. In cassava, the increase in tuber yield was 15-30% with BC ratio of 2.0-2.3, in addition to improving the soil quality under CF's.

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

Polysulphate is a natural mined product rich in nutrients (K_2O: 13.5%, CaO: 16.5%, MgO: 5.5%, S: 18.5%). The project initiated in June 2018, aims at studying the effect of polysulphates in cassava for the major cassava growing laterite and sandy soils of Kerala with respect to tuber yield, tuber quality, soil physico-chemical and

biological properties, and nutrient uptake to advice this multi nutrient rich product as a better soil amendment for Kerala soils which are deficient in K, Ca, Mg and S. The project was concluded in September 2020.

The study conducted for two years in five farmers' fields each of AEU 3 and AEU 9 and on station at ICAR-CTCRI brought out the following observations. Polysulphate is a good soil ameliorant for cassava in the acid laterite and sandy loam soils of Kerala. Pooled data on tuber yield of the six locations indicated that application can be done either as half lime and half dolomite as per lime requirement along with 1-2 t ha^{-1} polysulphate which gave a tuber yield of 53.33 t ha^{-1} on par with full dolomite along with polysulphate (50.32 t ha^{-1}) and polysulphate alone (49.24 t ha^{-1}). A comparison of yield with and without polysulphate under PoP, STBF, lime and dolomite together are presented in Fig. 116.

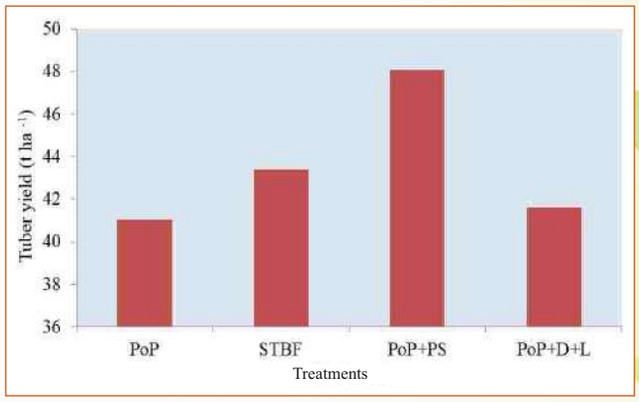


Fig. 116. Comparison of cassava tuber yield (pooled data) with and without polysulphate application

Bulking of tubers, improvement in cooking quality, starch content and lowering of bitterness were observed with polysulphate application (Fig. 117). Improvement in the soil status of nutrients especially, K, Ca, Mg and S (Fig. 118), which are essential for enhancing tuber yield and improving tuber quality was another advantage of applying this soil ameliorant especially in laterite and sandy loam soils which are deficient in these nutrients.

Fig. 117. Harvested tubers under different treatments

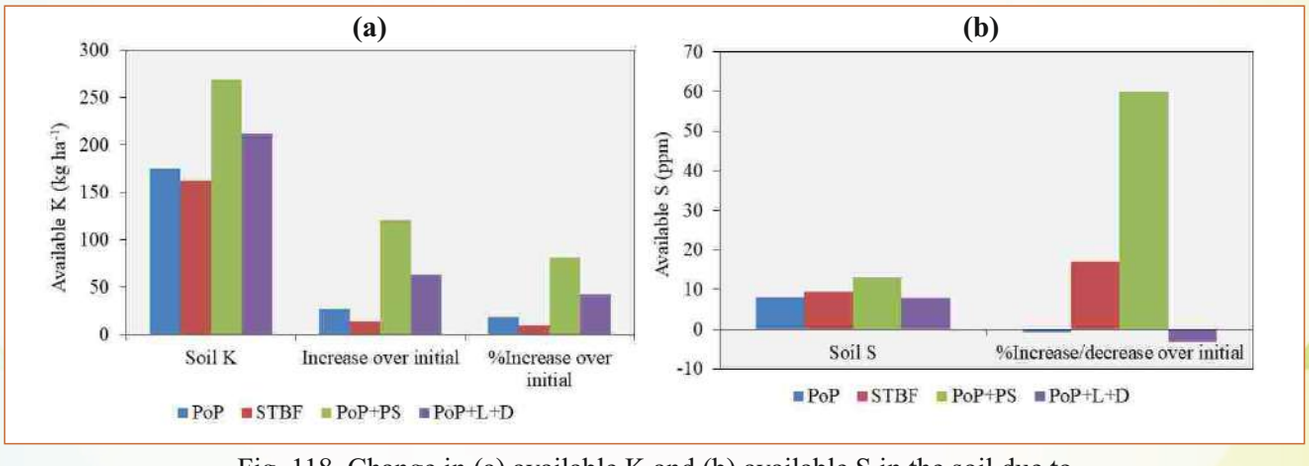


Fig. 118. Change in (a) available K and (b) available S in the soil due to application of polysulphate under cassava (Pooled data)

Higher productivity and profitability from coconut gardens through soil health management in tuber crops (Coconut Development Board, Government of India; PIs: Drs. G. Byju and G. Suja; Co-PI: Dr. D. Jaganathan)

On-farm validation of SSNM based customized fertilizers and organic farming were done in 10 coconut farms each in Kollam and Pathanamthitta districts. The effect of different treatments on the yield of elephant foot yam and greater yam under SSNM *vs* POP *vs* farmers' practice (FP) at Kollam showed that in both the crops, SSNM resulted in higher yield, followed by POP and FP. In elephant foot yam, SSNM resulted in higher yield over FP by 52.21% and POP by 7.25%. In yams,

SSNM performed better than FP by yielding 52.26% higher and POP by 21.47% (Fig. 119).

Effect of different treatments on the yield of elephant foot yam and greater yam under OF *vs* POP *vs* farmers' practice (FP) at Kollam showed that in elephant foot yam, OF resulted in higher yield, followed by POP and FP. In elephant foot yam, organic farming yielded higher over FP by 38.34% and POP by 16.56%. In yams, OF resulted in higher yield, followed by POP and FP, which were almost the same. In yams, organic farming yielded about 15% higher over FP and POP (Fig. 120).

In Pathanamthitta district, ten on-farm demonstrations were laid out during May-June 2020. Ten coconut gardens with 50 cents each were established for demonstrating technologies viz., customized fertilizers (SSNM) and organic farming (OF) in cassava and greater yam. Coconut gardens were selected based on the scoring procedure developed by the scientists of ICAR-CTCRI in consultation with the officials of Krishi Bhavans and KVK, Pathanamthitta. Data on socio-economic background, available resources, farming details, farming practices, knowledge on coconut and tuber crops farming, constraints in farming etc. were collected in detail with the active participation of the farmers. Soil samples were collected prior to the start of the validation trials of the experiment and are being analyzed for chemical properties. Demonstrations on customized fertilizers and organic farming were initiated as per approved technical programme. The crops are yet to be harvested and data are to be analyzed.

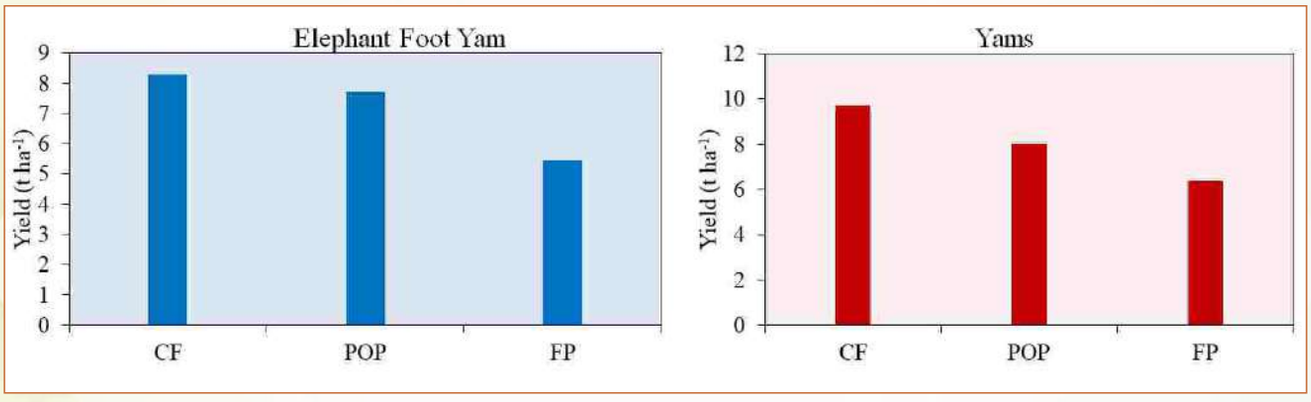


Fig. 119. Productivity of tuber crops under SSNM *vs* POP *vs* FP

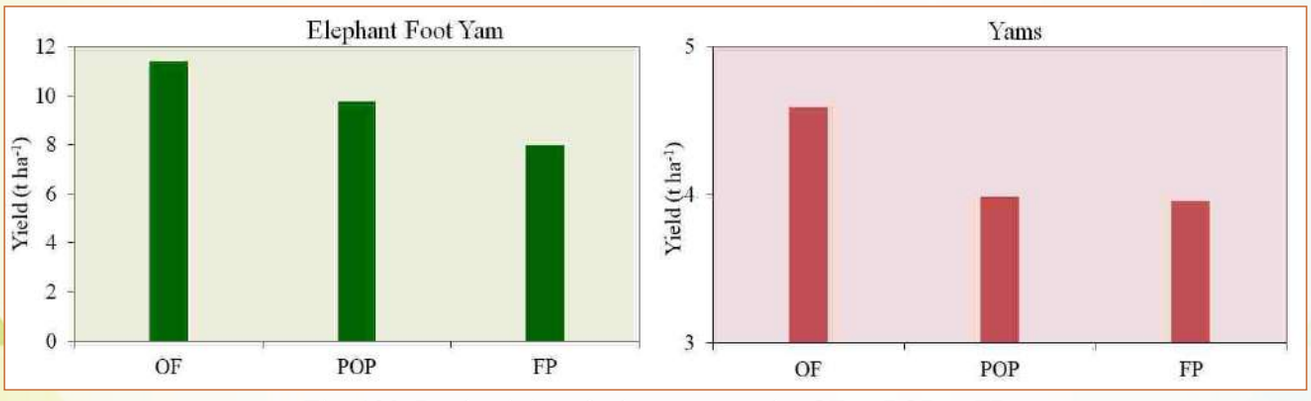


Fig. 120. Productivity of tuber crops under OF *vs* POP *vs* FP

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

Under the project, five different studies were completed during the period and the salient findings are summarized here.

Is cassava climate smart? A case study in India

The crop model predictions indicated the crop yield increase from 8.6 to 12% and 3.6 to 5.5% during 2030 for H-226 and Sree Vijaya, respectively. In 2050, the yield increase ranges from 3.3 to 6.7% for H-226 and -4.3 to 1.9% for Sree Vijaya, respectively (Fig. 121). The variety H-226 can be declared as climate-smart in the context of climate change and food security.

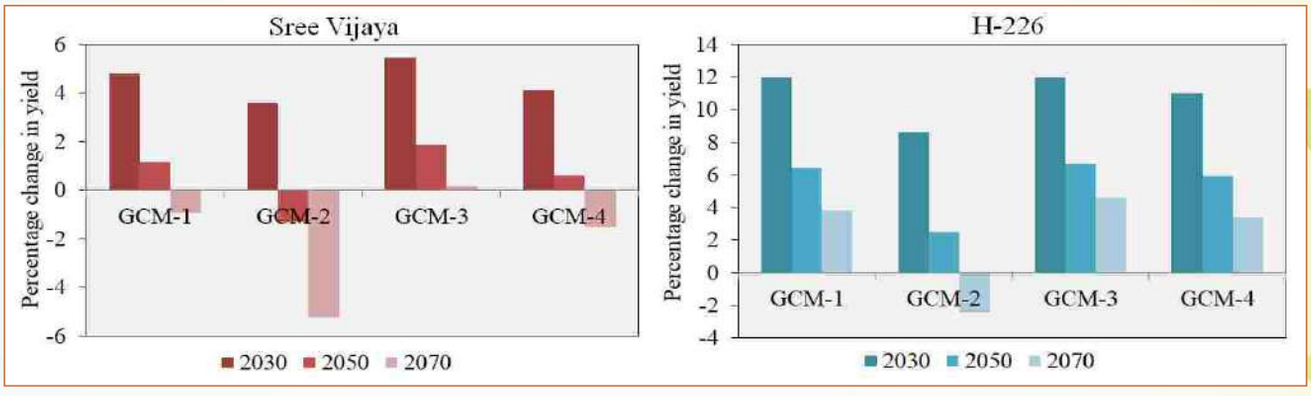


Fig. 121. Percentage changes in predicted yields based on the projections, RCP-4.5

Understand the sensitivity of root crop models to various meteorological parameters

The minimum temperature (yield variation: 4.94 to -7.65%) is highly influencing the yield of cassava followed by the maximum temperature (yield variation: 6.39 to -6.03%) and solar radiation (yield variation: -2.41 to 2.07%) with their changes from ±1 to ± 5%. The upper/lower limits observed for minimum and maximum temperatures for the study location to achieve higher yields of cassava are 25/15ºC and 33/25ºC, respectively. The other model inputs, rainfall, wind speed, and vapour pressure showed their changes are insensitive to the crop yield simulations.

Is cassava climate resilient? A meta analysis in the context of climate change and food security

Cassava can tolerate a temperature level of up to 40ºC, and thereafter the rate of photosynthesis decreases. Cassava can be cultivated in regions with variations in solar radiation without much compromise in its yield in the context of global dimming of sunshine duration. The resilience to water deficit stress and air humidity variations are adapted by reducing stomatal conductance without influencing the rate of photosynthesis. Cassava has an inbuilt mechanism to cope with water scarcity by leaf drooping. It has been already established that cassava can tolerate a salinity level of up to 150 mM and the younger ones can tolerate upto a level of 40 mM. Studies indicated a strong positive influence of elevated CO_2 of up to 700 ppm on the rate of photosynthesis and yield of cassava. Elevated CO_2 enhances the resilience of cassava to water stress and salinity. The combined effect of elevated CO_2 and higher temperatures increases the yield attributes of cassava. Studies showed its resilience to biotic stresses as well.

Modeling the yield, water requirement and water productivity of major tropical tuber crops using AquaCrop

The model simulations of cassava and sweet potato indicated the suitability of the AquaCrop in estimating the crop's yield irrespective of the agro-climatological conditions with percentage error values ranging from -2.33 to 3.92% and 0.3 to 5% in the cases of cassava and sweet potato, respectively (Fig. 122). The model also estimated the gross irrigation requirements and their corresponding water productivity values. The estimated water productivity of these crops is higher than that of the major food grain crops indicating their suitability in the context of water scarcity and food security.

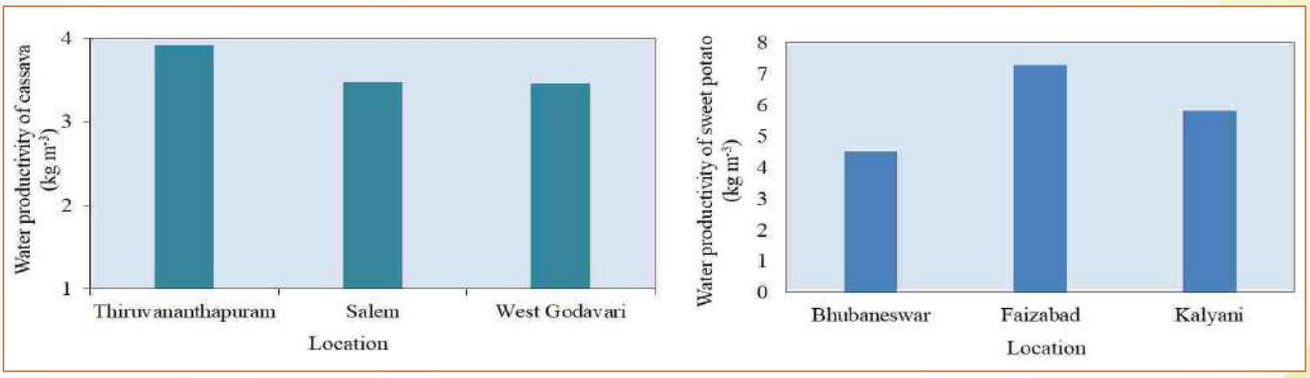


Fig. 122. Water productivity of cassava and sweet potato

Assessing the influence of climate model biases in predicting yield and water requirement of cassava

The change in crop yield predictions with and without bias corrections of meteorological variables ranged from 7.6 to 10.8%, 1.6 to 5.4%, and -3.0 to 4.0% respectively, for 2030, 2050 and 2070. The bias corrections made an increment in the gross irrigation requirements of cassava with percentages of 16.5%, 17.8%, and 16.0% in 2030, 2050 and 2070, respectively compared to the values without bias corrections (Fig. 123). The outcome of this study indicated that raw meteorological variables directly from the climate models result over/under-estimation of yield and irrigation requirements of cassava, and the bias corrections help to issue reliable crop yield predictions.

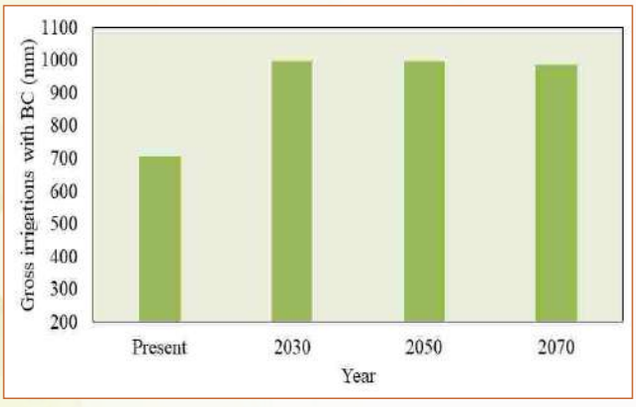


Fig. 123. Gross irrigation requirement during 2030, 2050 and 2070 (RCP-4.5)

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) (PI: Drs. K. Sunilkumar, J. Sreekumar, G. Byju; Co-PIs: Drs. M.N. Sheela, C.A. Jayaprakas, Sheela Immanuel, G. Suja, K. Susan John, V. Ramesh, R. Muthuraj, R. Saravanan, Sanket J. More and D. Jaganathan)

Different laboratory equipments were purchased under the project as part of infrastructure development. Construction of insect proof net house for the multiplication of virus free planting materials is in progress. Fertilizers and plant protection chemicals worth ₹2.874 lakhs were procured under the project for planting material production at the Institute farm. Cost of agro-inputs for demonstrations in ST farmers' fields were distributed to the beneficiaries of Kuttichal, Amboori, Tholikode and Vithura panchayats in Thiruvananthapuram district, Moonnilavu panchayat in Kottayam district and Kattappana panchayat in Idukki district. A total of 117 demonstrations were completed till date. Newly, 20 ST farmers were selected from two panchayats viz., Peringammala and Nanniyode in Thiruvananthapuram district during the period and planting materials of improved tuber crop varieties were supplied (Fig. 124). Planting materials of two varieties of cassava (Sree Reksha and Sree Pavithra) and four varieties of sweet potato (Sree Kanaka, Sree Arun, Gouri and Bhu Krishna) were supplied for demonstration. Presently, multiplication of planting materials at ICAR-CTCRI has been taken up with about 3.1 acres of elephant foot yam and 5.5 acres of cassava (Sree Reksha, Sree Pavithra, Sree Vijaya, Sree Jaya and Vellayani Hraswa).

To make the concept of 'tuber seed village' working, ICAR-CTCRI has started procuring the multiplied seed materials from other Institute programmes and prospective buyers of seed materials were directed to the demonstration plots established by beneficiary farmers under the RKVY project. Under this programme, elephant foot yam from Amboori panchayat, sweet potato from Kuttichal, Kottur, Tholikode and Vithura panchayats were bought back for various Institute programmes (Fig. 125).

Fig. 124. Distribution of planting materials to farmers

Fig. 125. RKVY beneficiaries in Kuttichal Panchayat with harvest of sweet potato tubers

Popularization of climate resilient and nutritionally rich varieties of tuber crops for economic development and nutritional security of farmers of Odisha (RKVY; PI: Dr.M. Nedunchezhiyan; Co-PIs: Dr. K. Laxminarayana, Dr. Kalidas Pati, Dr. V.B.S. Chauhan, Mr. K. Hanume Gowda, Mr. V.V. Bansode, Dr. Sheela Immanuel, Dr. G. Byju, Dr. P.S. Sivakumar, Dr. D. Jaganathan, Shri. Bharat Kumar Sahoo, Shri. Bibhudi Das).

Field level demonstrations on tuber crops were conducted in 78.25 ha (sweet potato 18.85 ha, cassava 11.5 ha, yam 12.2 ha, yam bean 15.85 ha, elephant foot yam 9.5 ha and taro 10.35 ha) and 892 farmers were covered under the FLDs (Fig. 126). Nucleus seed/planting material production for distributing to the farmers were undertaken at RS ICAR-CTCRI, Bhubaneswar with 2 ha each of sweet potato, cassava, greater yam, yam bean, and elephant foot yam nurseries and 1 ha of colocasia. Construction of a dehumidified storage shed (₹200 lakhs) is in progress.

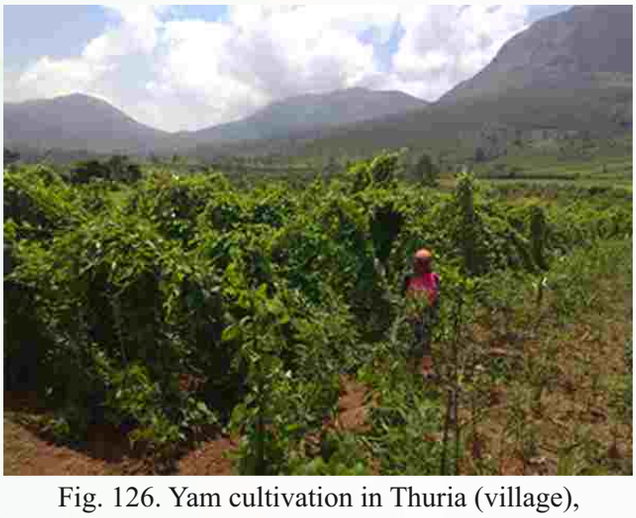


Fig. 126. Yam cultivation in Thuria (village), Pottangi (Block), Koraput district

Farm based S&T interventions for socio-economic development in the aspirational district of Nabarangpur, Odisha (RKVY; Sub project: Tuber crops technologies for food and nutrition security and livelihood improvement of farmers of Nabarangpur; PI: Dr.M. Nedunchezhiyan; Co-PIs: Dr. K. Laxminarayana, Dr. Kalidas Pati, Dr. V.B.S. Chauhan, Mr. K. Hanume Gowda and Mr. V.V. Bansode)

With the success of tuber crops demonstrations and overwhelming responses of the farmers during the year 2019-20, demonstrations were scaled up during the year 2020-21. Demonstrations on purple flesh sweet potato (var. Bhu Krishna) 2.0 ha, orange flesh sweet potato (var. Bhu Sona) 0.5 ha, white flesh sweet potato (var. Kishan) 0.5 ha, yam bean 2.0 ha, greater yam + maize intercropping system 1.0 ha were laid out in farmers' fields of Nabarangpur district (Fig. 127). Purple flesh sweet potato was given to 10 farmers in Chandahandi block of Nabarangpur district. Orange and white fleshed sweet potatoes, yam bean and greater yam were distributed to 30 farmers in Pappadahandi, Dabugaon and Nandahandi Blocks of Nabarangpur district.

Fig. 127. Purple flesh sweet potato field in Nabarangpur

Development and application of diagnostics to viruses infecting tuber crops (*Amorphophallus*, Cassava, Sweet potato and Yam) - (ICAR-CRP on Vaccines and Diagnostics; PI: Dr.T. Makeshkumar; Co-PIs: Drs. M. L. Jeeva, R. Arutselvan and R. Muthuraj)

Development and validation of ELISA based diagnostics

Development of Dasheen mosaic virus ELISA kit

DsMV polyclonal antibody obtained after immunization into two New Zealand white rabbits against Dasheen mosaic virus protein (DsMV-IgG) was

used for the development of diagnostic kit against Dasheen mosaic virus (DsMV ELISA KIT) (Fig. 128). The kit uses the sandwich assay format (Double Antibody Sandwich ELISA, DAS ELISA) and was optimized to detect DsMV present in infected (diseased) leaf samples using detection enzyme alkaline phosphatase (AP) along with chromogenic substrate (p-nitrophenyl phosphate, PNPP). The results can be visualized through the colour development (yellow) after substrate addition. Using DAS ELISA technique, this kit was validated with more than 250 elephant foot yam leaf samples from different locations which clearly detected the DsMV infection in the samples analyzed. Screening of taro and typhonium leaves showing mosaic symptoms was also done along with elephant foot yam leaves for validating the kit and they had DsMV infection.

Fig. 128. DsMV ELISA kit developed at ICAR-CTCRI

Development of diagnostic tools (DAC-ELISA and DIBA) for Sweet potato feathery mottle virus (SPFMV) detection and its validation

Sweet potato feathery mottle virus coat protein (SPFMV) polyclonal antibody (SPFMV-IgG) obtained after immunization into two New Zealand white rabbits with SPFMV coat protein (SPFMV-CP) was used for development of DAC ELISA diagnostic kit against SPFMV. Results from DIBA for checking the specificity of the raised polyclonal antibody revealed that the developed IgG reacted very efficiently with the SPFMV infected tissue and gave promising results (Fig. 129). Results from DAC-ELISA which was performed to evaluate the sensitivity of raised polyclonal antibody using different dilutions revealed that the developed IgG reacted very efficiently with SPFMV positive samples and gave positive results upto 1:6000 dilutions (Fig. 130).

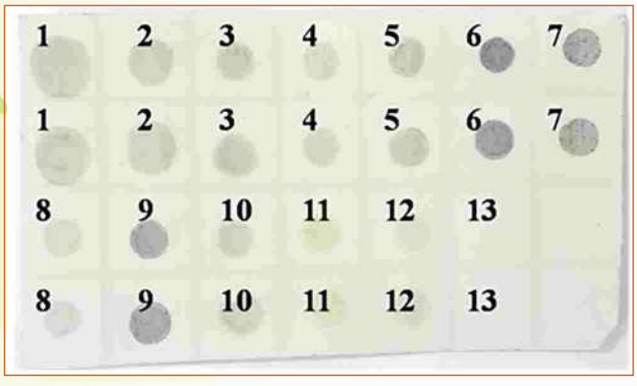


Fig. 129. Specificity assay of purified SPFMV polyclonal antiserum using DIBA Spots 1-9, leaf samples infected with SPFMV; spot 10, positive control; spot 11, healthy plant; spot 12, negative control; spot 13, buffer control

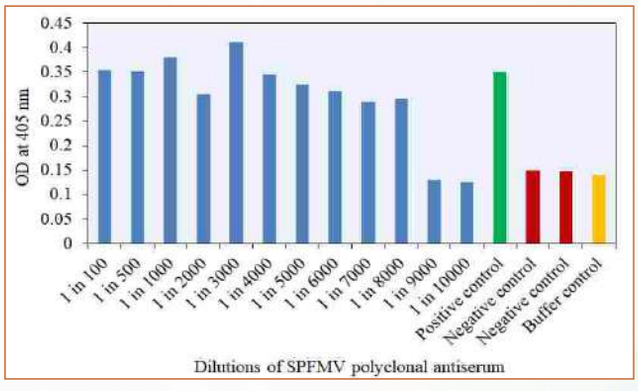


Fig. 130. Sensitivity assay of SPFMV polyclonal antiserum by DAC-ELISA

Development and validation of nucleic acid based diagnostics

Development of Recombinase Polymerase Amplification (RPA) kit for the detection of Sri Lankan cassava mosaic virus (SLCMV)

A highly efficient and cost-effective diagnostic technique using RPA (Recombinase Polymerase Amplification) was developed for the detection of SLCMV from field samples. Specific sets of RPA

primers targeting highly conserved region of coat protein gene of SLCMV were designed and the reaction was optimized according to the standard protocol (TwistDX). Results were validated by observing the presence of 1250 bp band in the gel after loading the samples in a 1% agarose gel and done the agarose gel electrophoresis (Fig. 131).

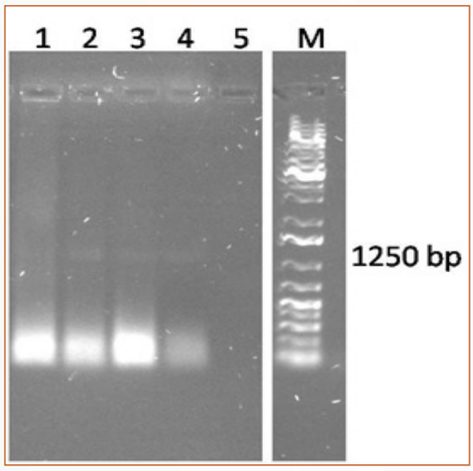


Fig. 131. RPA products run on 1% gel. Lanes 1 to 3: Infected cassava samples, Lane 4: SLCMV Positive control, Lane 5: Negative control, Lane M: 1 kb plus DNA ladder

High value compounds/Phytochemicals (ICAR Network Project; PI: Dr. A. N. Jyothi; Co-PIs: Drs. J. Sreekumar and Shirly Raichal Anil)

In silico QSAR analysis has been performed to establish the structure-antioxidant activity relationship of sweet potato and purple yam anthocyanins. The results revealed that acylated anthocyanins exhibited higher antioxidant potential than non-acylated anthocyanins. The purple yam anthocyanins acylated with sinapic acid and sweet potato anthocyanins acylated with caffeic and ferulic acids exhibited excellent antioxidant potential than others. The predicted antioxidant potential increased with increase in the number of acyl groups in anthocyanins. Molecular docking study conducted for the anticancer activity of sweet potato and purple yam anthocyanins using three cancer target proteins revealed the comparatively higher activity of anthocyanins towards breast cancer cells and this result was in accordance with those obtained from MTT assay.

Under this project, the anthocyanins present in the purple tubers of a sweet potato variety, Bhu Krishna; leaves of a sweet potato accession S-1467 and the tubers of a greater yam (*D. alata*) accession, Da-340 were isolated, purified, quantified by HPLC method, and structurally characterized by using high resolution MS analysis. *In vitro* antioxidant activity, antiproliferative activity and cell toxicity studies were carried out to establish the potential bioactivity of these anthocyanins. The QSAR analysis and molecular docking studies were performed to understand the structure-activity relationship and anticancer potential of the anthocyanins by *in silico* methods. The purified anthocyanins were co-pigmented with selected phenolic acids and plant extracts to enhance their antioxidant potential and colour. The purified anthocyanins were spray dried to produce encapsulated anthocyanins and tested for stability and colour parameters in model food systems. The tuber residue left after anthocyanin extraction was successfully utilized to prepare flour which can be used as a substitute for all-purpose flour in bakery products. The project was concluded in March 2020.

National Agricultural Innovation Fund (NAIF): (Component 1 Innovation Fund) (ICAR, New Delhi; PI: Dr. P. Sethuraman Sivakumar; Co-PIs: Drs. Sheela Immanuel, R. Muthuraj and P. Prakash)

IP Portfolio management

The response to First Examination Reports of two technologies 'Apparatus & process for extraction of biopesticides from cassava bio-wastes' (Patent Application No: 635/DEL/2012) and 'Electronic Crop' (Patent application no: 1388/CHE/2014) were filed.

Technology Commercialization through licensing

1. Super Absorbent Polymer technology was transferred to M/s SKR Agrotech, 5, Mohata Market, Wardha, Maharashtra for ₹5 lakhs on 04 March 2020.
2. Tuber crops fried food technology was transferred to Mr. Anoop S. Nair, Pothencode, Thiruvananthapuram for ₹25,000 on 21 December 2020.

National Agricultural Innovation Fund (NAIF): (Component II): Agribusiness Incubator (ICAR, New Delhi; PI: Dr. P. Sethuraman Sivakumar; Co-PI: Dr. Sheela Immanuel)

Effect of COVID-19 lockdown on Tuber crops technology start-ups

A survey on impact of COVID-19 lockdown was conducted among nine start-ups who licensed ICAR-CTCRI technologies or involved in tuber crops based business. All the surveyed start-ups were engaged in multiple activities. Majority of them focused on food processing, followed by agricultural equipment, seed production and production of agricultural inputs.

The COVID-19 lockdown has adversely impacted start-ups and they indicated multiple problems. About 16% start-ups indicated that their cash flows dampened, followed by problems in getting raw materials and other inputs (13.95%) and additional expenses spent for non-working hours of the employees e.g., salaries during lockdown period (11.62%). Among the start-ups surveyed, 56% start-ups are severely impacted and fully closed followed by 33% partially closed and 11% had manageable impact.

Entrepreneurial ecosystem development

To develop entrepreneurial ecosystem for tuber crops, a Social Entrepreneurship Meet was organized by ICAR-CTCRI ABI, in collaboration with North Eastern Hill University Incubation Centre (NEHU, Tura, Meghalaya), ICAR-National Institute for Biotic Stress Management (Raipur, Chhattisgarh) and ICAR-ABI, ICAR Research Complex for NEHR (Umiam, Meghalaya). This event was hosted by NEHU, Tura, Meghalaya on 06 March 2020. About 50 social entrepreneurs from NEH Region participated in this event.

An online Interface meeting between ICAR-CTCRI and SAGOSERVE was organized by ICAR-CTCRI ABI on 12 August 2020 to develop collaboration for scaling up of three ICAR-CTCRI technologies and develop a quality planting material production system. Twenty five scientists/officials from ICAR-CTCRI and SAGOSERVE participated in this event.

Revenue generation

ICAR-CTCRI ABI has conducted two Entrepreneurship and Market research skill development programmes through online mode and generated a revenue of ₹ 84,415.

TECHNOLOGIES ASSESSED, TRANSFERRED, CONSULTANCY AND PATENT SERVICES

Technologies Transferred

The Intellectual Property and Technology Management Unit (IPTMU), under the guidance of the Intellectual Property and Technology Management Committee (IPTMC) has carried out the following technology transfer and contract activities during 2020.

Technology Commercialization

- Technology for the production of fried snack foods from cassava transferred to Smt. Beenamma Peter, Grany Foods, Kozha, Kottayam, Kerala for ₹ 25,000 on 24 February 2020.
- Super Absorbent Polymer technology transferred to M/S. SKR Agrotech, 5, Mohata Market, Wardha, Maharashtra for ₹5.0 lakhs on 04 March 2020.
- Technology for the production of fried snack foods from cassava transferred to Mr. Anoop S Nair, Pothencode, Thiruvananthapuram, Kerala for ₹25,000 on 21 December 2020.

IP Portfolio management

The response to First Examination Reports of two technologies 'Apparatus & process for extraction of biopesticides from cassava bio-wastes' (Patent Application No: 635/DEL/2012) and 'Electronic Crop' (Patent application no: 1388/CHE/2014) were filed.

Revenue generation

An amount of ₹22.56 lakhs was generated through technology commercialization and other professional service functions as given in Table 2.

Table 2. Revenue generated through technology commercialization and other professional services

Sl. No.	Activity	Revenue generated (₹)
1.	Technology licensing	5,50,000
2.	Sale of technological products (Machineries and value added products)	3,36,588
3.	Professional training (ABI and TIC)	1,30,615
4.	Consultancy	25,000
5.	Students' fees	12,13,600
Total		22,55,803

Varieties/Technologies developed

Varieties and potential genotypes

- A high yielding greater yam variety, TGy12-1 was recommended for state release for laterite and sandy loam soils in south and central districts of Kerala with the name 'Sree Hima'. It is a hybrid (Da-402) with high yield (57.87 t ha^{-1}), high dry matter (30.19%), starch (26.3%), crude protein (5.28%) and excellent culinary quality with high organoleptic score (7.97).
- Identified a yellow-fleshed cassava genotype, 17S-325 with high β-carotene (6.01mg 100 g^{-1}) and high Ca (1840 ppm) content.
- Nutritional rich lines of taro viz., TRC-369 for antioxidant, TRC-868 for sugar, Andaman for starch, Nycle for manganese, Tripura local-2 for phenolic, crude protein & potassium and NBPGR-37 for phosphorous, iron, copper & zinc content were identified.

- *In vitro* plant regeneration protocol for anthocyanin rich purple flesh sweet potato var. Bhu Krishna, β-carotene rich orange flesh sweet potato var. Bhu Sona and white flesh sweet potato var. Kishan.
- *In vitro* plant regeneration protocols of taro var. Muktakeshi, yam var. Orissa Elite and cassava var. Sree Jaya.

Crop production technologies

- Agro ecological unit (AEU) based SSNM recommendations and customized fertilizer formulations for Cassava, Elephant Foot Yam and Yams.
- Methodology to study the impact of future climate on change in suitability of cassava (RCPs 4.5 & 8.5 for 2030 & 2050), elephant foot yam (SRES A1B, 2030) yam (SRES A1B, 2030) and taro (SRES A1B, 2030).
- Developed remote sensing methodology for cassava acreage and yield estimation using Sentinel-2b satellite imagery, support vector machine (SVM) and Montieth's model.
- Calibrated WOFOST model for cassava and the results showed varietal differences in adaptation to changing climate. H-226 is found more climate resilient than Sree Vijaya.
- Calibrated CROPWAT model for cassava and developed irrigation schedules, water requirements and crop water production function for cassava.
- Calibrated AQUACROP model to estimate the yield of cassava and sweet potato as well as to estimate water productivity and irrigation water requirements under changing climate.
- Based on three years morpho-physiological data, Sree Reksha was identified as drought tolerant variety.
- Organic packages for cassava-groundnut/ vegetable cowpea and taro-black gram/green gram.
- Production technology for dwarf white yam + green gram/soybean.
- Identified Sree Reksha suitable for organic farming.
- Cassava has been identified as a sustainable crop for long term cultivation in the same field (SYI, 0.833 under PoP).
- The four NPK use efficient cassava genotypes, viz., CI-905, CI-906, 7 III E3-5 and Sree Pavithra were identified as suitable for continuous cultivation in the same agricultural field without affecting the tuber yield with 25% of the recommended dose of PoP even after five years of cultivation in the same field.
- Integrated secondary and micronutrient package for sweet potato and elephant foot yam comprising of liming material, soil and foliar application of Ca, Mg, Zn and B for improved growth and yield.
- Customized fertilizer grades with N, P_2O_5, K_2O, Mg, Zn, B @7:12:24:2.5:1.25:0.4 applied @ 625 kg ha^{-1} and 7:3:25:3:1.25:0.4 applied @ 500 kg ha^{-1} was found best for elephant foot yam and cassava with BC ratios of 5.44 and 2.3, respectively under intercropping of these crops in coconut gardens.
- Polysulphate containing K_2O: CaO: MgO: S @ 13.5:16.5:5.5:18.5 kg ha^{-1} was found as a good soil ameliorant for cassava in the laterite (Ultisols) and sandy loam (Entisols) soils of Kerala.

Crop protection technologies

- Management of postharvest rot in elephant foot yam by dipping corms in Mancozeb + Carbendazim 0.2%.
- Treating the corms with *Trichoderma* in cow dung slurry for post harvest rot management in organic cultivation of elephant foot yam.
- Isolated two potential endophytes, *Bacillus amyloliquefaciens* from root of *Phyllanthus niruri* and *Bacillus licheniformis* from the leaf of *Aloe vera* against *Colletotrichum gloeosporioides* causing anthracnose in greater yam with growth promotion activities.
- Management of cassava root rot by application of lime @ 150 to 250 g per plant 10-15 days before planting, application of neem cake @ 20 g per plant, *Trichoderma asperellum* enriched FYM/ vermicompost @ one kg per plant, sett treatment with Carbendazim (0.1%) or combination of Carbendazim and Mancozeb (0.2%) for 10 minutes and drenching with the same fungicides starting from planting three times at 15 days interval.

Technologies for value added food products

- Anthocyanin and β-carotene rich nutri-jellies from sweet potato varieties Bhu Krishna and Bhu Sona, respectively.
- Ready-to-eat extruded puffed snacks from sweet potato.
- Beta carotene rich nutri-sauce from orange fleshed sweet potato variety, Bhu Sona.

Technologies for industrial products

- Technology for the production of high quality cassava flour by static pressing method.
- Particle boards from cassava stem-sugarcane bagasse using cashew nut shell liquid as binder.
- Prototype continuous steaming machine for sago wafers/sago papad production.
- Thermoplastic starch sheets from cassava starch - cassava stem fibrous flour.
- Food grade cassava starch phosphate suitable for use as gelling agent and thickening agent in low temperature processed foods.
- Rice analogues from cassava based composite flours.

Models/Packages/ICT Tools

- Online marketing platforms, HOMS (Horticulture Crops Online Marketing System) and TOMS (Tuber Crops Online Marketing System).
- An eCrop based smart farming system was developed and installed in the field.
- Self learning cassava model was developed to add learning capability to eCrop.
- A computational model for the prediction of plant-pathogen (*Phytophthora*) interaction using the protein sequence information.
- An interactive web application for the prediction of protein-protein interaction in plants which allows to select the protein features and prediction model.

EDUCATION, TRAINING AND CAPACITY BUILDING

Education

ICAR-CTCRI is the approved Research Centre of University of Kerala and Kannur University, Kerala; Manonmaniam Sundaranar University, Tamil Nadu; Utkal University and Orissa University of Agriculture and Technology, Odisha and Jawaharlal Nehru Krishi Viswavidyalaya, Jabalpur, Madhya Pradesh, for undertaking Ph.D. programmes on tuber crops. During the period, the Institute has offered exposure trainings to students and imparted technical guidance to Ph.D. programmes and project work of M.Sc. students. Besides, the scientists of ICAR-CTCRI have handled courses at College of Agriculture, Vellayani for the students of M.Sc. Course on Integrated Biotechnology.

Particulars of the programme	Number of students/scholars
B.Sc./B. Tech project work	44
M.Sc. project work	44
M.Sc. Integrated Biotechnology	6
Ph.D.	9

Award of Ph.D.

- Mr. Prakash, P. was awarded Ph.D. in Agricultural Economics from ICAR-Indian Agricultural Research Institute, New Delhi for the thesis titled 'Institutional Finance for Horticulture Development in India: A Case of Protected Cultivation in Maharashtra State' under the guidance of Dr. Pramod Kumar.
- Mr. Prakash Krishnan, B.S. was awarded Ph. D. in Biotechnology from the University of Kerala, Thiruvananthapuram for the thesis titled 'Replicase (AC1) gene mediated resistance in cassava (*Manihot esculenta* Crantz) against *Indian cassava mosaic virus*' under the guidance of Dr. T. Makesh kumar.
- Ms. Remya, K. was awarded Ph.D. in Environmental Science from the University of Kerala for the thesis titled 'Conservation agriculture: a tool for sustainable ecological intensification of elephant foot yam in banana based system under climate change' under the guidance of Dr. G. Suja.
- Ms. Anju, P. S. was awarded Ph.D. in Environmental Sciences from the University of Kerala for the thesis titled 'Development of customized fertilizer formulations for the cultivation of elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) in Kerala for better farm income and improved tuber and soil quality' under the guidance of Dr. Susan John, K.
- Ms. Sujina, M. G. was awarded Ph.D. in Biotechnology from the University of Kerala, Thiruvananthapuram for the thesis entitled 'Management of taro leaf blight using endophytes from medicinal plants' under the guidance of Dr. M. L. Jeeva.

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

Name of the student	Subject and University	Thesis title	Name of the supervisor
Anooja Anilkumar	M.Sc. (Biotechnology) Mahatma Gandhi University, Kottayam, Kerala	Proximate analysis of nutritive quality of cassava genotypes	Dr. M. N. Sheela
S. Athira		Proximate analysis of nutritive quality of greater yam genotypes	
S. Jobin		Study on variation in cyanogen content in cassava and its detoxification through processing	
Fathima N.	M.Sc. (Biotechnology) University of Kerala, Thiruvananthapuram, Kerala	Assessment of genetic purity of yam bean (*Pachyrhizus erosus*) through phenotyping of seedlings and molecular markers	Dr. P. Murugesan
Soorya Mohanan		Morphological and molecular genetic diversity studies in *Typhonium trilobatum* Schott. L - a minor tuber crop	
Ann Maria Varghese	M.Sc. (Biotechnology) Mahatma Gandhi University, Kottayam, Kerala	Molecular characterization of cassava (*Manihot esculenta* Crantz) germplasm using SSR and ISSR Markers	Dr. Asha K. I.
Aswani S. A.	B.Sc.-M.Sc. (Integrated Biotechnology) College of Agriculture, Vellayani, Thiruvananthapuram	Assessment of genetic variability among accessions of Chinese potato (*Plectranthus rotundifolius* (Poir.) J. K. Morton) using morphological and molecular markers	
Krishnaveni Vijayakumar	B.Sc.-M.Sc. (Integrated Biotechnology) College of Agriculture, Vellayani, Thiruvananthapuram	Genetic diversity analysis of *Xanthosoma sagittifolium* (L.) Schott using molecular markers	Dr. A. Asha Devi
Lavanya M.	M.Sc. (Biotechnology) University of Kerala, Thiruvananthapuram, Kerala	The genotyping and pheno typing of high starch mapping population using SSR markers	Dr. C. Mohan
Silpa Syam		The validation of CMD resistance using associated markers in cassava	
Mahima J.		Genetic mapping of high starch population using SSR markers in cassava	
Priyanka C.		Cassava mosaic disease associated marker validation in susceptible and resistant cassava lines	
Surya P. V.		Identification and development of molecular markers linked to high starch in cassava	

Name of the student	Subject and University	Thesis title	Name of the supervisor
Irina Abraham	M.Sc. (Biotechnology) Mahatma Gandhi University, Kottayam, Kerala	Comprehensive analysis of *glutathione S-transferase* (*GST*) family gene in cassava	Dr. K. M. Senthilkumar
Mahima S.	M.Sc. (Biotechnology) University of Kerala, Thiruvananthapuram, Kerala	Comprehensive analysis of *U-box* gene in cassava	
Sharanya Prasad	M.Sc. (Biotechnology) Mahatma Gandhi University, Kottayam, Kerala	*In vitro* conservation of sweet potato (*Ipomoea batatas* L)	Dr. Vivek Hegde
Athulya G Mohan	M.Sc. (Botany) University of Calicut, Kozhikode, Kerala	Genetic diversity in cassava based on EST-Microsatellite markers	Dr. A.V.V. Koundinya
Greena Assisi	M.Sc. (Biotechnology) University of Kerala, Thiruvananthapuram, Kerala	*In vitro* mutagenesis in cassava	
Ajeena Ajith	B.Sc.-M.Sc. (Integrated) Climate Change Adaptation Academy of Climate Change Education and Research (ACCER), Kerala Agricultural University	GIS based modelling to study potential climate change on cassava climate suitability	Dr. G. Byju
Madhavi Baiju	M.Sc. (Biochemistry) University of Kerala, Thiruvananthapuram, Kerala	Site specific nutrient management of cassava on soil biochemistry and soil quality	
Aiswarya Anil R.		Site specific nutrient management of greater yam on soil biochemistry and soil quality	
Fathima J. A.		Site specific nutrient management of white yam on soil biochemistry and soil quality	
S. R. Reshma	M.Sc. (Biochemistry) University of Kerala, Thiruvananthapuram, Kerala	Physico-chemical and biological composition of certain organic manures	Dr. G. Suja
S. A. Henal		Soil enzyme activity and chemical properties under different green manures	
Sruthi T. R.	M.Sc. (Biochemistry) University of Kerala, Thiruvananthapuram, Kerala	Tuber quality parameters and leaf cyanogen content of nutrient use efficient genotypes of cassava over period of time	Dr. Susan John K.

Name of the student	Subject and University	Thesis title	Name of the supervisor
Nooruniza N.	M.Sc. (Biochemistry) University of Kerala, Thiruvananthapuram, Kerala	Influence of secondary and micronutrients on the tuber quality parameters and leaf cyanogen content of cassava (*Manihot esculenta* Crantz) over period of time	Dr. Susan John K.
Reshma R.		Quality parameters of cassava tuber and leaf cyanogen as influenced by different organic manures over a period of time	
Anjali L.		Influence of liming materials on biochemical parameters of elephant foot yam	
Athira U. S.	M.Sc. (Biochemistry) University of Kerala, Thiruvananthapuram, Kerala	Evaluation of cassava (*Manihot esculenta* Crantz) varieties for water deficit stress condition based on biochemical parameters	Dr. Sanket J. More
Malavika M.		Heat stress management in sweet potato (*Ipomoea batatas* L.)	
Ketan Kumar	M.Sc. (Ag.) Soil Science & Agricultural Chemistry College of Agriculture, OUAT, Bhubaneswar	Zinc fractionation studies in profile soils under horticulture based cropping systems of coastal Odisha	Dr. K. Laxminarayana
Hariom Panigrahi		Effect of inorganic nutrients on soil enzymes under elephant foot yam-black gram cropping system	
Bijayeeni Mohanty	M.Sc. (Biotechnology) Utkal University	Effect of inorganic nutrients on soil microbial activities in relation to yield and proximate composition of *Colocasia*	
Rosalin Mohakud	M.Sc. (Biotechnology) Utkal University, Bhubaneswar, Odisha	Assessment of soil quality in relation to yield and bio-chemical constituents under various tropical tuber based cropping systems	
Rajalakshmy R.	B.Sc.-M.Sc. (Integrated) Biotechnology) College of Agriculture, Vellayani, Thiruvananthapuram	Expression of pathogenesis related proteins by plant growth promoting rhizobacteria in controlling taro leaf blight	Dr. S. S. Veena
Ancy A. L.	M.Sc. (Biotechnology) Kerala University of Fisheries and Ocean studies	Development of alginate based formulation with *Trichoderma* and *Bacillus*	
Jaseena M.	M.Sc. (Microbiology) Mahatma Gandhi University, Kottayam, Kerala	Bicarbonates for managing post-harvest fungal pathogens of *Amorphophallus paeoniifolius* and *Dioscorea alata*	

Name of the student	Subject and University	Thesis title	Name of the supervisor
Ms. Athira Nath R.	M.Sc. (Microbiology) Mahatma Gandhi University, Kottayam, Kerala	Isolation and screening of rhizosphere bacteria for growth promotion and pathogen suppression	Dr. S. S. Veena
Akhila J.	B.Sc.-M.Sc. (Integrated Biotechnology) College of Agriculture, Vellayani, Thiruvananthapuram	Role of mixed infection of cassava mosaic viruses in cassava mosaic disease development	Dr. T. Makeshkumar
Preeja P. S.		Screening of cassava genotypes for cassava mosaic disease resistance	
S. Gopakumar	M.Sc. (Biotechnology) University of Kerala, Thiruvananthapuram, Kerala	Genetic variability in important sucking pests of tropical tuber crops	Dr. E. R. Harish
Unnikrishnan M. V.		Morphological and molecular screening of *Ipomoea* species against sweet potato weevil infestation	Dr. B. G. Sangeetha
Anupriya E. A.	M.Sc. (Food Science and Technology) Cochin University of Fisheries and Ocean Science Technology, Ernakulam, Kerala	Characterization of thermoplastic sheet from cassava starch-sorbitol composites	Dr. M. S. Sajeev
Anjumol K. A.		Development of particle board from cassava stem - sugarcane bagasse composites using cnsl as bio-adhesive	
Firose Kamal	M.Sc. (Food Technology and Quality Assurance) College of Indigenous Food Technology, Council for Food Research and Development, Konni, Pathanamthitta, Kerala	Production of high quality flour from cassava mash by static pressing method	
Gayathri S. Nair		Development of rice analogue from the composite flour of cassava-maida-beetroot	
Neha Rajeev		Development of thermoplastic sheet from cassava starch-stem fibre composites	
Jaseera Siraj S.	M.Sc. (Biochemistry) University of Kerala, Thiruvananthapuram, Kerala	Biochemical profiling of Chinese potato (*Plectranthus rotundifolius*) tubers and determination of functional properties of its starch	Dr. A. N. Jyothi
Megha Madhavan		Phenolic content and *in vitro* antioxidant activity of Chinese potato (*Plectranthus rotundifolius*) tubers	
Reshma Bijoy	M.Sc. (Food Science and Technology) St. Aloysius College (Autonomous), Mangalore	Development and optimization of gluten free starch noodles from cassava based composite flour	Dr. T. Krishnakumar

Training Programmes

A total of 657 farmers, 368 students and 69 officials from different parts of the country had undergone training at ICAR-CTCRI and various places by ICAR-CTCRI staff. They were taught on the recent technologies of tuber crops for enhancing productivity and profitability in farming.

On campus training programmes

Particulars of training	Date	Number of beneficiaries and category	Sponsoring Institute/ State
Training on improved technologies of tuber crops	23 January 2020	110 farmers from Tirunelveli district of Tamil Nadu	ATMA, Tirunelveli, Tamil Nadu
Training on improved technologies of tuber crops	28 January 2020	47 farmers from Kozhikode district of Kerala	Prathiksha farmers club, Kozhikode
Training on scientific cultivation of tuber crops	29 January 2020	25 farmers from Theni district of Tamil Nadu	ATMA, Theni, Tamil Nadu
Training on scientific cultivation of tuber crops	30 January 2020	18 farmers from Thiruvarur district of Tamil Nadu	ATMA, Thiruvarur, Tamil Nadu
Training on improved technologies of tuber crops	05 February 2020	25 farmers from Udupi district of Karnataka	ATMA, Udupi, Karnataka
Agriculture Skill Council of India development training programme on Quality Seed Grower	07 February 2020 to 02 March 2020	20 Scheduled Caste farmers	Agricultural Skill Council of India (ASCI), Govt. of India
Training on improved technologies of tuber crops	19 February 2020	16 farmers from Bhubaneswar district of Odisha	Department of Agriculture, Govt. of Odisha
Training on improved technologies of tuber crops for enhancing farm income	19 February 2020	65 farmers from Kerala	Farmers clubs from different districts of Kerala
Training on scientific cultivation of tuber crops	29 February 2020	29 farmers from Kollam district of Kerala	Farmers Club, Kollam, Kerala
Online training on scale construction using structural equation modeling	30 April to 02 May 2020	64 officers/students from ICAR Institutes/ SAUs	ICAR-CTCRI, Thiruvananthapuram
Online RHWE training programme on improved technologies of tropical tuber crops	15 September to 31 December 2020	Eight B.Sc. Horticulture students of Dr. YSRHU, College of Horticulture, Andhra Pradesh	Dr. YSRHU, College of Horticulture, Andhra Pradesh
Training programme on improved technologies of tropical tuber crops	23-26 November 2020	Eight B.Sc. Horticulture students of KAU, College of Agriculture, Padannakkad, Kasaragod	Kerala Agricultural University, College of Agriculture, Padannakkad, Kasaragod

Particulars of training	Date	Number of beneficiaries and category	Sponsoring Institute/ State
Tuber Crops Rainbow Diet Campaign School Connect programme – Orientation training for Anganwadi workers	24 November 2020	50 Anganwadi workers from Tirunelveli district, Tamil Nadu	ICAR-CTCRI, Thiruvananthapuram
Online Entrepreneurship Development Programme for students of agriculture and allied sciences	03-05 December 2020	192 students of agriculture and allied sciences from 12 states	Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvananthapuram

Farmers from Thiruvarur, Tamil Nadu

Farmers from Kerala

RHWE training to B.Sc. (Hort.) students of Dr. YSRHU

Glimpses of on campus training programmes

Training Programme on Effective Health Management for Enhancing Work Efficiency of ICAR Employees

A training programme on 'Effective health management for enhancing work efficiency of ICAR employees' for the staff members including contractual staff and students at the Headquarters, Thiruvananthapuram as well as at Regional Station, Bhubaneswar, Odisha was organized on 07 October 2020 through online mode. Facebook live streaming was also done for the benefit of large number of participants. Dr. Sheela Immanuel, Course Director and HRD, Nodal officer gave an overview about the

training and welcomed the speakers and participants of the training. Dr. V. Ravi, Director, ICAR-CTCRI, delivered the presidential address in which he emphasized the need for healthy life styles including physical exercise and diet for boosting immunity. Dr. Vidhu Kumar K., M.D. (Psychiatry), Professor, Govt. Medical College, Ernakulam, delivered a lecture cum discussion on 'Mental well being during Pandemic'. Dr. Anupama, S., BSMS (Siddha Medicine), Siddha Medical Practitioner, Thiruvananthapuram spoke on 'Stress management through Siddha'. Sri. Ramachandran, K., Sauparnika gardens, Vattiyoorkavu, Thiruvananthapuram delivered an interactive lecture cum discussion on 'Art of Living for Spiritual health'. The participants had productive deliberations with the eminent speakers. Dr. D. Jaganathan, Senior Scientist & Coordinator of the training programme proposed the vote of thanks and Dr. H. Kesava Kumar, Scientist & Coordinator moderated the programme.

Professional Internship

- Dr. Sonia Tewari, Ph.D., G. B. Pant University of Agriculture and Technology, Pantnagar, Uttrakhand has undergone internship programme on Gender main streaming, during 01-30 November 2020 under the guidance of Dr. Sheela Immanuel.
- Ms. Zohmingmawii Sailo, Ph.D. Scholar, Department of Agricultural Extension, SASRD, Nagaland University, Nagaland has undergone internship programme on Livelihood analysis, during 16 November-14 December 2020 under the guidance of Dr. Sheela Immanuel.
- Mr. Vivek, S., Ph.D. Scholar, Kerala Agricultural University, College of Horticulture, Vellanikkara, Thrissur and Mr. Abhishek Rajeev and Ms. Anju Sreekumar, MSW Scholars, Christ University, Bengaluru have undergone internship programme on Innovation System Analysis, during 12 November-11 December 2020 under the guidance of Dr. D. Jaganathan.
- Dr. Deept Kothari, PDF, IDP-NAHEP, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttrakhand and Mr. Uttam Singh, SRF, ICAR-National Institute of Biotic Stress Management, Raipur, Chhattisgarh have undergone internship programme on Methodologies for impact assessment during 01-30 November 2020 under the guidance of Dr. P. Prakash.

Trainings organized by Techno Incubation Centre, ICAR-CTCRI

Seven hands on trainings on value added products from tuber crops were organized at the Techno incubation centre, ICAR-CTCRI, Thiruvananthapuram, which were attended by 113 participants. Technology for the production of fried snack food products from cassava was transferred to two entrepreneurs, viz., Ms. Beenamma, Grany Foods, Kozha, Kottayam and Mr. Anoop, Pothencode, Thriuvanathapuram, Kerala.

Trainings organized by RS ICAR-CTCRI Bhubaneswar

On campus training programmes

- Training programme on 'Tuber crops and allied agricultural technologies for livelihood and nutritional security' was held at ICAR-CTCRI, Bhubaneswar, Odisha during 6-10 January 2020.

Other training programmes were as follows:

Particulars of training	Date	Number and category of beneficiaries	Sponsoring Institute/ State
Training on 'Agro-techniques and value addition in tuber crops/soil health, nutrient management and its effect on crop production/ vermicompost production technology for sustainable crop production'	10 March 2020	27 progressive farmers along with 2 Agricultural Officers of Amudalavalasa, Burja and vajrapukotturu mandals of Srikakulam district, Andhra Pradesh	Farmers' Training Centre, Srikakulam, Andhra Pradesh
	09 December 2020	14 farmers of Parvatipuram mandal, Andhra Pradesh	Department of Horticulture, Government of Andhra Pradesh

Off campus training programmes

- Training on 'Scientific methods of cultivation and value addition in sweet potato' at Horticulture Department Nursery Station, Boudh to Assistant Directors of Horticulture, Assistant Horticultural Officers and Horticulture Extension Worker(s) of Boudh district, Odisha on 19 November 2020.
- Training on 'Agro-techniques and value addition in tuber crops/soil health, nutrient management and its effect on crop production/vermicompost production technology for sustainable crop production' was organized as given below.
  - 50 farmers including 10 women farmers of Tirtol block, Jagatsinghpur district, Odisha on 09 January 2020.
  - 50 farmers including 10 women farmers of Kujang block, Jagatsinghpur district, Odisha on 10 January 2020.
  - 50 farmers of Ramgarh and Hazaribagh districts, Jharkhand on 14 February 2020.
  - 13 farmers of Kuchinda block, Sambalpur district, Odisha on 15 February 2020.
  - 200 farmers of Lembucherra, Agartala, Tripura on 24 February 2020.
  - 17 farmers including 5 women farmers of Sambalpur and Bolangir districts, Odisha on 02 March 2020.

The following training programmes were conducted under the sponsorship of CIP, Bhubaneswar

Particulars of training	Date	Beneficiaries
Training programme on 'Processing and value addition of sweet potato' at Horticulture Department Nursery Station, Boudh, Odisha	05-08 October 2020 03-04 December 2020 07-10 December 2020	SHGs and farmers in Khurda district, Odisha
	27-28 October 2020	Farmers in Angul district, Odisha
	02-03 November 2020	SHGs and farmers in Keonjhar district, Odisha
	04-05 November 2020	SHGs and farmers in Gajpati district, Odisha
	06-07 November 2020	SHGs and farmers in Rayagada district, Odisha
	19-22 December 2020	SHGs and farmers in Kandhamal district, Odisha

Glimpses of Training programmes at RS ICAR-CTCRI, Bhubaneswar

Professional attachment training of newly recruited ARS scientists

- Ms. Ana Raj, J., Scientist (Agricultural Extension), ICAR-National Research Centre on Equines (NRCE), Hisar, Haryana, has undergone professional attachment training on the topic 'Gender mainstreaming in cassava cultivation in Kanyakumari district of Tamil Nadu' during 21 May to 18 August 2020 under the guidance of Dr. D. Jaganathan and Dr. P. Prakash, Section of Extension and Social Sciences, ICAR-CTCRI, Thiruvananthapuram.
- Mr. Subeesh A. of ICAR-Central Institute of Agricultural Engineering (CIAE), Bhopal,

Madhya Pradesh has undergone Professional Attachment Training on 'e-Crop Based Smart Farming and Development of Data Driven Self-learning Model for Cassava Production System' during 04 June to 04 September 2020 under the guidance of Dr. V. S. Santhosh Mithra, Principal Scientist, Section of Extension and Social Sciences, ICAR-CTCRI, Thiruvananthapuram.

- Ms. Sona Charles, Scientist (Bioinformatics), ICAR-Indian Institute of Spices Research, Kozhikode has undergone three months Professional Attachment Training on 'Host Virus Interaction Prediction Using Machine Learning Techniques' during 10 September to 10 December 2020 under the Guidance of Dr. J. Sreekumar, Principal Scientist, Section of Extension and Social Sciences, ICAR-CTCRI, Thiruvananthapuram.

Exposure visit-cum-training programmes

- One day exposure visit cum training on 'Improved technologies of tuber crops' was organized for the benefit of 330 farmers, 431 students and 30 officials across the nation at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram. Exposure visits to the Institute were organized by state department of agriculture/farmers' organizations.
- A one day exposure visit cum training on Tuber crops technologies was organized at RS ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha for 1472 persons comprising of farmers, students and officials.

Exposure visits of college students to ICAR-CTCRI

Resource person in Training programmes

More than 150 classes on production, protection, processing and value addition aspects were handled through online and offline mode by the scientists of various divisions under different programmes within and outside the Institute beneficial to department officials, subject matter specialists, students and farmers all over the country. The specific topics covered were improved varieties, tissue culture, agro-techniques with special focus on organic management, integrated nutrient management, integrated pest management, integrated disease management, vermicomposting, bio-pesticides and bio-control strategies, post-harvest management and value addition.

Trainings attended by ICAR-CTCRI staff

(a) Scientific staff

Sl.No.	Name	Particulars of the training	Period
1.	Dr. E. R. Harish	Online training course on Integrated pest management, organized by Center for Development of Technical Education, IIT Kanpur and the Commonwealth of Learning (COL), Canada.	21 April 2020 to 30 June 2020
2.	Dr. D. Jaganathan Dr. P. Prakash	Online training on Quantitative methods for Social Sciences, organized by ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi.	01-20 June 2020
3.	Dr. G. Suja	Web based Training on district wise synthesis of IFS models based on secondary data, organized by ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh	06 June 2020
4.	Dr. Sheela Immanuel Dr. D. Jaganathan Dr. P. Prakash	Online Training of Trainers programme on gender and social security, organized by V. V. Giri National Labour Institute, New Delhi	08-12 June 2020
5.	Dr. C.Visalakshi Chandra	Real time PCR based gene expression and disease diagnosis, organized by Satyabhama College of Science and Technology, Chennai.	06-07 July 2020
6.	Dr. C.Visalakshi Chandra	Intellectual Property Rights, organized by Jamal Mohamed College, Tiruchirappalli	18-19 July 2020
7.	Dr. P. S. Sivakumar	Online training on Understanding unconscious mind: Using online version of Inkblot testing, organized by Psychowaves and Dubey Healing Centre	18-19 July 2020
8.	Dr. M. N. Sheela Dr. A. V. V. Koundinya	Analysis of experimental data using R, organized by ICAR-NAARM, Hyderabad	05-11 August 2020
9.	Dr. J. Sreekumar	Online training workshop for Vigilance officers of ICAR Institutes, organized by ICAR-NAARM, Hyderabad	05-07 August 2020
10.	Dr. Asha K. I.	Data Analysis in R using STATCRAFT, organized by University of Lucknow, Lucknow	13 August 2020
11.	Dr. C.Visalakshi Chandra	Research methodology and data analysis at Bishop Caldwell College, Tuticorin, Tamil Nadu	16-20 August 2020
12.	Dr. P. S. Sivakumar Dr. P. Prakash	Online training on orientation workshop and training program for ABI units, organized by ICAR-NAARM, Hyderabad.	17-19 August 2020
13.	Dr. S. S. Veena Dr. T. Makeshkumar	Plant quarantine procedures for imports and exports, organized by National Institute of Plant Health Management, Hyderabad	24-28 August 2020
14.	Dr. Asha K. I.	Microbial Intervention in plant health and nutrition, organized by Navsari Agricultural University, Gujarat	25-26 August 2020

Sl.No.	Name	Particulars of the training	Period
15.	Dr. P. Prakash	Online training on Research methodology in Social Sciences, organized by NAHEP, CAMI and AAU, Anand, Gujarat.	01-11 September 2020
16.	Dr. P.S. Sivakumar	FDP on 'Advanced multivariant data analytics: moderation and mediation analysis using AMOS & Process Macro', organized by Indian Institute of Management, Visakhapatnam, Andhra Pradesh	07-11 September 2020
17.	Dr. D. Jaganathan	Gender mainstreaming in agriculture and allied sectors, organized by MANAGE, Hyderabad	07-11 September 2020
18.	Dr. D. Jaganathan	Innovative practices in extension research and evaluation, organized by ICAR-NAARM, Hyderabad	08-28 September 2020
19.	Dr. Vivek Hegde	ABC of Scientific writing organized by ICAR-National Rice Research Institute, Cuttack	18 August to 02 September 2020
20.	Dr. K. M. Senthilkumar	Fundamental concepts and applications of research methodology, organized by Bihar Agricultural University, Sabour	06-07 October 2020
21.	Dr. P. Murugesan	MDP on 'Priority setting, monitoring and evaluation of agricultural research projects', organized by ICAR-NAARM, Hyderabad	12-17 October 2020
22.	Dr. T. Krishnakumar	FDP international training on Emerging technologies in postharvest management and value addition in horticultural commodities, organized by Department of Agriculture and Environmental Sciences, NIFTEM, Sonipat, Haryana	02-06 November 2020
23.	Dr. K. Laxminarayana	On-line Management development programme on Leadership development (pre-RMP Programme), organized by ICAR-NAARM, Hyderabad	08-19 December 2020
24.	Dr. T. Makeshkumar	Introduction to Plant biosecurity and plant quarantine, organized by National Institute of Plant Health Management, Hyderabad	14-18 December 2020
25.	Dr. Asha K. I.	Geographical Indications - significance & registration procedures, organized by Kerala State Council for Science, Technology & Environment (KSCSTE), Thiruvananthapuram	18 December 2020
26.	Dr. S. S. Veena	Post harvest management and storage techniques, organized by National Institute of Plant Health Management, Hyderabad	28-31 December 2020
27.	Dr. R. Muthuraj	Emerging trends in seed production technology and quality control framework for effective Seed supply chain of horticulture crops at UHS, Bagalkot, Karnataka	28 December 2020 to 06 January 2021

(b) Technical staff

Sl.No.	Name	Particulars of the training	Period
1.	Smt. B. S. Deepa, Senior Technical Assistant (Library)	'KOHA for ICAR Library staff', ICAR-NAARM, Hyderabad	20-25 February 2020
2.	Smt. B. S. Deepa, Senior Technical Assistant (Library)	National level online webinar on 'Managing of library using google tools' organized by ILIS (Institutions for Librarians and Information Scientists)	11 July 2020

(c) Administrative staff

Sl.No.	Name	Particulars of the training	Period
1.	Mr. S. Sasikumar	XI batch training programme on 'Enhancing efficiency and behavioural skills' for Steno Gr.III, PA, PS and PPS of ICAR Institutes/HQs organized by ICAR-NAARM, Hyderabad.	24-29 February 2020

AWARDS AND RECOGNITIONS

Awards

- The QRT report of ICAR-Central Tuber Crops Research Institute and AICRP on Tuber Crops got the grade of 'Outstanding' for the significant achievements in research, extension and overall performance during last five years period from 01 April 2014 to 31 March 2019.
- The ICAR-CTCRI Institute Technology Management Unit bagged 'Best Entrepreneur Promotion Award' by the Incubation Centre, North Eastern Hill University, Tura, Meghalaya during March 2020 for the entrepreneurship promotion activities organized in the NEH region.

Best Entrepreneur Promotion Award
by the Incubation Centre,
North Eastern Hill University, Meghalaya

- ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram bagged first prize in the category of 'Best Exhibition Stall Award' in VAIGA 2020 during 04-07 January 2020 at Thekkinkadu Maidanam, Thrissur, Kerala.
- Two purple fleshed greater yam varieties viz., Sree Neelima and Da-340 enriched with anthocyanins and micronutrients were among the 17 biofortified varieties dedicated to the Nation by the Hon'ble Prime Minister on the occasion of World Food Day on 16 October 2020.

Dedication of anthocyanin rich greater yam varieties to the nation by Hon'ble PM on World Food Day

- ICAR-CTCRI received the 'Best Centre Award' in the 15th AGM of All India Network Programme on Organic Farming (AINPOF), held during 25-26 November 2020 (PI: G. Suja, Co-PIs: G. Byju, S. S. Veena, S. Sunitha, A. N. Jyothi and M. N. Sheela).


ICAR – Indian Institute of Farming Systems Research
Modipuram, Meerut – 250 110

CERTIFICATE

This certificate is presented to

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

in recognition of being the

Best Centre of All India Network Programme on Organic Farming (AI-NPOF)

during 2019-20 under

ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut- 250 110

The team comprising of Dr. G. Suja as Principal Investigator and Dr. G. Byju, Dr. S.S. Veena, Dr. S. Sunitha, Dr. A.N. Jyothi and Dr. M.N. Sheela as Co-Investigators contributed for better performance of the centre including successful experimentation, publications and development of technologies for tuber crops (cassava-ground nut/vegetable cowpea, taro–blackgram/greengram) under organic production system. An integrated organic farming system model involving tuber crops and dairy also established, besides, geo-tagged characterization of 131 organic growers. The centre also contributed for human resource development by organizing model training course on organic farming, besides effective implementation of scheduled caste sub plan programme of the scheme.

(N. Ravisankar)
National PI, AI-NPOF & (PF (CU)

(A.S. Panwar)
Director

Best Centre Award of AINPOF

- Dr. P. Murugesan bagged the 'Distinguished Horticulture Scientist (2018)' award by the Society for Horticulture Research and Development on 14 February 2020 in recognition of significant contributions to Horticultural Sciences.
- The MM UP School, Peroor, Kilimanoor received the best Science Project Award at National Science Fest for their project on 'Green energy from cassava wastes' based on technical and intellectual support provided by ICAR-CTCRI. Dr. G. Byju attended the School Annual Day and Science Fest as Chief Guest on 20 February 2020.
- Dr. Sabitha Soman and Dr. G. Byju received the best research paper award for the paper published in Current Horticulture in 2017 (Sabitha Soman and Byju, G. 2017. On-farm validation of site specific nutrient management in cassava (*Manihot esculenta*) in Thiruvananthapuram, Kerala, *Current Horticulture* 5(1): 20-29).
- Dr. T. Makeshkumar was conferred as Fellow of the Indian Virological Society instituted by the Indian Phytopathological Society, New Delhi on 02 February 2020.
- Dr. T. Krishnakumar bagged the Young Researcher Award 2020 by Institute of Scholars (InSc), Bengaluru, Karnataka (An ISO 9001:2015 certified institute by international accurate certification, accredited by UASL).
- Dr. N. Krishna Radhika was selected under the Third Call of the Indo-U.S. Genome engineering/ Editing Technology Initiative (GETin) Overseas Fellowship program module supported by the Department of Biotechnology (DBT), Govt. of India and implemented by the Indo-U.S. Science & Technology Forum (IUSSTF) for the proposal entitled 'Gene editing Indian cassava varieties to produce high value waxy starch' for a duration of six months under the U.S. Host, Dr. Nigel Taylor, Associate member and Dorothy J. King Distinguished Investigator, Donald Danforth Plant Science Centre, St. Louis (MO), USA.
- Dr. Shirly Raichal Anil bagged the best poster award for the research paper titled 'Development of potato genotypes from heat tolerant true potato seed (TPS) crosses for combating climate emergency' (Authors: Gupta, V. K., Shirly Raichal Anil, Sunitha, S. and Chakrabarti, S.K.) in the Global Potato Conclave held during 27-31 January 2020 at Gandhi Nagar, Gujarat.
- Dr. P. Prakash bagged best oral presentation award for the research paper titled 'Economic evaluation of protected cultivation of capsicum in Maharashtra' (Authors: Prakash, P., Pramod Kumar, Amit Kar, Prabhat Kishore and Awani Kumar Singh) in National Conference on vegetable farmer's forum 2020 during 25-26 June 2020 organized by ICAR-Indian Agricultural Research Institute, New Delhi.
- Dr. P. Prakash was conferred 'Young Researcher Award 2020' in Agricultural Economics from Institute of Scholars, InSc units of SDPL, Bengaluru for the research paper entitled 'Status and impact of protected cultivation of horticultural crops in Maharashtra'.
- Dr. D. Jaganathan bagged best oral presentation award (Authors: Jaganathan, D., Sheela Immanuel,

Prakash, P. and Sivakumar, P. S.) in National Conference on Agricultural Resource Management for Atma Nirbhar Bharat during 17-19 July 2020 organized by Central Agricultural University, Imphal, Manipur.

- Dr. D. Jaganathan bagged best oral presentation award (Authors: Ana Raj, Jaganathan, D., Prakash, P. and Sheela Immanuel) in National Workshop on Gender issues and Atma Nirbhar Bharat in Agriculture during 15-17 October 2020 organized by Central Agricultural University, Imphal, Manipur.
- Dr. P. Prakash bagged best oral presentation award for the paper titled 'Progress, perception and utilization by beneficiaries of PMKISAN scheme of Karnataka' (Authors: Kavitha H.N., Pramod Kumar, Anbukkani, P., Burman R. R. and Prakash, P.) in International e-conference on marketled extension management: Focus on COVID-19 during 17-18 October 2020 organized by CCS National Institute of Agricultural Marketing, Jaipur and International Society of Extension Education, Nagpur at NIAM, Jaipur, Rajasthan.
- Dr. K. M. Senthilkumar was awarded the second best oral presentation award for the research work entitled Genome-wide identification, classification, collinearity and expression analysis of *MeHsp70* family genes in Cassava (*Manihot esculenta* Crantz) (Authors: Senthilkumar, K. M., Pushpitha, P. and Sheela, M. N.) in the International E-Conference on 'Advances and Future Outlook in Biotechnology and Crop Improvement for Sustainable Productivity' held during 24-27 November 2020 organized by the Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru.
- Dr. T. Makeshkumar bagged four best oral presentation awards for the research papers titled 'A protocol for the regeneration of cassava mosaic disease resistant variety' (Authors: Divya K. and Makeshkumar, T.); 'Cloning of antisense sequence of replicase gene of Sri Lankan cassava mosaic virus' (Authors: Iype Praveen Thomas and Makeshkumar, T.); 'Identification of conserved micro RNAs from a CMD tolerant cassava variety in response to cassava mosaic virus infection' (Authors: Summayya, M. and Makeshkumar, T.) and 'Production of disease free plants of elephant foot yam through tissue culture' (Authors: Merlin Graceson Cherian and Makeshkumar, T.) in the IPS-Virtual National Symposium 2020 on Advances in crop health management held during 01-02 December 2020.
- Dr.M.S.Sajeev bagged the 'Outstanding Achievement Award 2020' in 11th International Conference on Agriculture, Horticulture and Plant Sciences held at STA Office, New Delhi during 19-20 December 2020, organized by the Society of Tropical Agriculture.

Recognitions

Division of Crop Improvement

Dr. M. N. Sheela

- Secretary, Indian Society for Root Crops.
- Member, Board of Studies, Faculty of Agriculture, Kerala Agricultural University.
- Member, Institute Management Committee of ICAR-Directorate of Cashew Research, Puttur, Karnataka.
- External examiner, evaluation of M.Sc. (Ag.) thesis of Sri. Pamarthi Vinod, Plant Breeding and Genetics, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram, Kerala.
- Member, DPC for considering the promotion of ARS scientists of ICAR-Indian Institute of Spices Research, Kozhikode.
- DG's nominee, for considering the promotion of ARS scientists of ICAR-Directorate of Medicinal and Aromatic Plants Research, Anand, Gujarat.

Dr. Asha, K. I.

- Editor-in-Chief of ICAR-CTCRI Newsletter.
- External examiner for the evaluation of M.Sc. (Ag.) thesis of Ms. Amala Benny, Plant Biotechnology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram, Kerala.

Dr. Mohan, C.

- Evaluated the thesis of Ms. Bhoomika B. K., M. Sc. (Plant Breeding and Genetics) student from College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram, Kerala.

Dr. P. Murugesan

- Member Secretary, Committee for implementation of NABL accreditation at ICAR-CTCRI.

- Expert member, Panel for technical paper evaluation committee of 31st and 32nd Kerala Science Congress.
- Technical member of the expert team for the accreditation and rating of horticultural nurseries in Kerala under National Horticultural Board.
- Invited speaker in the Webinar on 'Oil palm genetic resources: present status future needs in India', held on 07 October 2020 at ICAR-Indian Institute of Oil Palm Research, Pedavegi, Andhra Pradesh.
- Chairman and Nodal Officer, ICAR-CTCRI of the task force on Innovation Excellence Indicators for Public Funded R&D Organizations Innovation (an initiative of the Principal Scientific Adviser to Government of India).
- As the external expert, evaluated the thesis of M.Sc. (Ag.) students of Tamil Nadu Agricultural University, Coimbatore and Agricultural College and Research Institute, Madurai, Tamil Nadu.
- Member Secretary, Expert Committee to screen the varieties developed in ICAR-CTCRI for submitting the proposals to Central/State Varietal Release Committee.
- Reviewer for the Journal of Oil Palm Research.

Dr. A. Asha Devi

- External Expert for the Assessment Committee for extension of CSIR Fellowship of Ms. Manjula K. K., Senior Research scholar of the Department of Botany, University of Kerala on 22 October 2020.

Dr. Shirly Raichal Anil

- Secretary, Science Forum, ICAR-CTCRI.

Dr. Kalidas Pati

- Chairman of the Interview board for selection of YP-I and YP-II under different DUS Projects funded by PPV&FRA, New Delhi.

Dr. N. Krishna Radhika

- Editor, Journal of Root Crops.
- Editor, Newsletter, ICAR-CTCRI.

Dr. Senthilkumar K. M.

- Member, Committee for implementation of NABL accreditation at ICAR-CTCRI.
- Member, Institute biosafety committee.
- Awarded with 'Quarterly Franklin Membership by London Journal Press, 1210th, Arlington Business Park, Theale, United Kingdom.
- Web-Editor, Journal of Root Crops.
- Convener, Biotechnology and Biomedical session in the 29th Swadeshi Science Congress-National Conference on Science and Technology for Sustainable Development during 27-29 February 2020 at ICAR-CPCRI, Kasaragod.

Dr. Vivek Hegde

- Reviewer for International Journal of Agriculture Sciences, World Research Journal of Agricultural Sciences and cryoletters.

Dr. Vijay Bahadur Singh Chauhan

- Awarded with 'Quarterly Franklin Membership by London Journal Press, 1210th, Arlington Business Park, Theale, United Kingdom.
- Awarded with 'Certificate of Excellence in Reviewing' by Chief Managing Editor of Asian Journal of Agricultural and Horticultural Research and Asian Journal of Applied Chemistry Research Certificate of Excellence in Reviewing.

Dr. A.V.V. Koundinya

- Reviewer, Journal of Water and Climate Change, Applied Biological Research, International Journal of Vegetable Science, Psyche and Asian Research Journal of Agriculture.

Division of Crop Production

Dr. G. Byju

- Conferred Fellow, Society for Horticulture Research and Development (SHRD), New Delhi, India.
- Conferred Fellow, Confederation of Horticulture Association of India (CHAI), New Delhi, India.
- Member Secretary, QRT 2014-2019 of ICAR-CTCRI and AICRP on Tuber Crops.
- As the External Examiner, evaluated the Ph.D. thesis titled 'Growing out of hunger: towards an improved understanding of the water and nutrient limited yield of cassava', and conducted the Final Viva Voce of Mrs. Joy G. Adiele, Department of Plant Production Science, Wageningen University, The Netherlands.
- Reviewer Plant Production Science, Acta Agrobotanica, International Journal of Climatology, Journal of Plant Nutrition, Communications in Soil Science and Plant

Analysis, Chemistry and Ecology and Journal of Environmental Biology.

- Member Advisory Committee, M.Sc.(Ag.) Soil Science & Agrl. Chemistry student, College of Agriculture, Vellayani, Kerala.
- External Examiner for the evaluation of two Ph.D. thesis and three M.Sc.(Ag.) thesis of Kerala Agricultural University.
- Mentor of two women scientists: Potential impact of climate change on tropical tuber crops yield in the major growing areas of India (DST, Govt. of India, WOS-A Scheme – Mentee Woman Scientist: Dr. P. Raji) & Climate smart natural resource management of cassava (*Manihot esculenta* Crantz) using geoinformatics tools (KSCSTE, Govt. of Kerala, Women Scientist Back-to-Lab Scheme - Mentee Woman Scientist - Mrs. R. Shiny).

Dr. G. Suja

- Member Secretary, RAC VIII of ICAR-CTCRI.
- Editor, Journal of Root Crops, Indian Society of Root Crops.
- Subject Expert, XII Scientific Advisory Committee Meeting of KVK, Kottayam on 12 February 2020.
- External Examiner of qualifying viva voce of 14 M.Sc. students, Department of Agronomy, College of Agriculture, Vellayani. External examiner for evaluation of thesis of 5 M.Sc. Agronomy students of the Department of Agronomy, College of Agriculture, Thiruvananthapuram and College of Horticulture, Vellanikkara, Thrissur under Kerala Agricultural University and Directorate of Crop Management, Tamil Nadu Agricultural University.
- Member, Advisory Committee of 2 students, Ph.D. programme, & B.Sc.-M.Sc. (Integrated) Climate Change, Kerala Agricultural University.
- Conducted the final thesis viva as a member, Advisory Committee, Ph. D. Research Programme, of Ms. K. Sreelakshmi, Department of Agronomy, College of Horticulture, Vellanikkara, Kerala Agricultural University.
- Reviewer of 5 research papers to Archives of Agronomy and Soil Science, Hort Science, Journal of Environmental Biology, Journal of Spices and Aromatic Plants and Journal of Root Crops respectively

Dr. K. Susan John

- External examiner for conducting the qualifying viva-voce examination of 9 M.Sc. (Ag.) students of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani and one M.Sc. (Ag.) thesis evaluation of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellanikkara under Kerala Agricultural University.
- Resource person for the DST sponsored Training programme on 'Integrated nutrient management and nutrient budgeting through advanced models to improved crop productivity' at ICAR-Indian Institute of Soil and Water Conservation Research, Centre, Ooty, Tamil Nadu during 03-07 February 2020.
- Received the award of appreciation from Director and Staff, ICAR-CTCRI during the International Women's day celebration at ICAR-CTCRI on 10 March 2020.
- Reviewer for one research paper each for Indian Journal of Agronomy, Scientific Reports, Springer Nature, and Rubber Science
- Invited Speaker for presenting the theme lecture titled 'Exploring soil biodiversity: the key to soil health' under the World Soil Day 2020 celebration of Kerala Agricultural University on 5 December 2020.
- Delivered two invited lectures for the DST sponsored Training programme at the ICAR-Indian Institute of Soil and Water Conservation Research, Centre, Ooty, Tamil Nadu during 3-7 February 2020.
- Chairperson, Store purchase advisory committee, ICAR-CTCRI.

Dr. K. Laxminarayana

- External Member for the selection of Project Associate-I and Project/Field Assistant under the DST sponsored project at ICAR-IIWM, Chandrasekharpur, Bhubaneswar, Odisha.

Dr. V. Ramesh

- Member, Committee for implementation of NABL accreditation at ICAR-CTCRI.
- Treasurer, Indian Society for Root Crops.
- External examiner for evaluation of thesis of 3 M.Sc. (Ag.) students of the Department of Soil

Science and Agricultural Chemistry, College of Agriculture, Thiruvananthapuram and College of Horticulture, Vellanikkara, Thrissur, Kerala.

- Evaluated the thesis of two Ph.D. students of the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore and conducted the final thesis viva as external examiner for Mr. K. Sivasabari and Ms. K. Theresa.
- External examiner for conducting the final thesis viva of one Ph.D. student of Calicut University, Kerala.

Dr. K. Sunil Kumar

- Panelist for webinar on 'Oil palm genetic resources-present status and future needs in India' on 7.10.2020 organized by IIOPR, Pedavegi.
- External examiner for adjudication of thesis of one Ph.D. (Horticulture) student, Department of Plantation Crops & Spices and 2 M.Sc. (Horticulture- Fruit Science and Plantation Crops & Spices) students, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram.

Dr. Sanket J. More

- Editor, Journal of Root Crops
- Reviewer for the journal, Multilogic in Science.

Division of Crop Protection

Dr. C. A. Jayaprakas

- Chief Public Information Officer, Right to Information.
- Expert Committee Member, Programme Advisory Committee (PAC), Technology Development Programme (TDP), DST, Govt. of India.
- Expert Committee Member, Evaluation of Project for Chancellor's award, KSHEC, Govt. of Kerala.
- Expert Committee Member, 27th Research Council meeting of Science Research Scheme (RC-SRS), Thiruvananthapuram, Kerala.
- Reviewed five projects for Kerala State Council for Science Technology and Environment (KSCSTE) and one project for Mahatma Gandhi University, Kottayam under Rashtriya Uchchatar Shiksha Abhiyan (RUSA).
- Executive Council Member, Central University of Kerala, Govt. of India.
- Member, Board of Studies, CMS College, Kottayam.
- Joint Secretary, Association of Advancement of Entomology.
- External examiner, evaluation of thesis of 6 Ph.D. students of University of Mysore, Karnataka; Guru Nanak Dev University, Punjab; Maharaja's College & University of Calicut, Kerala.
- External examiner for conduct of qualifying viva-voce examination of 11 M.Sc. (Ag.) students of Kerala Agricultural University.
- Question paper setter for Ph.D. course work in University of Kerala.
- Judge, Essay competition for the students in connection with Children' Biodiversity Congress-2020.

Dr. M. L. Jeeva

- External examiner, evaluation of thesis and conduct of final viva-voce examination of 2 Ph.D. Plant Pathology students from Kerala Agricultural University and Tamil Nadu Agricultural University.
- External examiner for conduct of qualifying viva-voce examination of 10 M.Sc. Plant Pathology students of Kerala Agricultural University.
- External examiner, evaluation of thesis of 4 M.Sc. Plant Pathology students of Kerala Agricultural University.
- Judge, Prof. M. J. Narasimhan academic award contest and poster session at Indian Phytopathological Society (IPS) - South Zone Virtual Symposium held on 02 December 2020.
- Reviewer, Journal of Sugarcane Research, Indian Phytopathology, Archives of Phytopathology and Crop Protection.

Dr. S. S. Veena

- Member, Advisory Committee, Ph. D. programme of Kerala Agricultural University.
- External examiner, evaluation of thesis and conduct of final viva-voce examination of Ph.D. Plant Pathology student of Kerala Agricultural University.
- External examiner, evaluation of thesis of 2 B.Sc.-M.Sc. (Integrated) Biotechnology students of Kerala Agricultural University.

- External examiner, evaluation of thesis of 5 M.Sc. (Plant Pathology) students of Kerala Agricultural University.
- Member, Editorial board, Journal of Agricultural Research Advances.
- Reviewer, Microbial Ecology, Archives of Microbiology, Journal of Tropical Agriculture, Indian Phytopathology, Journal of Spices and Aromatic Crops, Journal of Horticultural Sciences and Journal of International Research in Medicinal and Pharmaceutical Sciences.
- Member, Agriculture Knowledge Centre, Attingal Block, Kerala.
- Research Supervisor, Biotechnology, Faculty of Applied Sciences and Technology, University of Kerala.
- Judge, Prof. M. J. Narasimhan Academic Award and poster session at Indian Phytopathological Society (IPS) - South Zone Virtual Symposium held on 02 December 2020.

Dr. T. Makeshkumar

- Chairman, Committee for implementation of NABL accreditation at ICAR-CTCRI.
- Member, Institute Management Committee, ICAR-CPCRI, Kasaragod and ICAR-IISR, Kozhikode (2018-2020).
- Member, Institute Biosafety committee of ICAR-IISR, Kozhikode (2020-2022).
- Member, Editorial Board, Indian Phytopathological Society (2020-2023).
- External examiner for the Ph.D. thesis evaluation of students from KAU, ANGRAU, TNAU and Jain University.
- External examiner for the thesis evaluation of five M. Sc. (Ag.) Plant Pathology students of Kerala Agricultural University.
- Guest faculty for B.Sc. (Ag.) students of VIT Vellore, Tamil Nadu and delivered a lecture on Plant virus transmission on 16 March 2020.
- Reviewer for the journals, PLOS One, Annals of Applied Biology, Indian Phytopathology and Virus disease.

Dr. E. R. Harish

- Member, Executive committee, Indian Society for Root Crops.
- Member, Executive committee, Association for Advancement of Entomology.

Dr. H. Kesava Kumar

- Jury, State Agricultural Awards 2020 and Extension Personnel Award 2020, Govt. of Kerala.
- Editor, Journal of Root Crops, Indian Society of Root Crops.
- Member, Working Group, Open Access India 2020.
- Reviewer, Indian Journal of Entomology, International Journal of Agricultural Sciences and Vegetos.

Dr. B.G. Sangeetha

- Member, Committee for implementation of NABL accreditation at ICAR-CTCRI.

Section of Crop Utilization

Dr. M. S. Sajeev

- External Examiner for the Ph.D. viva-voce of one student from TNAU, Coimbatore on 22 July 2020, Ph.D./M.Tech (AP&FE) viva-voce of 2 students from KCAET, Tavanur on 05 August 2020 and 25 November 2020 and one student from IIT, Kharagpur on 20 August 2020.
- Examiner for the qualifying viva to promote one JRF to SRF at NIIST, Thiruvananthapuram and another one at ICAR-CTCRI, Thiruvananthapuram.

Dr. A. N. Jyothi

- Member, Technical Committee of State Pesticide Testing Laboratory, Department of Agriculture, Govt. of Kerala.
- Chairperson for the Board of Adjudicators for evaluation and conducting the open defence of one Ph.D. student of Department of Chemistry, Calicut University, Kerala.
- Member, Advisory Committee of one student, Ph.D. programme, Kerala Agricultural University.

Dr. T. Krishnakumar

- Editor, Journal of Root Crops and ICAR-CTCRI Newsletter.
- Technical committee member, SAGOSERVE, Salem, Tamil Nadu.
- Member, Committee for implementation of NABL accreditation at ICAR-CTCRI.
- Reviewer for the Current Journal of Applied Science and Technology.

- Professional member, Institute of Scholars (InSc), Bengaluru.

Section of Extension and Social Sciences

Dr. Sheela Immanuel

- Resource person for PGDAEM-MANAGE correspondence course and delivered lectures of the course on Participatory Approaches in Agricultural Extension during 18-19 November 2020 at SAMETI, Anayara, Thiruvananthapuram.
- Reviewer for four journals namely Agricultural Research, Fishery Technology, Indian Journal of Fisheries and Journal of Root Crops.
- Expert, Project evaluation, KDISC, Govt. of Kerala, Thiruvananthapuram.
- Delivered invited talks in meeting in connection with World Fisheries Day, 21 November 2020, organized by Dr. M. G. R. Fisheries College and Research Institute, Ponneri, Thiruvallur, Tamil Nadu and Seminar organized by the Morning star Home Science College, Angamally, Ernakulam on 17 October 2020.

Dr. J. Sreekumar

- Chief Vigilance Officer of ICAR-CTCRI, Sreekariyam, Thiruvananthapuram.
- Member of the Editorial Board of Journal of Tropical Agriculture (JTA) of Kerala Agricultural University.
- External Examiner for the qualifying viva-voce examination (Online) of one Ph.D. (Bioinformatics) Scholar of ICAR-IARI, New Delhi on 21 July 2020.
- External examiner for the final viva-voce examination of three M.Sc. students (Agricultural Statistics) of Kerala Agricultural University, College of Agriculture, Vellayani.

Dr. P. S. Sivakumar

- Resource person in the PGDAEM course sponsored by MANAGE, Hyderabad for delivering two sessions on Research methods in Agricultural Extension on 25 November 2020 at SAMETI, Anayara, Thiruvananthapuram.
- Delivered an invited talk on Non-parametric Data Analysis in Fisheries on 20 August 2020 in the Online Training Programme on 'Data Analytics in Fisheries' organized by Dr. MGR Fisheries College and Research Institute, Nagapattinam, Tamil Nadu.
- Handled a session on Advances in Research methodology for extension research on 08 April 2020 for the M.Sc. and Ph.D. (Veterinary Extension) students of ICAR-IVRI, Izatnagar, Uttar Pradesh.
- Delivered invited lecture to the students of IVRI, Bareilly and GB Pant University of Agriculture & Technology (GBPUAT), Pantnagar on 23 April 2020.
- Co-Chairman for the session on Advances in Extension Research in the National Conference on Transformation of Agricultural Extension-Strategies for Effective Reformation (TAESERE 2020) during 20-21 August 2020 organized by Department of Agricultural Extension, Agricultural College, Bapatla.
- External Examiner for the conduct of the qualifying viva-voce of ten M.Sc. (Agricultural Extension) students of College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram during 20-21 May 2020.
- External Examiner of three M.Sc. (Agricultural Extension) students of College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram.

Dr. D. Jaganathan

- Resource person for PGDAEM-MANAGE correspondence course and delivered lectures of the course on Principles and Practices of Extension Management on 19 November 2020 at SAMETI, Anayara, Thiruvananthapuram.
- External Examiner for evaluation of one M.Sc. (Ag.) thesis of Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvananthapuram.
- Reviewer of Journal of Agricultural Economics and Rural Development and Journal of Economics and Development.
- Editor, Journal of Root Crops, Indian Society of Root Crops.

Dr. P. Prakash

- Reviewer of the journal Net Journal of Agricultural Sciences (NJAS).

LINKAGES AND COLLABORATIONS

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 of International Potato Centre (CIP), Lima, Peru and International Potash Institute (India Region). 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), National Institute of Agricultural Extension Management (MANAGE), Hyderabad; DST; DBT; Department of Atomic Energy, Govt. of India; Potash Research Insititute of India; Coconut Development Board; Rashtriya Krishi Vikas Yojana (RKVY), Govt. of Odisha and Govt. of Kerala; Department of Agriculture and Farmer's Welfare, Govt. of Kerala; Kerala State Planning Board; Small Farmers Agri-business Consortium (SFAC); Kerala State Council for Science, Technology and Environment (KSCSTE) and Kerala State Horticulture Mission, Govt. of Kerala.

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; 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, Kasaragod; 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, Bengaluru; Kerala Agricultural University, Thrissur; Orissa University of Agricultural & Technology, Bhubaneswar and Tamil Nadu Agricultural University, Coimbatore. In addition, collaboration also exists with Department of Horticulture and Department of Agriculture, Government of Odisha and Department of Agriculture, Government of Kerala, Government 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 National Institute of Agricultural Extension Management (MANAGE), Hyderabad and Centre for Research on Innovation and Science Policy (CRISP), Hyderabad. ICAR-CTCRI ABI has collaboration with Indian Institute of Technology, Roorkee and Central Agricultural University (CAU), Imphal. 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. Functional collaborations were developed with College of Agriculture, Kerala Agricultural University, Vellayani,

Thiruvananthapuram 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, Thiruvananthapuram for conducting courses and carrying out project work of M.Sc. Integrated Biotechnology students. The Institute is the approved research centre by the University of Kerala and Kannur University for Ph.D. programmes. MoU has been signed with Indian Institute of Crop Processing Technology, Thanjavur for mutual utilization of research facilities and Jawaharlal Nehru Krishi Vigyan Kendra, Jabalpur for PG research. A MoU was inked on 30 December 2020 between ICAR-CTCRI and Dr. YSR Horticultural University, Andhra Pradesh for collaboration in academic acivities and trainings. 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 inter cropped 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.

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.

ALL INDIA CO-ORDINATED RESEARCH PROJECT ON TUBER CROPS

All India Co-ordinated Research Project on Tuber Crops (AICRP TC) is the largest national network of tropical tuber and root crops covering eighteen states and one union territory consisting of north-eastern, eastern, western and southern parts of India. Presently the AICRP TC is having 21centres, located in 12 State Agricultural Universities, 3 ICAR Institutes and two Central Agricultural Universities.

Achievements of AICRP on Tuber Crops during 2020

The 20th Annual group meeting of All India Co-ordinated Research Project on Tuber Crops was held online at ICAR-Central Tuber Crops Research Institute during 10-12 June 2020. Dr. Anand Kumar Singh, DDG (Hort. Sci.), Dr. T. Janakiram, ADG (Hort. Sci.), Dr. P. Rethinam, Chairman, QRT and Scientists from 21 AICRP TC and ICAR-CTCRI Headquarters and Regional Station, Bhubaneswar participated in the meeting. The DDG (Hort. Sci.) inaugurated the meeting and released the publication on 'Standard Operating Procedure (SOP) for AICRP on Tuber Crops' and a mobile app 'Data Collector' for real time data collection of AICRP TC projects. Two yam bean varieties were recommended for release during the meeting.

Technologies recommended for adoption

- Based on the varietal evaluation trials conducted across various centres, two yam bean varieties were recommended for release, one for the state of West Bengal [TYb14-8 (DPH-69), entry from Dholi centre] and the another for the state of Bihar [TYb14-9 (DPH-6), entry from Dholi centre].
- Successful tuber crops based integrated farming system models, comprising of improved varieties of vegetables, tuber crops, cereals, pulses, fruit crops, piggery, fish culture, livestock and poultry, were recommended for more units in North-Eastern states and tribal areas.
- Organic farming technology in elephant foot yam, comprising of raising green manure cowpea, use of organically produced planting material, seed treatment with cow dung, neem cake and *Trichoderma,* application of *Trichoderma* incorporated farmyard manure, neem cake and ash, was recommended for the states of Maharashtra, Jharkhand, Bihar, Gujarat, Andhra Pradesh and West Bengal.
- Organic farming technology in greater yam, comprising of raising green manure cowpea, application of farmyard manure, neem cake, ash and bio-fertilizers, was recommended for the states of Tamil Nadu, Rajasthan, Manipur, Andhra Pradesh and West Bengal.
- Organic farming technology in taro, comprising of raising green manure cowpea, application of farmyard manure, neem cake, ash and bio-fertilizers, was recommended for the states of Tamil Nadu, Jharkhand, Manipur, Assam, Telangana, and West Bengal.
- Use of weed control ground cover was found effective for weed management in elephant foot yam and was recommended for the states of Tamil Nadu, Bihar, West Bengal, Andhra Pradesh and Andaman and Nicobar Islands. Post emergence

application of herbicide, Glyphosate at 30, 60 and 90 DAP was found effective in the states of Himachal Pradesh, Gujarat, Chhattisgarh, Jharkhand and Tripura and was recommended for adoption.

Glimpses of 20th Annual Group Meeting of AICRP TC, ICAR-CTCRI

PUBLICATIONS

Papers in Research Journals

Amit Kar, Emal Shegiwal, Pramod Kumar and Prakash, P. 2020. Impact of contract farming on basmati rice (*Oryza sativa*) in India, *Indian J. Agric. Sci.* **90** (7): 66-69. (NASS: 6.25).

Amit Kar, Pramod Kumar, Prakash, P., Singh, D. R., Dabas, J. P., Sathish Gowda, C. S, Nayan Deepak, Vijay Pooniya and Bana, R. S. 2020. Doubling farmers' income in Delhi state: An introspection, *Indian J. Agric. Sci.* **90** (8): 124-132. (NASS: 6.25).

Anju, P.S., Susan John, K., Bhadraray, S., Suja, G., Jeena Mathew, Nair, K.M., Sunitha, S. and Veena, S.S. 2020. Customized fertilizer formulations for elephant foot yam *Amorphophallus paeoniifolius* (Dennst.) Nicolson) under intercropping in coconut gardens for Kerala, India. *J. Indian Soc. Soil Sci.* **68** (2): 221-235. (NAAS: 5.23).

Asha, K.I., Reya Rene Philip and Navya, M. 2020. Molecular profiling of landraces of cassava (*Manihot esculenta* Crantz) using IISR markers. *Int. J. Eng. Sci. Manag. Res.* **3** (7): 343-349.

Bansode, V. V., Chauhan V. B. S., Pati, K., Nedunchezhiyan, M., Giri, N. A., Krishnakumar, T. and Mahanand, S. 2020. Development and storage study of anthocyanin rich jelly from purple fleshed sweet potato variety *Bhu Krishna*. *J. Pharmacogn. Phytochem.* **9** (2): 388-391. (NAAS: 5.21).

Byju, G. and Suja, G. 2020. Mineral nutrition of cassava. *Adv. Agron.* **159**: 169-235. (NAAS rating: 9.60; Clarivate Analytics Impact Factor 5.073).

Byju, G., Nedunchezhiyan, M., James George, Sunitha, S., Sabitha Soman and Hridya, A.C. 2020. Fertilizer best management practices by SSNM and customized fertilizers for cassava (*Manihot esculenta* Crantz) cultivation in India. *Current Horticulture* **8** (1): 56-64. (NAAS: 3.71).

Dhanya, S., Sherin Varghese, Divya, K., Sreekumar, J. and Jisha, M. S. 2020. *Pseudomonas taiwanensis* (MTCC11631) mediated induction of systemic resistance in *Anthurium andreanum* L against blight disease and visualisation of defence related secondary metabolites using confocal laser scanning microscopy. *Biocatal. Agric. Biotechnol.* **24:**101561.

Giri, N. A., Anjudas, Sajeev, M. S. and Krishnakumar, T. 2020. Development and physico-chemical evaluation of protein rich cookies using underutilized *Curcuma angustifolia* starch. *J. Pharmacogn. Phytochem.* **9**(6): 91-97.(NAAS: 5.21).

Gourilekshmi, S. S., Jyothi, A. N. and Sreekumar, J. 2020. Physicochemical and structural properties of starch from cassava roots differing in growing duration and ploidy level. *Starch/Stärke* **72**: 11-12.(NAAS: 7.8).

Jaganathan, D., Sheela Immanuel, Prakash, P. and Sivakumar, P. S. 2020. Sustainable livelihood assessment of taro and paddy growers in Nayagarh district of Odisha. *Journal of Community Mobilization and Sustainable Development.* **15** (3): 686-693. (NASS: 5.30).

Krishnakumar, T., Sajeev, M. S. and Suja, G. 2020. Effect of planting methods and varieties on performance of modified TNAU cassava harvester. *Int. J. Chem. Stud.* **8** (5): 997-1002. (NAAS: 5.31).

Krishnakumar, T., Sajeev, M. S., Raju, S., Giri, N. A., Pradeepika, C. and Bansode, V. V. 2020. Studies on the development of cassava based reconstituted dry starch with modified starch as binder and characterization of its physico-functional properties. *J. Environ. Biol.* **41**: 29-34. (NAAS: 6.56).

Krishnan, J. U., Jayaprakas, C. A., Harish, E. R. and Rajeswari, L. S. 2020. Banana (*Musa* spp.)- an unseen umbrella crop? Insect diversity on *Musa* spp. in the Indo-Pacific region. *Orient. insects* **54**(3): 433-445.

Laxminarayana, K. 2020. Bio-chemical constituents, value addition and alternative uses of colocasia (*Colocasia esculenta* L.). *Acta Scientific Agriculture* **4** (3): 1-11.

Laxminarayana, K., Sulekha Pradhan, Madhumita Das, M. and Nedunchezhiyan, M. 2020. Assessment of soil microbes and enzyme activities in the degraded soils adjacent to industries and mines and its relation with heavy metal contaminants. *Acta Scientific Agriculture* **4** (8): 77-90.

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Visalakshi Chandra, C., Sheela, M. N., Shirly Raichal Anil, Asha Devi, A., Sunitha, S. and Suresh kumar, J. 2020. High yielding varieties of tuber crops suitable for north eastern region. In: *Training manual on 'Genetic resources, agro-techniques, value addition and utilisation in tuber crops: Current prospects for North Eastern states in India'*, ICAR-CTCRI, Sreekariyam, Thiruvananthapuram, Kerala. pp. 27-36.

Vivek Hegde, Mohan, C., Senthilkumar, K. M., Koundinya, A.V.V. and Chauhan, V.B.S. 2020. Agro techniques of tropical tuber crops. In: *Training Manual on Potential tropical tuber crops: Production technologies, value-added and functional foods*. ICAR-CTCRI Rainbow diet campaign, Mizoram, 21-22 February 2020, pp. 16-40.

Business models

Sajeev, M. S., Namrata A. Giri, Krishnakumar, T. and Byju, G. 2020. Business model on Entrepreneurial opportunities with cassava based value added products, ICAR-CTCRI, Thiruvananthapuram, Kerala.

Sajeev, M. S., Krishnakumar, T., Namrata A. Giri and Bansode, V. V. 2020. Business model on Cassava/ Tapioca flour based micro food processing enterprises, ICAR-CTCRI, Thiruvananthapuram, Kerala.

Institute Publications

Annual Report of ICAR-CTCRI 2019 (English and Hindi).

Annual Report of AICRP on Tuber Crops 2019-2020.

Research Highlights of ICAR-CTCRI 2019.

ICAR-CTCRI Newsletter July-December 2019, January-June 2020

46th Annual Institute Research Council Meeting, Salient Achievements 2019-20, ICAR-CTCRI, Thiruvananthapuram.

46th Annual Institute Research Council Meeting, New Project Proposals 2020-2025 and Activity Milestones 2020-21, ICAR-CTCRI, Thiruvananthapuram.

Quinquennial Review Team Report 2014-2019, ICAR-CTCRI, Thiruvananthapuram, 136 p.

Technical Report of 20th Annual Group Meeting of AICRP on Tuber Crops held online at ICAR-CTCRI, Thiruvananthapuram during 10-12 June 2020, 188 p.

Proceedings of 20th Annual Group Meeting (AGM), ICAR-CTCRI, Thiruvananthapuram, held online during 10-12 June 2020, 53p.

Radio Talks

Byju, G. 2020. Discussion on climate change and its impact on agriculture. 23 March 2020, AIR, Thiruvananthapuram.

Byju, G. 2020. Advisories for tuber crops cultivation. 16 April 2020, AIR, Thiruvananthapuram.

Byju, G. 2020. Importance of biodiversity conservation in agriculture. 05 and 17 June 2020, AIR, Thiruvananthapuram.

Byju, G. 2020. International day of rural women. 15 October 2020, AIR, Thiruvananthapuram.

Suja, G. 2020. Planting time of tuber crops- Management practices to be followed (*Kizhangu vilakulade nadeel kalam anuvarthikkenda margangal*) 28 January 2020, AIR, Thiruvananthapuram.

Suja, G. 2020. Role of tropical tuber crops in poverty eradication. (*Daridrya nirmanjanathil kizhangu vilakalude pangu*), on the occasion of International Poverty Eradication Day, 17 October 2020, AIR, Thiruvananthapuram.

Susan John, K. 2020. New approaches in the integrated nutrient management of tropical tuber crops, 21 July 2020, Farm and Home of AIR.

Susan John, K. 2020. World Soil Day 2020 broadcast on the theme 'Keep soil alive, protect soil biodiversity', 05 December 2020, Farm and Home of AIR.

TV Talks

Byju, G. 2020. Impact of rising temperature on Kerala agriculture. Asianet News, 17 February 2020.

Byju, G. 2020. Post COVID-19 Kerala agriculture. Promote tuber crops to thwart any possible threat of famine. Asianet News, 29 April 2020.

Byju, G. 2020. Post COVID-19 Kerala agriculture. Promote tuber crops to thwart any possible threat of famine. Jai Hind TV, 05 May 2020.

Veena, S. S. 2020. Diseases of tuber crops and their management. Live phone in program Krishidarshan, Doordarshan Kendra, Thiruvananthapuram, 24 January 2020.

Facebook Live

Byju, G. 2020. Tuber crops cultivation. Facebook live video programme, Haritha Keralam Mission Facebook Group, Govt. of Kerala, 27 April 2020.

Suja, G. 2020. Good Agricultural Practices for tropical tuber crops, RATTC, Kazhakuttam on 15 August 2020.

Suja, G. 2020. Good Agricultural Practices for tropical tuber crops, KVK, Thrissur on 19 October 2020.

Suja, G. 2020. Good Agricultural Practices for tropical tuber crops, Krishi Padashala-95: Farmers Training Programme in Facebook live, State Agricultural Management and Extension Training Institute (SAMETI), 21 December 2020.

Susan John, K. 2020. FB live (*Njattuvela*) on 'Integrated nutruint management in tuber crops', FM broadcast on 29 January 2020.

Susan John, K. FB live on 'Tropical tuber crops for food security in Kerala' for Krishijagran Kerala on 20 May 2020.

Susan John, K. FB live on 'Soil health management and soil health card programme' for Farmers Training Centre, Pandalam on 16 October 2020.

Susan John, K. FB live on 'New approaches in the integrated nutrient management of tropical tuber

crops' in *Krishipadasala-43* for SAMETI under Department of Agriculture, Government of Kerala on 21 October 2020.

Susan John, K. 2020. FB live on 'Nutrient management in tropical tuber crops' for Farmers Training Centre, Pandalam on 24 November 2020.

YouTube Channel

Byju, G. 2020. How to collect soil samples, 05 April 2020.

Byju, G. 2020. How to grow microgreens, 10 April 2020.

Byju, G. 2020. How to harvest elephant foot yam, 10 April 2020.

Byju, G. 2020. How to plant elephant foot yam, 11 April 2020.

Byju, G. 2020. How to sample cassava for nutrient uptake studies, 12 April 2020.

Byju, G. 2020. Tuber crops cultivation, 27 April 2020.

Byju, G. 2020. Post COVID-19 Kerala agriculture, 30 April 2020.

Byju, G. 2020. Climate change to affect agriculture in Kerala, 30 April 2020.

Byju, G. 2020. Post COVID-19 Kerala agriculture – impact and recommendations, 06 May 2020.

E-Publications

Byju, G., Sanket J. More and Jaganathan, D. 2020. E-Proceedings of the International Webinar on Harnessing the Potential of Tropical Tuber Crops under Changing Climate, 27 October 2020, ICAR-CTCRI, Thiruvananthapuram, 110 p.

Shakuntala, I., Mohan, C., Senthilkumar, K. M., Krishnakumar, T., Hegde V., Chauhan, V.B.S. and Dayal, V. 2020. Training cum awareness programme on "Rainbow diet campaign for NEH region for promoting tuber crops based rainbow diet for food, nutrition and health security". Kiran (Empowering Agricultural Knowledge and Innovation in North East), Indian Council of Agricultural Research, New Delhi.

Mohan C., Shakunthala I., Dayal,V., Krishnakumar, T., Hegde,V., Chauhan, V.B.S. and Senthilkumar, K. M. 2020. Rainbow diet campaign for NEH region, Mizoram on INRINNI (Mizo language), 22 February 2020.

Video

Suja, G., Jaganathan, D. and Ravi, V. 2020. Video on 'Profile of ICAR-CTCRI and Technologies of tropical tuber crops' produced in collaboration with Govt. Higher Secondary School, Kulathur, ICAR-CTCRI, Sreekariyam, Thiruvananthapuram.

PARTICIPATION OF SCIENTISTS IN CONFERENCES/ SEMINARS/MEETINGS/WEBINARS

Programme	Particulars of Programme	Name of the Participant
107th Indian Science Congress	University of Agricultural Sciences, Bengaluru 03-07 January 2020	Dr. A. V. V. Koundinya
National seminar on emerging technologies and enabling tools in diagnosis and management of plant diseases	Faculty of Agriculture, Annamalainagar, Tamil Nadu 08-09 January 2020	Dr. M. L. Jeeva
Webinar on Research Ethics	India Bioscience, Department of Biotechnology (DBT), New Delhi 11 January 2020	Dr. K. M. Senthilkumar
7th International Conference on Phytopathology in Achieving UN Sustainable Development Goals	ICAR-IARI, New Delhi 16-20 January 2020	Dr. T. Makeshkumar
35th Annual Workshop of AICRP on Post-harvest Engineering & Technology	JNKVV, Jabalpur, Madhya Pradesh 23-25 January 2020	Dr. T. Krishankumar
Final QRT meeting of ICAR-CTCRI and AICRP on Tuber crops	ICAR-CTCRI, Thiruvananthapuram 24-26 January 2020	All Scientists
Annual review meeting of the project titled 'Higher productivity and profitability from coconut gardens through soil health management in tuber crops'	Coconut Development Board, Kochi 27 January 2020	Dr. D. Jaganathan
Global Potato Conclave 2020	Gandhinagar, Gujarat 28-31 January 2020	Dr. C. A. Jayaprakas Dr. Shirly Raichal Anil Dr. R. Muthuraj
Annual review meeting of ICAR-CRP on Vaccines and Diagnostics network project	ICAR-CTCRI, Thiruvananthapuram 29-30 January 2020	Dr. M. L. Jeeva Dr. S. S. Veena Dr. T. Makeshkumar
Consultative Workshop of Experts in the field of Biodiversity Conservation	Kerala Biodiversity Board, Thiruvananthapuram 17 February 2020	Dr. C. A. Jayaprakas
International Conference on Evolution of viruses and viral diseases (VIROCON 2020)	INSA, New Delhi 18-20 February 2020	Dr. T. Makeshkumar
National Science Day	ICAR-CTCRI, Thiruvananthapuram 26 February 2020	All Scientists

Programme	Particulars of Programme	Name of the Participant
29th Swadeshi Science Congress-National Conference on Science and Technology for Sustainable Development	ICAR-Central Plantation Crops Research Institute, Kasaragod 27-29 February 2020	Dr. C. A. Jayaprakas Dr. E. R. Harish Dr. D. Jaganathan Dr. Sangeetha, B. G. Dr. K. M. Senthilkumar
Rural India Business Conclave (Invited lecture: Tuber crops technologies for commercialization and entrepreneurship)	ICAR-Central Plantation Crops Research Institute, Kasaragod 27 February - 03 March 2020	Dr. D. Jaganathan
Webinar on Approaches and strategies to support vegetable farming post Covid 19	Federation of Indian Chamber of Commerce and Industry, New Delhi 01 May 2020	Dr. D. Jaganathan
Workshop on Training Management Information System	HRM Unit, ICAR, New Delhi 08 May 2020	Dr. Sheela Immanuel
Webinar on Next Generation Genomics and Integrated Breeding for Crop Improvement (VII-NGGIBCI) - Genomics for food, health and nutrition	ICRISAT, Hyderabad 14 May 2020	Dr. T. Makeshkumar Dr. S. S. Veena Dr. K. M. Senthilkumar Dr. C. Visalakshi Chandra
KVK Action Plan Meeting for Thiruvananthapuram, Kozhikode and Pathanamthitta	Kerala Agricultural University 20 May 2020	Dr. G. Suja
International Webinar on Rethinking social change in south Asia amidst Covid19	University of Delhi, New Delhi 21 May 2020	Dr. Sheela Immanuel Dr. D. Jaganathan Dr. P. Prakash
46th Annual Institute Research Council Meeting	ICAR-CTCRI, Thiruvananthapuram 26-29 May 2020	All Scientists
Review meeting (virtual) of 'All India Network Programme on Organic farming (AINPOF)'	ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh 27 May 2020	Dr. G. Suja
Webinar on IFS Models	ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh 29 May 2020	Dr. G. Suja
Review Meeting of RKVY funded project 'Popularization of climate resilient and nutritionally rich varieties of tuber crops for economic development and nutritional security of farmers of Odisha'	Krushi Bhawan, Bhubaneswar 04 June 2020	Dr. K. Laxminarayana

Programme	Particulars of Programme	Name of the Participant
Commercialization of bio-fertilizers and bio-fungicides-regulatory constraints	SAGE University, Bhopal 05 June 2020	Dr. T. Makeshkumar
State Level Monitoring Committee on Doubling Farmers Income	Department of Agriculture & Farmers Welfare, Kerala 08 June 2020	Dr. G. Suja
Peer Review Meeting of the RKVY funded projects being implemented by International Research Institutes	IMAGE, Bhubaneswar, Odisha 08-09 June 2020	Dr. K. Laxminarayana
20th Annual group meeting of AICRP on tuber crops	ICAR-CTCRI, Thiruvananthapuram 10-12 June 2020	AICRP TC Project team and All HODs
Webinar on Commercialization of bio-fertilizers and bio-fungicides-regulatory constraints	Auburn University, USA 15 June 2020	Dr. S. S. Veena
Webinar on Agriculture during COVID-19: Economic Package and Reforms	ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi 16 June 2020	Dr. D. Jaganathan Dr. P. Prakash
Meeting on Research Innovation Network Kerala (RINK)	Kerala Start up Mission, Govt. of Kerala 19 June 2020	Dr. Sheela Immanuel
International Web-Conference on New Trends in Agriculture, Environmental & Biological Sciences for Inclusive Development	Agro Environmental Development Society, Rampur, Uttar Pradesh 21-22 June 2020	Dr. Sanket J. More
Socio-economic lecture series (Invited talk: Conducting social science research during and after pandemics-challenges and opportunities	Kerala Agricultural University under ICAR-NAHEP-CAAST Project 24 June 2020	Dr. P. S. Sivakumar
National Webinar on Recent Biotechnological Tools for Crop Improvement	IDP-ANGRAU, Lam, Guntur, Andhra Pradesh 24 June 2020	Dr. Sirisha Tadigiri
National Web Conference on Post Lockdown with Particular Emphasis on Plant Protection	ICAR-Indian Agricultural Research Institute, New Delhi 25-26 June 2020	Dr. E. R. Harish Dr. Sirisha Tadigiri Dr. P. Prakash
Review meeting on Audit Paras/ compliances of RKVY funded projects	IMAGE, Bhubaneswar, Odisha 03 July 2020	Dr. K. Laxminarayana
Webinar on Editor talk series on the journal 'Agricultural Systems'	CRISP, MANAGE and ICAR-CTCRI 14 July 2020	Dr. Sheela Immanuel Dr. P. S. Sivakumar Dr. D. Jaganathan Dr. P. Prakash

Programme	Particulars of Programme	Name of the Participant
Indian Phytopathology Webinar series	Indian Phytopathological Society, New Delhi 14-31 July 2020	Dr. S. S. Veena
Global impact of GM crops	ISAAA Southeast Asia Center 15 July 2020	Dr. T. Makeshkumar
ICAR Foundation day celebrations	ICAR, New Delhi 16 July 2020	All Scientists
National Web Conference on Agricultural resource management for Atma Nirbhar Bharat	Central Agricultural University, Imphal, Manipur 17-19 July 2020	Dr. D. Jaganathan Dr. P. Prakash
NABL Accreditation	ICAR, New Delhi 22 July 2020	Dr. T. Makeshkumar
Webinar on Vision - Doubling farmers income: Opportunities and Challenges	Federation of Indian Chamber of Commerce and Industry, Tamil Nadu 22 July 2020	Dr. D. Jaganathan Dr. P. Prakash
Paradigm shift in plant disease management for the millennium	ICAR-NBAIR, Bengaluru 24 July 2020	Dr. M. L. Jeeva Dr. T. Makeshkumar
Webinar on Women empowerment, entrepreneurship and employment	Federation of Indian Chamber of Commerce and Industry, Kerala 28 July 2020	Dr. D. Jaganathan
ICAR-NRCB Webinar Series 2020	ICAR-NRCB, Tiruchirapalli 29 July 2020, 04, 07 and 21 August 2020	Dr. S. S. Veena
Nematodes - the Hidden Enemy	Kyle Parke, 31 July 2020	Dr. Sirisha Tadigiri
Kosambi International Webinar Series on Plant Genomics	Department of Botany, SPPU, Pune and NABI Mohali 31 July to 02 August 2020	Dr. K. M. Senthilkumar Dr. C. Visalakshi Chandra
Integrated insect pests and nematodes management in banana	ICAR-NRCB, Tiruchirappalli 04 August 2020	Dr. E. R. Harish Dr. H. Kesava Kumar Dr. Sirisha Tadigiri
Webinar on Plant Genome Engineering for Agriculture, Food and Nutrition	Shri Vaishnav Institute of Science, Indore, Madhya Pradesh 04 August 2020	Dr. Vivek Hegde
'Likha' Webinar Series, 2020 (Invited talk: Nutrigenomics)	SCT College of Engineering, Thiruvananthapuram 05 August 2020	Dr. N. Krishna Radhika
Webinar lecture series	Indian Phytopathological Society, New Delhi 14, 17, 21 and 31 July 2020 07 and 10 August 2020	Dr. M. L. Jeeva

Programme	Particulars of Programme	Name of the Participant
Export challenges and mitigation strategies for fresh and processed fruits and vegetables in Covid-19 times	National Institute of Food Technology Entrepreneurship and Management, Sonipat, Haryana 08 August 2020	Dr. D. Jaganathan Dr. P. Prakash
Nematode Problems in Horticultural Crops and their Management	Choudhary Charan Singh Agricultural University, Haryana 09 August 2020	Dr. H. Kesava Kumar
Virtual Interface Meeting of Strengthening Research and Extension activities	ICAR-CTCRI and SAGOSERVE, Salem, Tamil Nadu 12 August 2020	Dr. M. S. Sajeev Dr. T. Makeshkumar Dr. A. N. Jyothi Dr. T. Krishnakumar
Webinar on Mainstreaming Biodiversity into Food and Agriculture Sector: Towards enhancing Agrobiodiversity, Nutrition, Sustainable Livelihoods and Business opportunities	National Biodiversity Authority, Chennai 18 August 2020	Dr. M. N. Sheela Dr. Asha, K. I. Dr. Shirly Raichal Anil Dr. A. Asha Devi Dr. K. M. Senthilkumar
Online Workshop on Microbial intervention in plant health and nutrition	Navsari Agricultural University, Bharuch, Gujarat 25-26 August 2020	Dr. H. Kesava Kumar
Brainstorming Workshop on Identification of new dimensions for preparing national/global level database on women in agriculture	ICAR-Central Institute for Women in Agriculture, Bhubaneswar 28 August 2020	Dr. D. Jaganathan
Inaugural programme of Academic and Administrative Building of Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh	PMO, New Delhi 29 August 2020	All Scientists
Webinar on Block chain Technology and Supply Chain in Agriculture	Department of Social Science AC&RI, Killikulam, Tuticorin 29 August 2020	Dr. P. Prakash
National Webinar on Plant Health Management for Sustainable Agriculture organized on the eve of International Year of Plant Health	National Institute of Plant Health Management, Hyderabad 04 September 2020	Dr. M. L. Jeeva Dr. T. Makeshkumar
International Webinar on Advances in Red Palm Weevil Research and Management	Don Bosco College of Agriculture, Sulcorna, Goa 08 September 2020	Dr. E. R. Harish
Webinar on bioinformatics analysis on soil microbial community sequence data	World Bank- NAHEP- ICAR 12-13 August 2020	Dr. S. S. Veena
Virtual Consultative meeting on Recent Progress in Germplasm Utilization and Breeding in Sweet potato	ICAR-CTCRI, Thiruvananthapuram 14 September 2020	All Scientists

Programme	Particulars of Programme	Name of the Participant
National Webinar on Herbal remedies in managing pandemics-Scientific evaluation	Kerala Academy of Sciences, Thiruvananthapuram and S. D. College, Alappuzha, Kerala 14 September 2020	Dr. A. N. Jyothi
Advances in Plant Pathology with special reference to diagnosis and management	Dr. YSR Horticultural University, Andhra Pradesh 16 September 2020	Dr. S. S. Veena
Genome editing in agriculture: Innovations for sustainable production and food systems	CGIAR 22 September 2020	Dr. S. S. Veena
Institute Management Committee meeting of ICAR-IISR	ICAR-IISR, Kozhikode 23 September 2020	Dr. T. Makeshkumar
International Webinar on Tissue Engineering - A Material Chemistry Approach	Kerala University Department of Chemistry Alumni Association 26 September 2020	Dr. A. N. Jyothi
Webinar on 150th Birth Anniversary of Mahatma Gandhi	ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh 28-30 September 2020	Dr. G. Suja
Soil Spectroscopy, an emerging technique for rapid soil health assessment	Indian Institute of Soil Science and ICRAF, Nairobi 01 October 2020	Dr. Susan John, K.
VAIBHAV Summit, Interaction with Overseas Academicians and Researchers	PMO, New Delhi 02 October 2020	Dr. T. Makeshkumar
Pest Management in Fruit and Vegetable Systems	University of Florida 02 October 2020	Dr. H. Kesava Kumar
International Conference on Biodiversity Genomics 2020	Wellcome Sanger Institute, U.K. 05-09 October 2020	Dr. K. M. Senthilkumar
Webinar on DUS data management/Automation/ Image analysis under Indo-German bilateral programme	PPV&FRA, New Delhi 06-07 October 2020	Dr. M. N. Sheela Dr. J. Sreekumar Dr. A. Ashadevi Dr. Kalidas Pati
International E-Conference on Multidisciplinary approaches for plant disease management in achieving sustainability in agriculture	College of Horticulture, Bengaluru (University of Horticultural Sciences, Bagalkot) 06-09 October 2020	Dr. M. L. Jeeva Dr. S. S. Veena Dr. T. Makeshkumar Dr. Sirisha Tadigiri
Spicing up science: ICAR-IISR Lecture series on CRISPR/CAS 9: Basics and Applications	ICAR-Indian Institute for Spices Research, Kozhikode 06-09 October 2020	Dr. Sirisha Tadigiri
National Conference on Agricultural Scientific Tamil	Jointly organized by Agricultural Scientific Tamil Society and Tamil Nadu Agricultural University, Coimbatore 09-10 October 2020	Dr. T. Krishankumar

Programme	Particulars of Programme	Name of the Participant
Translating Physiology into Techniques for Abiotic Stress Tolerance	ICAR-National Institute of Abiotic Stress Management, Pune, Maharashtra 09 October 2020	Dr. Sanket J. More
Virtual Program on World Food Day 'Release of Commemorative coin on the occasion of FAO @ 75' and World Food Day by PM	PMO, New Delhi 16 October 2020	Dr. T. Makeshkumar
Virtual Sago Conference	M/s Global Lab and Consultancy services, Salem, Tamil Nadu 16-17 October 2020	Dr. T. Krishankumar
KAU Webinar Series	College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram 19-23 October 2020	Dr. S. S. Veena
International Webinar on Harnessing the Potential of Tropical Tuber Crops under Changing Climate (HPTTC 2020)	ICAR-CTCRI, Thiruvananthapuram 27 October 2020	All Scientists
Webinar on Plant Parasitic Nematodes, The Hidden Enemy for Perennial Crops	ADAMA, New York, USA 30 October 2020	Dr. H. Kesava Kumar
International Science Conference on Organic Farming Research, Technologies and Extension	BIOFACH 2020 and ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh 31 October 2020	Dr. G. Suja
4th Interactive Session for IBSCs registered on IBKP portal	Department of Biotechnology, Govt. of India, New Delhi 05 November 2020	Dr. T. Makeshkumar
Talk on Transformative Technologies and Entrepreneurship in Agriculture	ICAR-NAHEP (Education Division), New Delhi 09 November 2020	Dr. Asha, K. I.
CGIAR germplasm health webinar series on 'Phytosanitary safety for transboundary pest prevention'	CGIAR 09-10 November 2020	Dr. S. S. Veena
National Webinar on Challenges and Opportunities of Vegetable Production in Warm Humid Tropics	Kerala Agricultural University and Indian Society of Vegetable Sciences 11 to 13 November 2020	Dr. M. N. Sheela Dr. A. Asha Devi Dr. K. M. Senthilkumar
National Webinar on Management of Root-rot disease of Horticultural Crops	College of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar 24 November 2020	Dr. S. S. Veena

Programme	Particulars of Programme	Name of the Participant
Impact of water stress on crop productivity: its mitigation and adaptation strategies	Center of Excellence on Water Management, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar 24-26 November 2020	Dr. E. R. Harish
15th Annual Group Meeting of AINPOF	ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh 25-26 November 2020	Dr. G. Suja Dr. G. Byju Dr. M. N. Sheela Dr. S. Sunitha Dr. S. S. Veena Dr. A. N. Jyothi
International Webinar on Plant Biosecurity	National Institute of Plant Health Management, Hyderabad 26 November 2020	Dr. T. Makeshkumar
International Conference on Perspectives of Crop & Nutrition Security in the New Normal (PCNNN 2020)	Department of Agriculture Engineering & Department of Food Technology, Bannari Amman Institute of Technology, Sathyamangalam, Tamil Nadu 26-27 November 2020	Dr. T. Krishankumar
Webinar on Genomics Strategies for Improvement of Abiotic Stress Tolerance in Crop Plants	ICAR-National Institute of Abiotic Stress Management, Baramati 27 November 2020	Dr. J. Sreekumar
Biointensive Management of Plant Parasitic Nematodes	National Institute of Plant Health Management, Hyderabad 27 November 2020	Dr. E. R. Harish
Talk on Plant Variety Protection: International Scenario	ICAR-NAHEP (Education Division), New Delhi 01 December 2020	Dr. Asha, K. I.
Indian Phytopathological Society: South Zone Virtual Symposium - 2020 on Advances in Crop Health Management	IARI Regional Station, Wellington, Tamil Nadu 01-02 December 2020	Dr. S. S. Veena Dr. T. Makeshkumar Dr. V. S. Santhosh Mithra
Preliminary meeting of VAIGA	Department of Agriculture, Govt. of Kerala 02 December 2020	Dr. M. S. Sajeev Dr. Sheela Immanuel
World Soil Day 2020	ICAR-CTCRI, Thiruvananthapuram 05 December 2020	All Scientists
Webinar on Biological Diversity Act 2020 and Scope of conservation of wild edibles (especially *Dioscorea*) in connection with Tuber Crops Day 2020 celebration	ICAR-CTCRI, Thiruvananthapuram 07 December 2020	All Scientists
Talk on The International Governance of PGR for Food Security	ICAR-NAHEP (Education Division), New Delhi 11 December 2020	Dr. Asha, K. I.

Programme	Particulars of Programme	Name of the Participant
Gene Editing for Agriculture, Society & Sustainable Development: Prospects and Perspectives	Tata Institute for Genetics and Society, New Delhi 15 December 2020	Dr. T. Makeshkumar
Third meeting of Research Advisory Committee (RAC VIII)	ICAR-CTCRI, Thiruvananthapuram 16 December 2020	All Scientists
National webinar series on Recent Molecular approaches for plant disease diagnosis-I	SV Agricultural College, Tirupati 17 December 2020	Dr. S. S. Veena
PM Kisan money release function through video conferencing	PMO, New Delhi 25 December 2020	All Scientists
Alternatives to plastics for sustainable soil and environmental health	ICAR-Indian Institute of Soil Science, Bhopal 30 December 2020	Dr. Susan John, K.
State Level Project Screening Committee (SLPSC) meeting on Rashtriya Krishi Vikas Yojana (RKVY-RAFTAR)	RS ICAR-CTCRI, Bhubaneswar, Odisha 21 March 2020, 19 November 2020 and 30 December 2020	Dr. Kalidas Pati

DISTINGUISHED VISITORS

- Justice Shri. M. R. Hariharan Nair, Former Judge, High Court of Kerala.
- Dr. P. Rethinam, Former ADG, ICAR; Chairman, CDB, GOI & Executive Director, APCC, Jakarta, Indonesia.
- Dr. S. K. Naskar, Former Director, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram.
- Dr. M. S. Palaniswami, Former Project Co-ordinator (AICRP on Tuber Crops), ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram.
- Dr. Malavika Dadlani, Former Joint Director (Research), ICAR-Indian Agricultural Research Institute, New Delhi.
- Dr. K. Vasuki IAS, Director of Agriculture, Government of Kerala.
- Dr. R. V. S. K. Reddy, Director of Research, Dr. YSR Horticultural University, Venkataramannagudem, West Godavari, Andhra Pradesh.
- Dr. L. Pugalendhi, Dean, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.
- Dr. E. V. Soniya, Scientist G, Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram, Kerala.
- Mrs. Amrutha Rahim, Assistant Professor, Mar Gregorios College of Law, Thiruvananthapuram, Kerala.

QRT Team at ICAR-CTCRI

Dr. K. Vasuki, Director of Agriculture
Govt. of Kerala at Techno Incubation Centre,
ICAR-CTCRI

CTCRI STAFF MEMBERS

Managerial Personnel

Dr. V. Ravi	:	Director (Acting) Head, Crop Production (till 03.12.2020, Acting Head w.e.f 04.12.2020)
Dr. C. A. Jayaprakas	:	Head (Acting), Crop Protection & Central Public Information Officer
Dr. M. N. Sheela	:	Head (i/c), Crop Improvement
Dr. Sheela Immanuel	:	Scientist (i/c), Extension and Social Sciences
Dr. M. S. Sajeev	:	Scientist (i/c), Crop Utilization
Dr. M. Nedunchezhiyan	:	Scientist (i/c), Regional Station, Bhubaneswar
Dr. J. Sreekumar	:	Vigilance Officer
Shri. Ramdeen	:	Senior Administrative Officer
Shri. P. Krishnakumaran	:	Finance and Accounts Officer

Personnel

HEADQUARTERS, Thiruvananthapuram	
Director (Acting)	**Dr. V. Ravi**
Division of Crop Improvement	
Dr. M. N. Sheela	Principal Scientist & Head (i/c)
Dr. P. Murugesan	Principal Scientist
Dr. K. I. Asha	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. C. Visalakshi Chandra	Scientist
Dr. K. M. Senthilkumar	Scientist
Dr. A. V. V. Koundinya	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. S. Sunitha	Principal Scientist

Dr. K. Sunil Kumar	Principal Scientist
Dr. V. Ramesh	Principal Scientist
Dr. R. Muthuraj	Principal Scientist
Dr. Saravanan Raju	Principal Scientist
Dr. Sanket J. More	Scientist
Dr. J. Sureshkumar	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. E.R. Harish	Scientist
Dr. H. Kesava Kumar	Scientist
Dr. B. G. Sangeetha	Scientist
Dr. Sirisha Tadigiri (up to 03.11.2020)	Scientist
Section of Crop Utilization	
Dr. M. S. Sajeev	Principal Scientist & Scientist (i/c)
Dr. A. N. Jyothi	Principal Scientist
Dr. Namrata Ankush Giri (up to 30.07.2020)	Scientist
Ms. Pradeepika Chintha	Scientist
Dr. T. Krishnakumar	Scientist
Section of Extension and Social Sciences	
Dr. Sheela Immanuel	Principal Scientist & Scientist (i/c)
Dr. J. Sreekumar	Principal Scientist
Dr. V. S. Santhosh Mithra	Principal Scientist
Dr. P. Sethuraman Sivakumar	Principal Scientist
Dr. D. Jaganathan	Senior Scientist
Dr. P. Prakash	Scientist
Library/PME Unit	
Shri. R. Bharathan (up to 04.09.2020)	Chief Technical Officer
Smt. T. K. Sudhalatha (Rtd. on 31.10.2020)	Assistant Chief Technical Officer
Shri. I. Puviyarasan	Assistant Chief Technical Officer
Smt. B. S. Deepa	Senior Technical Assistant

Field/Farm/Lab. Technical Staff	
Smt. N. Sujatha Kumari	Chief Technical Officer
Dr. L. S. Rajeswari	Assistant Chief Technical Officer
Shri. A. Madhu	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. S. Sreekumar	Senior Technical Officer
Shri. V. Ganesh	Technical Officer
Shri. Patric M. Mascrene	Technical Officer
Shri. S. Natarajan (Rtd. on 30.04.2020)	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
Shri. K. Sunil	Technical Assistant
Shri. T. Raghavan	Technical Assistant
Shri. B. Satheesan	Senior Technician
Shri. D. T. Rejin	Senior Technician
Shri. T. M. Shinil	Senior Technician
Shri. C. Krishnamoorthy	Technician
Shri. K. Velayudhan	Technician
Shri. T. Manikantan Nair	Technician
Administration and Accounts	
Shri. Ramdeen	Senior Administrative Officer
Shri. 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. K. Unnikrishnan Nair	Assistant
Shri. S. Hareendrakumar	Assistant
Shri. Arjun Murali	Assistant
Shri. S. Sreekumar	Assistant
Shri. O. C. Ayyappan	Assistant
Smt. V. Sathyabhama (Rtd. on 31.05.2020)	U. D. C.
Shri. R. S. Adarsh	U. D. C.
Shri. C. Chandru	U. D. C.
Shri. N. Jayachandran	L. D. C.
Smt. C. G. Chandra Bindu	L. D. C.
Smt. Rohini K. Nair	L. D. C.
Shri. D. Arunraj	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. M. Syamala (Rtd. on 31.03.2020)	Skilled Support Staff
Shri. T. Lawrence	Skilled Support Staff
Shri. K. Sivadas	Skilled Support Staff
Shri. L. Samynathan	Skilled Support Staff
Shri. S. Sreekumaran	Skilled Support Staff
Shri. K. Chandran	Skilled Support Staff
Smt. S. S. Sneha	Skilled Support Staff

Smt. Rini Alocious	Skilled Support Staff
Ms. C. P. Gayathri	Skilled Support Staff
Smt. R. Nijamol	Skilled Support Staff
Shri. S. Abhishek	Skilled Support Staff
Smt. S. L. Jyothi	Skilled Support Staff
Shri. Stiphin George	Skilled Support Staff
Smt. P. Vidhya	Skilled Support Staff
Shri. SreenathVijay	Skilled Support Staff
Ms. S. Anjitha	Skilled Support Staff
Shri. S. Sudhish	Skilled Support Staff
Shri. P. Aswin Raj	Skilled Support Staff
Smt. V. S. Remya	Skilled Support Staff
Smt. R. Anuja (w.e.f 14.05.2020)	Skilled Support Staff
Shri. N. Shiju (w.e.f. 04.09.2020)	Skilled Support Staff
REGIONAL STATION, Bhubaneswar	
Scientific Staff	
Dr. M. Nedunchezhiyan	Principal Scientist & Scientist i/c
Dr. K. Laxminarayana	Principal Scientist
Dr. Kalidas Pati	Scientist
Dr.Vijay Bahadur Singh Chauhan	Scientist
Shri. Venkatraman V. Bansode	Scientist
Shri. K. Hanume Gowda	Scientist
Dr. R. Arutselvan	Scientist
Field / Farm / Lab. Technical Staff	
Shri. N. C. Jena (Rtd. on 30.06.2020)	Technical Officer
Shri. Pramod Kumar Mati	Technical Officer
Shri. Bibhuti Bhusan Das	Technical Officer
Shri. Bharat Kumar Sahoo (Rtd. on 29.02.2020)	Technical Officer
Shri. Sushanta Kumar Jata	Senior Technical Assistant
Shri. Raja K.	Technical Assistant
Shri. Keshab Paikaray	Senior Technician
Administration and Accounts Staff	
Shri. P. K. Acharya	Private Secretary

Shri. A. Lakshmana Rao	Assistant
Skilled Support Staff	
Shri. Purna Samal (Rtd. on 31.03.2020)	Skilled Support Staff
Shri. Sauri Pradhan	Skilled Support Staff
Shri. Babuli Sethi	Skilled Support Staff
Shri. Fakir Charan Bhoi (Rtd. on 30.06.2020)	Skilled Support Staff
Shri. Samsuddin Khan	Skilled Support Staff
Shri. Prakash Kumar Nayak	Skilled Support Staff

OTHER INFORMATION

Tuber day organized at Kandhamal, a tribal dominated district of Odisha

The Regional Station of ICAR-CTCRI, Bhubaneswar has organized 'Tuber Day' at TSP village Tikabali, Kandhamal District, Odisha on 17 January 2020. Around 500 tribal farmers participated in the programme. Tuber day was an attempt to make awareness about the production of quality planting materials, scientific production technologies, nutritional value of the tuber crops, value added products developed from different tuber crops particularly biofortified β-carotene rich orange flesh and anthocyanin rich purple flesh sweet potato varieties. Tuber day highlighted the importance of development of seed villages for providing sufficient quality planting materials to the tribal community. Scientist from different Institutes like ICAR-CTCRI, ICAR-NRRI, ICAR-CIWA, OUAT and NGO (ORISSA) delivered lectures on tuber crops cultivation, value added products, dry land agriculture, rice-tuber crops ecosystem, water use efficiency under changing climatic conditions and clarified the farmer's doubts during the farmers-scientists interactive session. The DDH, Kandhamal provided information about the different schemes of Odisha State Horticulture department. The progressive tuber crops farmers showcased their tuber crops materials in the exhibition. Tuber crops tribal farmers were also awarded and facilitated during the programme.

Tuber Day celebration at Tikabali, Kandhamal, Odisha

Quinquennial Review Team Meeting

The Indian Council of Agricultural Research vide Office Order F. No. HS/1-3/2013-IA-V dated 19.08.2019 has constituted a Quinquennial Review Team (QRT) to review the work of ICAR-CTCRI and AICRP TC during 01.04.2014 to 31.03.2019. The QRT team comprises of the experts viz., Dr. P. Rethinam, Former ADG, ICAR; Chairman, CDB, GOI & Executive Director, APCC, Jakarta, Indonesia as QRT Chairman and Dr. S. K. Naskar, Former Director, ICAR-CTCRI; Dr. Ramabhau Tumadu Patil, Former Director, ICAR-CIPHET; Dr. Malavika Dadlani, Former Joint Director (Research), ICAR-IARI and Dr. M. S. Palaniswami, Former Project Coordinator, AICRP on TC as QRT members and Dr. G. Byju, Principal Scientist, Division of Crop Production as the Member Secretary, QRT.

The QRT scrutinized all the available documents

provided by the Institute, received inputs from the scientific presentation by Director, Project Coordinator, Project Heads, different stakeholders of tropical tuber crops, discussed with officials of ICAR, Director and scientists of the Institute, all centres of AICRP Tuber Crops and KVKs and visited laboratories, experimental fields and farmers fields. All the concerned scientists made presentations on their achievements, constraints and the way forward. The QRT also had discussion with progressive farmers, processors, NGOs, starch/sago factory owners and exporters. The QRT also met and discussed with the officers of administration and accounts of the Institute. All the inputs received from the above meetings and discussions were synthesized for the preparation of this report.

The final meeting of QRT was held during 24-26 January 2020. A stakeholders meeting was organized on 24 January 2020. Dr. Pugalendhi expressed his concern about the spread of cassava mosaic disease in Tamil Nadu which needs to be addressed either by purifying the existing varieties or distributing newly released mosaic resistant varieties which are drought tolerant and high in starch. The salt deposition in top soil due to the use of ground water in irrigated areas also needs immediate attention. Dr. R. V. S. K. Reddy expressed the demand for short duration varieties with consumer preference. Soft rot disease of elephant foot yam, high cost of planting material and lack of varieties suitable for problematic soils are some of the issues to be addressed. Representatives from SAUs/KVKs/ farmers also participated and provided valuable inputs to the QRT. The final QRT report was presented to Dr. Trilochan Mohapatra, Secretary, DARE and DG, ICAR on 08 June 2020 by Dr. P. Rethinam, Chairman, QRT. The report and salient recommendations of the QRT was approved by the ICAR for implementation by ICAR-CTCRI and AICRP TC centres.

Stakeholders Interface organized during the final meeting of QRT

Tuber Crops Harvest Festival

ICAR-CTCRI initiated a novel programme at the ITI to inculcate farming interests among the students as well as to popularize high yielding varieties and technologies of tuber crops as a part of 'Haritha Campus' project. Performance of different varieties of cassava, elephant foot yam and yams and customized fertilizers were demonstrated. Dr. G. Byju inaugurated the Tuber Crops Harvest Festival at ITI, Dhanuvachapuram on 10 February 2020. Bumper yields were obtained from the tuber crops.

Tuber crops varieties and SSNM technologies being demonstrated at ITI, Dhanuvachapuram

National Science Day Celebration

The National Science day for the year 2020 was celebrated by ICAR-CTCRI during 26-27 February 2020. The theme of Science Day was 'Women in Science'. Dr. V. Ravi, Director (Acting), ICAR-CTCRI, delivered the presidential address in the National Science Day inaugural function. Thirty students from Christ College, Irinjalakkuda also attended the meeting. Dr. Sibi K. S., Assistant Professor and Head, Department of Physics, University of Kerala delivered the National Science Day lecture on the topic 'Making Sense with Sound'. He dealt with the definition of sound in various aspects like diverse types of sound waves, frequency and in relation to the theme women in Science. In-house poster making competition, elocution and essay writing competitions were conducted as part of the NSD celebrations. Dr. Susan John K., Principal Scientist, ICAR-CTCRI delivered the theme lecture on the 'Role of women in the scientific developments'. Dr. Shirly Raichal Anil, Principal Scientist, Division of Crop Improvement was the programme Co-ordinator and Dr. V. Ramesh, Principal Scientist, Division of Crop Production was the General Convenor of the NSD-2020 celebrations at ICAR-CTCRI.

National Science Day celebrations

International Women's Day Celebration 2020

The International Women's Day 2020 was celebrated at ICAR-CTCRI on 10 March 2020. The theme of the International Women's day was 'I am generation equality: Realizing women's right'. As per the instructions from ICAR the event on the theme 'Each for equal' was organized in a befitting manner. The one day programme commenced at 10.30 am with the welcome address by Dr. M. L. Jeeva, Chairperson, Women Cell, ICAR-CTCRI. The programme was presided over by Dr. V. Ravi Director (Acting), ICAR-CTCRI and he highlighted the achievements made by women in different fields in his presidential address. Dr. Soniya, E.V., Scientist G, RGCB, Thiruvananthapuram delivered a talk on the challenges and issues faced by women professionals and the ways to tackle them. A special talk on this occasion was delivered by Smt. Amrutha Rahim, Assistant Professor, Mar Gregorios College of Law, Thiruvananthapuram. She gave a brief account on the responsibility of the public to sensitize gender equality within the households. She also briefed about the different basic rights of women in our country. In connection with the International Women's day 2020, various competitions were conducted for the staff and students and the prizes for the winners were given away by the Chief Guest. The Chief Guest honoured Smt. M. Shyamala, Skilled Support Staff and Smt. V. Sathyabhama, Assistant, who were going to retire after meritorious service at ICAR-CTCRI. Mrs. Sujatha kumari, Chief Tehnical Officer delivered the vote of thanks.

International Women's day celebrations

46th Annual Institute Research Council meeting

The 46th Annual Institute Research Council of ICAR-CTCRI was held during 26-29 May 2020 at the Millennium Hall of ICAR-CTCRI under the chairmanship of Dr. V. Ravi, Director (A). The meeting was primarily conducted through video conferencing to maintain social distancing norms in the wake of COVID-19 outbreak. Dr. Anand Kumar Singh, DDG (Hort. Sci.), and Dr. T. Janakiram, ADG (Hort-I) participated in the meeting through online. All the scientists from Headquarters and RS ICAR-CTCRI attended the meeting. Dr. Saravanan Raju, Member Secretary, IRC welcomed the Chief guests, chairman and members of the IRC. In the inaugural address, Dr. V. Ravi, Director (Acting) congratulated all scientists for the progress made during the year and acknowledged their contributions in developing appropriate tuber crops technologies for the farming communities and other stakeholders of tropical tuber crops. Dr. G. Suja, Member Secretary, RAC-VIII presented RAC recommendations for the members to use as a roadmap to undertake R&D projects.

On 26 and 27 May 2020, Heads of Divisions presented the overall achievements of their respective divisions. The achievements of 10 Institute mega projects completed in the previous year were presented by the project leaders, which covered 74 activities. The results and outcomes of individual activities were presented and discussed. On 27 and 28 May 2020, 8 new mega projects were proposed for the next five year period (April 2020 to March 2025). All the projects were thoroughly discussed and the suggestions were recorded and documented in the proceedings. The DDG emphasized that research activities should match with the mandate of Govt. of India. He stressed that use of modern tools & technologies like AI and drones should be explored for research activities and value in terms of income should be assessed before area expansion. He pointed out the need to provide a holistic package of tuber crops technologies while expanding these crops in non-traditional areas, registration of elite lines with NBPGR and identification of compounds for health in biofortified varieties, economically profitable cropping systems and health drinks from biofortified varieties. The meeting concluded on 29 May 2020 with the plenary session.

IRC Meeting at ICAR-CTCRI

Editor Talk Series

ICAR-CTCRI Agri-Business Incubator in collaboration with Centre for Research on Innovation and Science Policy (*CRISP)* and National Institute of Agricultural Extension Management (MANAGE), Hyderabad organized two Editor Talk Series sessions to sensitise the scientists and scholars of Agricultural extension on publishing papers in high quality journals. In this series, Dr. Val Snow, Chief Editor, Agricultural Systems, Elsevier (14 July 2020) and Dr. Kristin Davis, Editor, Journal of Agricultural Education and Extension, Taylor & Francis (29 July 2020) handled sessions on editorial policies and other aspects related to publishing papers in their journals.

Editor talk by Dr. Val Snow

Virtual Consultative Meet on Recent Progress in Germplasm Utilization and Breeding in Sweet Potato

ICAR-CTCRI in collaboration with Horticulture Science Division of ICAR and International Potato Centre, Peru organized a one day 'Virtual Consultative Meet on Recent Progress in Germplasm Utilization and Breeding in Sweet Potato' on 14 September 2020 to discuss recent advances in germplasm utilization and breeding of sweet potato for diverse applications and to introgress new ideas into ongoing research programmes. Dr. A. K. Singh, Deputy Director General (Hort. Sci.), ICAR chaired the meeting. Three delegates, viz., Dr. Simon Heck, Dr. Wolfgang J. Grüneberg and Dr. Guilherme da Silva Pereira from International Potato Center (CIP) were invited to present their ideas and to participate in the discussion. Dr. Shirly Raichal Anil from ICAR-CTCRI presented the recent progress in germplasm utilization and breeding of sweet potato in India. Dr. V. Ravi, Dr. Vikramadithya Pandey (ADG, Hort. Sci., ICAR), Dr. M. N. Sheela and Dr. U. S. Singh also participated in the event. Dr. P. Murugesan was the convener and Dr. A.V. V. Koundinya and Dr. C. Visalakshi Chandra were co-conveners of the programme. All the scientists of ICAR-CTCRI and AICRP TC centers were also on board. During the meeting, sweet potato seed system development; advances in sweet potato breeding like accelerated breeding system, application of molecular markers and genomic selection models; and sweet potato breeding for food, feed, fodder and industrial applications and stress tolerance were discussed. The proceedings and recommendations of the meeting were documented and published.

Glimpses of the Virtual Consultative Meet

International webinar on Harnessing the Potential of Tropical Tuber Crops

ICAR-Central Tuber Crops Research Institute organized an International Webinar on 'Harnessing the Potential of Tropical Tuber Crops under Changing Climate (HPTTC 2020)' on 27 October 2020 under the chairmanship of Dr. V. Ravi, Director, ICAR-CTCRI. Dr. A. K. Singh, Deputy Director General (Hort. Sci.), ICAR, New Delhi, India inaugurated the Webinar and in his inaugural speech, he has emphasised the role of tropical tuber crops in mitigating climate change consequences. Dr. Vikramaditya Pandey, Assistant Director General (Hort. Sci.), ICAR, in his special address highlighted the significance of tropical tuber crops. About 300 delegates from different countries attended the Webinar. Lead talk was given by Dr. Jan W. Low, World Food Prize Laureate and Principal Scientist at International Potato Centre, CIP, Nairobi Centre, Kenya, wherein she stressed the calibre of climate-resilient orange-fleshed sweet potato in combating hidden hunger and malnutrition thereby uplifting the socio-economic status of the people of Sub-Saharan African regions. There were three technical sessions viz., Crop Improvement and Breeding Strategies, Integrated Crop and Soil Management and Plant Health Management. The lectures were delivered by Dr. M. N. Sheela, Principal Scientist and Head, Division of Crop Improvement, ICAR-CTCRI; Dr. Asrat Asfaw, Yam Breeder, International Institute of Tropical Agriculture, Nigeria; Dr. Al Imran Malik, Cassava Production Systems Specialist at Asia Regional Office of International Centre for Tropical Agriculture (CIAT), Vientiane Centre, Lao PDR; Dr. Joy G. Adiele, Systems Agronomist at National Root Crops Research Institute

(NRCRI), Abia, Nigeria; Dr. Arthur Villordon, Professor, Sweet Potato Research Station, College of Agriculture, Louisiana State University, Louisiana, USA; Dr. C. A. Jayaprakas, Principal Scientist and Head, Division of Crop Protection, ICAR-CTCRI; Dr. M. L. Jeeva, Principal Scientist, Division of Crop Protection, ICAR-CTCRI and Dr. G. Byju, Principal Scientist, ICAR-CTCRI and Convener, HPTTC 2020 in different sessions. Dr. D. Jaganathan, Senior Scientist was the co-convener and Dr. Sanket J. More, Scientist, Division of Crop Production, ICAR-CTCRI, was the organizing secretary of the webinar.

Glimpses of International webinar on HPTTC 2020

Vigilance Awareness Week 2020: Vigilant India, Prosperous India

As per the directive of Central Vigilance Commission, 'Vigilance Awareness Week' was observed at ICAR-CTCRI during the period 27 October 2020 to 02 November 2020. The activities commenced with a pledge by all the officials and staff on 27 October 2020. This year the main focus of Vigilance Awareness Week was SATARK BHARAT, SAMRIDDH BHARAT (Vigilant India, Prosperous India). All the staff and stakeholders had actively participated in the mass campaign to undertake the online CVC Integrity Pledge for the Citizens through CTCRI website (www.ctcri.org/ipledge.php).

Observation of Vigilance Awareness Week

Constitution Year Celebration

Constitution Year was celebrated from 26 November 2019 to 26 November 2020 in connection with 70th year of the Indian constitution. As part of the celebration, an awareness programme was organized at ICAR-CTCRI on 10 January 2020 in the Millennium hall. Dr. K. Sunilkumar, Principal Scientist and Chairman of the Constitution celebration committee welcomed the dignitaries and participants to the programme and gave a brief account of the importance of observing the constitution year. The programme was chaired by Dr. V. Ravi, Director (Acting), ICAR-CTCRI and he stressed the need for awareness of citizens' duties in addition to the Fundamental rights in his presidential address. Justice Shri. M. R. Hariharan Nair, Former Judge, High Court of Kerala delivered an expert talk on 'Constitution and Fundamental Duties'. In his lecture, he has given thrust for the importance of duties of government staff and the need to respect constitution and national symbols.

An awareness seminar on 'Constitution and Fundamental Duties' was organized for the students of Government College, Kariavattom, Thriuvananthapuram at ICAR-CTCRI. An expert talk on Indian Constitution with special emphasis on women rights was delivered by Dr. Amrutha Rahim, Assistant Professor, Mar Gregorios College of Law, Thiruvananthapuram on 10 March 2020. To create awareness among the staff/citizens regarding constitution, different banners/posters made available by Department of Justice, Ministry of Law and Justice, GOI were also displayed at vantage positions in the Institute campus as well as in the notice board with the logo on the topic regarding importance of Constitution, national symbols, fundamental duties of citizen and preservation of cultural heritage. On 14 April 2020, on the occasion of the birthday of Dr. B. R. Ambedkar, the preamble of the Constitution was circulated to the staff members.

Constitution day celebration on 26 November 2020 was organized on virtual mode by following SOPs of COVID-19. The programme marked the culmination of the year long celebration of the 70th anniversary of adoption of THE CONSITUTION OF INDIA. The session started with preamble reading by Dr. V. Ravi, Director (A), along with the staff of the Institute. The Chief guest, Justice Shri. M. R. Hariharan Nair, Former Judge, High Court of Kerala delivered an expert talk on 'The Constitution and Social Inclusion'. Dr. K. S. Ajay Kumar, Professor, Mar Gregorios College of Law and Former Principal, Government Law College, Thiruvananthapuram delivered an expert talk on 'A Common Man's Approach to the Constitution of India', which was followed by an interactive/ discussion session.

Glimpses of Constitution Year Celebrations

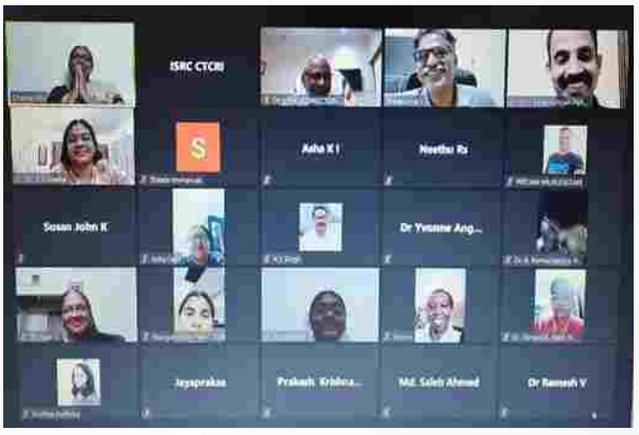
World Soil Day 2020

World Soil Day (WDS) 2020 was celebrated at ICAR-CTCRI on 05 December on virtual mode. Dr. V. Ravi, Director (A), made the presidential address narrating the significance of soil and the soil biodiversity comprising of microfauna, mesofauna, macrofauna and megafauna with invisible microbes ranging from bacteria, fungi to millipedes, centipedes to earthworms, toads, moles etc. in keeping the soil ecosystem alive and healthy and incidentally the entire life on the universe. The WSD pledge was administered by the Director on the occasion. The theme lecture on the topic 'Keep Soil Alive, Protect Soil Biodiversity' befitting to this year's WSD theme Agro Residues to Keep the Soil Alive, was given by Dr. Murali Gopal, Principal Scientist (Agricultural Microbiology), ICAR-CPCRI, highlighting topics like soil biodiversity in maintaining and sustaining soil health, recycling technologies for palm and cocoa biomass residues, unravelling their microbiology and impact on soil health through meta genomic studies, developing PGPR and mycorrhizal inoculants for coconut and cocoa, whole genome sequencing of the PGPR's and microbial control of coconut insect pests and on transferring of soil and plant health rejuvenating technologies to farming communities. Dr. Susan John, K., Principal Scientist and Nodal Officer of the Soil Health Card programme welcomed the participants and Dr.V. Ramesh, Principal Scientist and Convenor of the programme proposed vote of thanks. The meeting was attended by scientists from ICAR-CTCRI, ICAR-IISR, Calicut and extension personnel from Department of Agriculture, Government of Kerala.

World soil day celebration at ICAR-CTCRI

Tuber crops day 2020

The Indian Society for Root Crops (ISRC) and ICAR-Central Tuber Crops Research Institute jointly organized a webinar in connection with Tuber Crops day celebrations on 07 December 2020. Dr. M.N. Sheela, Secretary, ISRC welcomed the gathering and briefed the main objectives of the webinar. Dr. V. Ravi, Director (Acting) delivered the presidential address and emphasised the importance of organizing such webinars for the benefit of the tuber crops community. Dr. V. Balakrishnan, Former Member Secretary, Kerala State Biodiversity Board and Former Director, MSSRF, Wayanad delivered an invited talk on 'Biological Diversity Act 2002 and Scope of conservation of wild edibles (especially *Dioscorea*)'. All the scientific staff of ICAR-CTCRI, AICRP TC centres and ISRC members participated in the webinar. Interactive session with fruitful discussions were held regarding the conservation of tuber crops germplasm.



Participants of Tuber crops day 2020 webinar

Third Meeting of Research Advisory Committee VIII

The third meeting of VIII RAC was held through Virtual (Zoom Platform) mode on 16 December 2020 at ICAR-CTCRI. Dr. G. Kalloo, Former DDG (Hort. Sci.), ICAR, chaired the meeting. The following members were present:

1. Dr. Vikramaditya Pandey, ADG (Hort. Sci.), ICAR
2. Dr. C. Devakumar, Former ADG (EP & D), ICAR
3. Dr. S. Arulraj, Former Director, ICAR-IIOPR
4. Dr. S. K. Nanda, Former PC, AICRP on PHT, ICAR-CIPHET
5. Dr. P. Kalia, Emeritus Scientist & Former Head, ICAR-IARI
6. Advocate Shri. Ranjit Sreenivas, Non-official member
7. Dr. Anil Vaidyamangalam, Non-official member
8. Dr. V. Ravi, Director, ICAR-CTCRI
9. Dr. Suja G., Principal Scientist, ICAR-CTCRI (Member Secretary)

Dr. Suja G., Member Secretary, welcomed the Chairman and members of RAC and all the Scientists. Dr. V. Ravi, Director (Acting), ICAR-CTCRI made a presentation on ongoing Institute projects, externally funded and students' projects, significant research achievements, technologies developed, technologies commercialized, publications, infrastructure developed, equipment procured, planting material production, trainings conducted, frontline demonstrations/OFTs conducted and other general programmes like Rainbow Diet Programme organized in NEH states, SCSP, MGMG and other events conducted. Dr. S. Sunitha, Principal Scientist, Project Co-ordinator's Cell, AICRP on Tuber Crops also briefed the Committee about the activities and achievements of ICAR-AICRP on tuber crops.The action taken report of the second meeting of VIII RAC was presented by the Member Secretary, which was discussed and approved. The Heads of Divisions presented the salient achievements of 8 ongoing Institute projects and 29 externally funded projects and the targets for 2020-21. Based on the presentations and discussions as well as in depth interaction with the RAC members on 16 December 2020, the following recommendations were finalized. They are genomic resources generation, trait specific germplasm identification and tapping potential of wild relatives of tropical tuber crops for retrieving and using genes of interest for biotic and abiotic stresses and micro nutrients, usage of gene editing CRISPR/cas technology for starch modification and important diseases, breeding biofortified varieties for anthocyanins, beta-carotene and minerals and breeding against antinutritional factors using MAS, development of short duration varieties, improvement of underutilized tuber crops, use of multi-parent mapping populations sand multi-parent advanced generation intercross for effective QTL discovery and identification of rare alleles in important tuber crops, development of package of practices of naturally biofortified varieties, studies on the impact of soil nutrient status on the quality traits of tubers, preparation of future roadmap for strengthening of seed chain in tuber crops including enhanced coverage of area under biofortified varieties, standardization and utilization of hydroponics, aeroponics, tissue culture, innovative nursery techniques etc for mass multiplication of pest and disease free and genetically pure planting materials, survey and surveillance of emerging pests and diseases in tuber crops, integrated pest and disease management including biopesticides, microbial formulations, nano formulations etc., suitably supported by IT-based decision support systems, validation of cassava based biopesticides against major pests of horticultural crops, generation of scientific and technological database on demonstration of the potential of tuber crops for industrial uses supported with pilot scale data for high value products and assessment of the qualitative and quantitative post-harvest losses in all tuber crops, exploration of the role of institutional innovations like agribusiness incubators and FPOs for scaling up tuber crops technologies.

RAC Meeting in online mode

Institute Management Committee Meeting

The XVII Institute Management Committee Meeting of ICAR-CTCRI was held on 18 December 2020 under the Chairmanship of Dr. V. Ravi, Director (Acting), ICAR-CTCRI, Thiruvananthapuram in virtual mode and the following Members/Dignitaries/Officers attended the meeting.

1.	Dr. V. Ravi Director (A), ICAR-CTCRI, Thiruvananthapuram	Chairman
2.	Dr. K. Vasuki, IAS Director of Agriculture, Govt. of Kerala [Represented by Shri. K Radhakrishnan, Additional Director of Agriculture (Crop Production), Govt. of Kerala]	Member
3.	Dr.Vikramaditya Pandey Asst. Director General (Hort. Science-I), ICAR, New Delhi	Member
4.	Dr. L.Pugalendhi Dean (Hort.), Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore	Member
5.	Dr. A. Anilkumar Dean, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram	Member
6.	Dr. M. P. Anil Vaidyamangalam TC 5/2090, VGRA 64, Kowdiar P.O., Thiruvananthapuram	Member
7.	Adv. Shri. Ranjeet Srinivas Kunnumpurath, Parvati Amman Kovil Road, M.O. Ward, Alappuzha	Member
8.	Dr. H. P. Maheswarappa Project Co-ordinator (AICRP on Palms), ICAR-CPCRI, Kasaragod	Member
9.	Dr. C. Palaniswami Principal Scientist & Head, Division of Crop Production, ICAR-SBI, Coimbatore	Member
10.	Dr. M. Pitchaimuthu Principal Scientist, Division of Vegetable Crops, ICAR-IIHR, Bengaluru	Member
11.	Dr. J. Rema Principal Scientist, ICAR-IISR, Kozhikode	Member
12.	Shri. R. K. Babu Finance & Accounts Officer, ICAR-CIBA, Chennai	Member
13.	Shri. Ramdeen Senior Administrative Officer, ICAR-CTCRI	Member Secretary
14.	Dr. C. A. Jayaprakas Principal Scientist & Head (Acting), Division of Crop Protection, ICAR-CTCRI	Special Invitee
15.	Dr. M. N. Sheela Principal Scientist & Head i/c, Division of Crop Improvement, ICAR-CTCRI	Special Invitee
16.	Dr. M. S. Sajeev Principal Scientist & Scientist i/c, Section of Crop Utilization, ICAR-CTCRI	Special Invitee
17.	Dr. Sheela Immanuel Principal Scientist & Scientist i/c, Section of Extension & Social Sciences, ICAR-CTCRI	Special Invitee
18.	Dr. P. Murugesan Principal Scientist & SIC (PME Cell), ICAR-CTCRI	Special Invitee
19.	Dr. K. Sunilkumar Principal Scientist & SIC (Farm), ICAR-CTCRI	Special Invitee
20.	Shri. P. Krishnakumaran Finance & Accounts Officer, ICAR-CTCRI	Special Invitee
21.	Smt. Jessymol Antony Asst. Finance & Accounts Officer, ICAR-CTCRI	Special Invitee
22.	Shri. P. C. Noble Assistant Administrative Officer, ICAR-CTCRI	Special Invitee
23.	Shri. T.Vijayakumara Kurup Assistant Administrative Officer, ICAR-CTCRI	Special Invitee

A brief presentation on the mandate, research activities and achievements of the Institute was made by Dr. V. Ravi, Director (Acting), ICAR-CTCRI. 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 Senior Administrative Officer presented the report of Establishment and Personnel Section and the Finance & Accounts Officer presented the Progressive Expenditure up to 25 November 2020.

Stakeholders interface

A stakeholders interface on improved technologies of tuber crops for enhancing farm income was organized on 18 December 2020 at Chenkal, Thiruvananthapuram. Dr. G. Byju, Principal Scientist, Dr. D. Jaganathan, Senior Scientist and Dr. B. G. Sangeetha, Scientist, ICAR-CTCRI, Agricultural Officers from Krishibhavan and officials from VFPCK, Government of Kerala were the resource persons for the interface. Eight B.Sc., (Hort.) final year students from College of Horticulture, Ananthurajupeta, Dr. YSR Horticultural University, Andhra Pradesh attended the programme in connection with their RHWE programme at ICAR-CTCRI. Exhibition was also organized for the benefit of more than 80 farmers and other stakeholders.

Farmers meeting on the occasion of Hon'ble Prime Minister's address during PM Kisan money release

ICAR-CTCRI has organized a farmers' meeting in connection with Hon'ble Prime Minister's address during PM Kisan money release on 25 December 2020. During the meeting, the farmers viewed Hon'ble Prime Minister's address and learned about the provisions and progress of PM Kisan scheme.

Farmers meeting at ICAR-CTCRI in connection with Hon'ble Prime Minister's address during PM Kisan money release

State of art of *Mera Gaon Mera Gaurav*

The MGMG programme was implemented by ICAR-CTCRI in the selected villages in and around Thiruvananthapuram district and in Bhubaneswar, Odisha. This programme was implemented in collaboration with state departments, Krishi Vigyan Kendras, agricultural university and other line departments.

During the period under report the following activities were undertaken.

Sl. No.	Name of the activity	No. of activities conducted	No. of farmers participated & benefitted
1.	Awareness created	14	340
2.	Demonstrations conducted	10	179
3.	Interface meeting/ *Goshthies*	8	367
4.	Literature support provided	85	233
5.	Training organized	8	343
6.	Visit to village by teams	20	266
7.	Mobile based advisories	215	199
	Total	**360**	**1927**

Awareness programmes were conducted to the different stakeholders in the villages on different aspects of tuber crops. A total of 14 activities were conducted and 340 farmers were benefitted. Ten demonstrations were conducted in the MGMG villages and the number of farmers benefitted was 179. The demonstrations were conducted on improved varieties of tuber crops, SSNM of cassava, tuber crops processing and value addition. Literature support was provided to 233 farmers. Training programmes were conducted on improved methods of tuber crops cultivation and value addition. Mobile based advisories were given to 199 farmers through various social media.

Low income, lack of crop diversification, price fluctuation, pests and diseases etc were the major constraints faced by farmers in the MGMG villages in

Thiruvananthapuram district of Kerala. Scientists from the Institute visited the farmers' fields and suggested technological interventions and advisories to minimize the problems encountered by the farmers.

The Krishibhavans, Krishi Vigyan Kendra, ATMA, SHGs are linked with farmers for doing profitable agriculture. Various government schemes viz., Pradhan Mantri Krishi Sinchai Yojana, Paramparagat Krishi Vikas Yojana, PM Kisan, Pradhan Mantri FasalBima Yojana etc. are being used by the farmers through Department of Agriculture and other related agencies.

Distribution of liquid organic manure to farmers

Distribution of CMD resistant cassava variety 'Sree Reksha' to farmers under SCSP of AINPOF project

Distribution of planting materials of new varieties of tuber crops

Farm advisory visits

Mera Gaon Mera Gaurav activities

Field Level Demonstrations/OFTs conducted

Demonstrations on improved varieties of cassava, sweet potato, taro and Chinese potato; Fertilizer Best Management Practices and other production and protection technologies of tuber crops were established in Kerala, Tamil Nadu, Andhra Pradesh and North Eastern states with 142 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

- A team consisting of Dr. D. Jaganathan, Dr. E. R. Harish and Dr. H. Kesava Kumar conducted farm advisory visits among cassava growers of Kanyakumari district of Tamil Nadu during January 2020.
- A team consisting of Dr. D. Jaganathan, Dr. H. Kesava Kumar, and Dr. P. Prakash conducted farm advisory visits among tuber crops growers of Amboori and Kuttichal of Thiruvananthapuram during January 2020.
- Dr. D. Jaganathan and Dr. P. Prakash conducted farm advisory visits among taro growers of Nayagarh district of Odisha during January 2020.
- A team consisting of Dr. Sheela Immanuel, Dr. R. Muthuraj and Dr. D. Jaganathan conducted farm advisory visits among tuber crops growers of Kilimanoor panchayat of Thiruvananthapuram during January and February 2020.
- Dr. G. Byju and Dr. D. Jaganathan conducted farm advisory visits among tuber crops growers of Vadakkekara and Thiruvankulam panchayats of Ernakulam district of Kerala during November 2020.
- Farm advisory visits among cassava and greater yam growers were conducted by Dr. G. Byju and Dr. D. Jaganathan in Pathanamthitta district of Kerala during November 2020.
- A team consisting of Dr. R. Muthuraj, Dr. D. Jaganathan and Dr. T. Krishnakumar conducted farm advisory visits among farmers of elephant foot yam and Chinese Potato in Tenkasi and Tirunelveli districts of Tamil Nadu during December 2020.
- Dr. G. Byju and Dr. D. Jaganathan conducted farm advisory visits among farmers of cassava in Chenkal village of Thiruvananthapuram district of Kerala during December 2020.
- An expert team comprising of Dr. P. Sethuraman Sivakumar, Dr. R. Muthuraj and Dr. H. Kesava Kumar along with officials from KVK, Tirunelveli visited nematode-affected areas of Chinese potato fields in Tenkasi district, Tamil Nadu during 28-29 December 2020 and surveyed the affected areas. On December 29, 2020, a Field day on Chinese potato was organized in the Ravanasamudhram village, Tenkasi district, Tamil Nadu where Dr. H. Kesava Kumar interacted with 50 Chinese potato farmers and imparted training on nematode management. The Sree Dhara variety released by ICAR-CTCRI was also introduced in the meeting and few progressive farmers were provided with quality planting materials for further multiplication.


Kanyakumari, Tamil Nadu


Tenkasi, Tamil Nadu


Ernakulam and Thiruvananthapuram, Kerala

Tirunelveli, Tamil Nadu

Nayagarh, Odisha

Farm Advisory Visits by ICAR-CTCRI team

Swacch Bharat Abhiyan

ICAR-CTCRI is dedicatedly involved in various activities related to 'Swachh Bharat Mission', the nation-wide cleanliness programme conceptualized by the Hon'ble Prime Minister of India. Various cleanliness initiatives have been implemented as follows.

- Swachh Bharat Abhiyan was conducted weekly on every Saturday for half an hour and all the staff members were instructed to clean their respective laboratories, sitting areas and surroundings. On the last working day of the month, Swachh Bharat Abhiyan was conducted for one hour, during which all the staff members were involved in cleaning the campus as a whole.
- Attendance register was maintained to ensure active participation of members.
- Dustbins were kept at regular intervals in the premises, hand gloves and brooms were provided for cleaning work.
- All members participated to clean common areas such as labs, garden area, main road area, processing complex, canteen and field area.
- Plastics, bottles, papers etc were collected and destroyed completely by using incinerator.
- Old and broken items, furniture, glassware and plastics were replaced.
- Digitization of office records and disposal of old files following ICAR prescribed file retention schedule were taken up as part of Swacch Bharat Mission.
- Implementation of e-office for paperless correspondence as part of Swacch Bharat Mission.
- Vermicomposting of agrowastes/biomass generated from crop production activities was implemented at the Research Farm.
- Swachhata awareness class was handled by Dr. K. Sunilkumar and Shri. B. Satheesan to beneficiary farmers under Subhiksha Keralam programme at Maranallur Panchayat, Thiruvanathapuram.
- Activity-wise Swachhata Action Plan (SAP) was prepared and progress report of ICAR-CTCRI was communicated to the council on regular intervals.

Swachhata awareness class

150th Birth Anniversary Celebration of Father of Nation

As per the directions received from the Secretary, Ministry of Culture, Government of India, ICAR-CTCRI organized Swachhata pledge administration and cleanliness drive to celebrate the occasion of 150th Birth Anniversary of Mahatma Gandhi.

Swachhata Pakhwada 2020 (16 to 31 December 2020)

Under Swachhata Pakhwada, swachhata pledge was administered by the Director of ICAR-CTCRI along with all the members of Institute. Dr. V. Ravi, Director (Acting), in his address highlighted the importance of observing Swachhata Pakhwada and also briefed on the activities to be carried out during 16 to 31 December, 2020. The Swachhata awareness banner was displayed at the main entrance of the Institute both at HQ and RC, Bhubaneswar and other prominent places for public view. In connection with Swachhata Pakhwada 2020, cleanliness drive was conducted to remove plastic wastes from both inside and outside of the Institute premises on day-to-day basis by the staff members during the fortnight. In-house slogan competition to create awareness on Swachh Bharat was conducted following the COVID-19 protocol. All the scientific and other staff of ICAR-CTCRI were involved in the cleaning drive. ICAR-CTCRI, Regional Station had also spread the message of cleanliness and actively

participated in cleaning schools and villages during the occasion to spread the message of cleanliness to the public.

Swachhata Pakhwada at Regional Station ICAR-CTCRI

Library Corner

Library continued the information support services to the research and training activities of the Institute. In addition to the routine services, an amount of ₹90,106 was spent for the purchase of 17 titles of scientific books. In addition, the following services were also made available to the users of the library:

1. **Maintenance:** The library maintains around 18,300 documents which includes, books, bound back volumes of journals, theses etc.
2. **Circulation of books:** A total of 66 books were issued to the users on loan.
3. **CeRA:** As a part of literature search, the staff and students of the Institute used jgateplus.com platform for downloading articles from CeRA. Remote access facility has been provided for access to CeRA through the ID and password supplied by DKMA during the Covid-19 lock down period.
4. **Ready-reference service:** The library provided ready assistance and solutions to the user's various queries. These include enquiries in person or over the phone regarding any matters related to information sources like URLS of websites related to our work, downloading of files, common plant names, phone numbers, geographical information, etc. More than 400 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., Ph.D. and PDF research works under the guidance of the Institute scientists. They were given necessary guidance in the use of reference resources and photocopying facility.
6. **Photocopying:** Library continued to provide photocopying service to the Institute staff and other library users on official/payment basis. During this period, about 5,500 copies were provided against their work indents, which included official copies and private copies.

Recreation Club Corner

The new executive committee of recreation club commenced their activities with New Year celebration. All the members gathered in the canteen, ICAR-CTCRI and New Year speeches/messages were delivered by the Director (Acting), Heads of various Divisions, SAO and FAO. In addition, there was a mini cultural programme; distribution of prizes to winners of lucky dip and ceremonial cake cutting. Recreation Club made efforts to spread awareness about COVID-19 pandemic and the essential measures to be followed to reduce the spread of COVID-19 by putting posters in entrances of all buildings and distributing reusable masks to members. During lockdown period, the club joined Community Kitchen, an effort by government to feed the needy by distributing essential groceries. The Club also put efforts to initiate sanitization of corridors and siting places of employees.

Club organized farewell functions to Smt. M. Syamala (SSS), Shri. S. Natarajan (Technical Officer), Smt. V. Sathyabhama (UDC), Shri. R. Bharathan (Chief Technical Officer) and Smt. T. K. Sudhalatha (Asst. Chief Technical Officer) consequent to their superannuation or transfer to sister Institute. As a token of member's respect and affection to these members, befitting gifts were presented to all during the farewell function. Republic Day and Independence Day were celebrated by following COVID-19 protocol. Onam was celebrated by making a '*Pookkalam*' (floral alpana) at the entrance of main building. Christmas was celebrated by making a beautiful crib at the entrance of the Institute.

Recreation Club efforts to manage COVID-19 pandemic

Hindi Corner (January - December 2020)

Hindi Workshop was held during this year on 28 February 2020 by the Official Language Implementation Committee (OLIC). The workshop was conducted by Shri. N. Samraj, Retd. Rajbhasha Adhikari, Southern Railway, Thiruvananthapuram on the topic, OL Awareness Programme. Three OLIC meetings were also conducted during this period on 23 March 2020, 29 June 2020 and 30 September 2020. Various issues related to Official Language Implementation was discussed during these meetings. The Hindi Fortnight 2020 was celebrated during 14-28 September 2020. Around nine competitions were organized for the staff of the Institute and many people participated in the competitions with enthusiasm in spite of the pandemic maintaining all Covid-19 protocol strictly. The event was inaugurated by Dr. V. Ravi, Director (A) on 15 September 2020. On 31 October 2020, Smt. Sudhalatha, Assistant Chief Technical Officer (Hindi) and Member Secretary, Official Language Implementation Committee superannuated from her service.

Infrastructure Development

A Livestock Shed & Dairy Unit with 2 cows and 2 calves as a part of IOFS under AINPOF was established. It was formally inaugurated on 11 May 2020 by Dr. V. Ravi, Director (A), ICAR-CTCRI as a part of Integrated Organic Farming System Model of AI-NPOF. Integration of cereals, tuber crops, fodder, fruit crops, vegetables, pulses and oilseeds and cows in the IOFS would provide safe food, income, employment opportunities and nutrient recycling. All the crop components have been established.

View of Livestock Shed & Dairy Unit at ICAR-CTCRI

Tuber crops for food and nutrition security during COVID-19 pandemic crisis

Farm agro advisory on production technologies in English and regional languages have been uploaded in the Institute website for the benefit of farmers growing tuber crops. The *Arogya sethu* app was given maximum publicity through Whatsapp and other social media to group of farmers and other stakeholders. Being a consumer state, fear of a COVID-19 lockdown-triggered food shortage in the months ahead has prompted Kerala to go back to its 'roots' to guarantee food security. The Government of Kerala has already started implementing an action plan to boost agricultural production in the state to make it self-sufficient and has been named 'Subiksha Keralam'. The massive, ambitious programme aims to boost farming of cassava, yam, elephant foot yam, sweet potato, taro and Chinese potato among agricultural clubs and Farming Groups utilizing fallow lands and at homestead-levels, promote food processing industries to develop small scale entrepreneurs and establish Food Processing Clusters in Kerala. In this regard, ICAR-CTCRI supplied planting materials worth of ₹2.7 lakhs to Govt. of Kerala for further multiplication in district agriculture farms under Department of Agriculture for distribution to farmers.

In Kerala, sellers and buyers were facing the problem of marketing their produce particularly during lockdown and curfew for containing Corona virus disease. ICAR-CTCRI developed an online marketing app 'HOMS' (Horticulture Online Marketing System) facilitating marketing of tubers, vegetables and fruits. Publicity about the availability of this app is also given in local newspapers.

During the COVID-19 pandemic period, ICAR-CTCRI, Thiruvananthapuram, Kerala and its Regional Station at Bhubaneswar, Odisha have donated 10 tonnes of cassava tubers, 100 kg elephant foot yam tubers, 260 kg yam tubers, 60 kg taro tubers and 60 kg sweet potatoes to 'Community Kitchens' run by nine group of beneficiaries including Municipal Corporation, Panchayats, NGOs and farmers from nearby MGMG villages and police personnel in Thiruvananthapuram and Bhubaneswar. Agro-advisories through TV, Radio, Youtube and Facebook were also given during the period to help tuber crop farmers during lock down period.

Supply of planting materials to Govt. of Kerala

Supply of cassava to Panchayats and Municipal Corporation, Thiruvananthapuram

Supply of tuber crops to needy people at RS ICAR-CTCRI, Bhubaneswar

Participations in Exhibitions

ICAR-CTCRI Thiruvananthapuram and its Regional Station at Odisha participated in the following exhibitions for the benefit of stakeholders. Large number of farmers, college and school students, industrialists and other public acquired knowledge on improved technologies of tuber crops.

- Exhibition in connection with Karshikamela during 27 December 2019 to 01 January 2020 at Newman College, Thodupuzha, Idukki, Kerala.
- Exhibition in connection with Value Addition for Income Generation in Agriculture (VAIGA) during 04-07 January 2020 at Thekkinkadu maidanam, Thrissur, Kerala.
- Exhibition in connection with State Agriculture Fair, 'Krushi Odisha-2020' organized by the Department of Agriculture & Farmers Empowerment, Government of Odisha during 20-24 January 2020 at Janata Maidan, Chandrasekharpur, Bhubaneswar, Odisha.
- Exhibition in connection with Stakeholders interface on Strengthening tuber crops research and development on 24 January 2020 at ICAR-CTCRI, Sreekariyam, Thiruvananthapuram, Kerala.
- Exhibition in connection with Global Potato Conclave 2020 during 28-31 January 2020 at Gandhinagar, Gujarat.
- Krishi Mela during 25-28 February 2020 at Kanakakunnu palace, Thiruvananthapuram, Kerala.
- Exhibition in connection with stakeholders' interface programme on 'Improved technologies of tuber crops for enhancing farm income' on 18 December 2020 at Chenkal, Thiruvananthapuram, Kerala.

VAIGA 2020 Thrissur, Kerala

Exhibition at Chenkal, Thiruvananthapuram

वर्ष 2020 के दौरान इस संस्थान में की गयी राजभाषा कार्यान्वयन से सम्बन्धित कार्यक्रम

राजभाषा कार्यान्वयन समिति की बैठक का आयोजन

इस संस्थान कि निदेशक महोदय (कार्यकारी), डॉ. वे. रवि की अध्यक्षता में, ता. 23 मार्च 2020, ता. 29 जून 2020 और ता. 30 सितम्बर 2020 को राजभाषा कार्यान्वयन समिति की बौठकों का आयोजन किया गया। इस अवसर पर राजभाषा कार्यान्वयन से संबंधित विभिन्न मुघों पर विचार - विमर्श किया गया। उसके आधार पर उक्त मुघों के अनुपालन किया जा रहा है।

हिन्दी कार्यशाला का आयोजन

केंद्र सरकार की राजभाषा नीति के अनुपालन में इस संस्थान के सभी कर्मचारियों के लिए ता. 28 फ़रवरी 2020 को "राजभाषा जागरूकता कार्यक्रम" पर एक दिन की हिन्दी कार्यशाला आयोजित की गाई। डॉ. वे. रवि, निदेशक (कार्यकारी) और अध्यक्ष (राजभाषा), भा. कृ. अनु. प-केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनन्तपुरम ने अध्यक्षीय भाषण दिया । उनहोंने हिन्दी के महत्व पर प्रकाश डालते हुए समारोह का उघ्घाटन किया। डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) सभा का स्वागत किया। श्री.एन. सामराज, सेवानिवृत राजभाषा अधिकारी, दक्षिण रेलवे, तिरुवनन्तपुरम "राजभाषा जागरूकता कार्यक्रम" पर व्याख्यान लिया। कुल 30 प्रतिभारियों कार्यशाला में भाग लिए।

हिन्दी पखवाड़ा समारोह का आयोजन

ता.14-28 सितम्बर 2020 को हिन्दी पखवाड़ा मनाया गया। इस समारोह का उघ्घाटन ता. 15 सितम्बर 2020, को निदेशक (कार्यकारी), डॉ. वे. रवि द्वारा किए गया। इस संस्थान की कर्मचारियों के लिए विविध हिंदी प्रतियोगिताएं आयोजित की गई। 1. निबंध लेखन 2. अनुवाद 3. भाषण 4. कविता-पाठ 5. सुलेख 6. खुला मंच 7. सिर्फ एक मिनट 8. श्रुतलेख आदी प्रतियोगिताएं आयोजित की गई। इसमें निम्नलिखित 5 श्रेणियों के कर्मचारियों भाग लिया (वैज्ञानिक, तकनीकी/प्रशासनिक, कुशल सहायक कर्मचारी एवं अस्थायी कर्मचारी)। प्रतियोगिताओं में कुल 19 प्रतिभागियों ने भाग लिया।

अन्य सार्वजनिक कार्यकलापें

इस संस्थान की सभी रबड़ की मोहरें, नाम पट्ट, साइन बोर्ड, फॉर्म, पत्र शीर्ष आदि द्विभाषी रूप में बनाया था। हिंदी में प्राप्त पत्रों के उत्तर हिंदी में दिए गए। सभी परिपत्र, धारा 3(3) के सभी कागजात, द्विभाषी रूप में किया गया। वार्षिक कार्यक्रम के निर्धारित लक्ष्यानुसार अधिक से अधिक पत्राचार हिंदी में किया जा रहा है।

सेवा-निवृत्ति

श्रीमती टी. के. सुधालता, सहायक मुख्य तकनीकी अधिकारी (हिन्दी) एवं सदस्य सचिव (रा भा का स), भाकृअनुप - केन्द्रीय कंद फसल अनुस्धान संस्थान ने 31 ओक्टोबर 2020 को एक लंबी और मूल्यवान सेवा के बाद सेवानिवृत्त हुई।

IMPORTANT EVENTS AND ACHIEVEMENTS AT A GLANCE

Events

Events	Date
Tuber day at Kandhamal, a tribal dominated district of Odisha	17 January 2020
Quinquennial Review Team Meeting	24-26 January 2020
Training programme on 'Promoting tuber crops based rainbow diet for food and nutritional security' at ICAR-RC NEH, Kolasib, Mizoram	21-22 February 2020
Workshop cum Training on Promoting Rainbow Diet "Achieving Food, Nutritional and Health Security through Tuber Crops" at ICAR-NEH Tripura Centre, Lembucherra, Agartala, Tripura	24 February 2020
Stakeholders cum Interface Meet on 'Promoting tuber crops based Rainbow diet for food, nutrition and health security' in Tripura	25 February 2020
National Science day celebration	26-27 February 2020
International Women's Day 2020 celebration	10 March 2020
46th Annual Institute Research Council meeting	26-29 May 2020
The 20th Annual Group Meeting of ICAR-All India Coordinated Research Project on Tuber Crops	10-12 June 2020
Virtual Consultative Meet on Recent Progress in Germplasm Utilization and Breeding in Sweet Potato	14 September 2020
Training programme on Effective Health Management for Enhancing Work Efficiency of ICAR Employees	07 October 2020
International Webinar on Harnessing the Potential of Tropical Tuber Crops under Changing Climate (HPTTC 2020)	27 October 2020
Vigilance Awareness Week	27 October 2020 to 02 November 2020
Constitution Year celebration	26 November 2019 to 26 November 2020
Constitution Day celebration	26 November 2020
World Soil Day celebration	05 December 2020
Tuber Crops Day celebration	07 December 2020
Third meeting of VIII RAC meeting	16 December 2020
The XVII Institute Management Committee meeting	18 December 2020
Hon'ble Prime Minister's address during PM Kisan money release-Live Web Telecast	25 December 2020

Achievements

Particulars	No.
Institute projects	8
External aided projects	23
Tuber crops germplasm maintained in the field gene bank	5,713
Tuber crops varieties recommended for release	1
Technologies commercialized	3
ICT Apps developed	2
Revenue generated through technology commercialization and professional service functions (₹lakhs)	22.55
B. Sc. students guided	44
M. Sc. students guided	50
Ph. D. scholars guided	9
Ph. D. awarded	5
Farmers visited the Institute	657
Students visited the Institute	398
Officers visited the Institute	69
Trainings conducted	41
Institute staff members trained	21
Publications in peer reviewed journals	60
Papers presented in conferences/seminars/symposia/workshops etc.	56
Books	5
Book chapters	9
Popular articles	59
Folders, leaflets, pamphlets	8
Radio talks	8
TV programme	4
Facebook live	9
Dignitaries visited the Institute	10
Exhibitions organized	7

QUALITY PLANTING MATERIAL PRODUCTION OF TUBER CROPS

Sl.No.	Name of the Crops	Varieties	Quantity
1.	Cassava (No. of stems)	Sree Vijaya	30,000
		Sree Jaya	25,000
		Sree Reksha	50,000
		Sree Suvarna	5,000
		Sree Sakthi	5,000
		Total	1,15,000
2.	Elephant foot Yam (tonnes)	Gajendra	37.50
		Sree Padma	0.50
		Total	38.00
3.	Greater Yam (tonnes)	Sree Shilpa	32.50
		Sree Roopa	
		Sree Keerthi	
		Sree Karthika	
		Sree Nidhi	
	White Yam (tonnes)	Sree Priya	3.00
		Sree Dhanya	
	Lesser Yam (tonnes)	Sree Latha	3.50
		Total	39.00
4.	Taro (tonnes)	Muktakeshi	2.50
		Telia	
5.	Sweet Potato (No. of vine cuttings)	Bhu Sona	5,50,000
		Bhu Krishna	5,04,000
		Kisan	4,00,000
		Sree Arun	2,000
		Sree Kanaka	2,000
		Gouri	2,000
		Total	14,60,000
6.	Chinese Potato (No. of vine cuttings)	Sree Dhara	30,000
7.	Yam Bean seeds (kg)	RM-1	200

LIST OF VARIETIES 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 SreeSahya (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 $100g^{-1}$) and salinity tolerance
4.	Sweet potato	*Ipomoea batatas*	IC0593651	ST-13	Bhu Krishna	13021	2013	JP-13	S.K. Naskar and Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar Odisha	High anthocyanin (85-90 mg $100g^{-1}$) and salinity tolerance
5.	Sweet potato	*Ipomoea batatas*	IC0593652	ST-10	Bhu Swami	13022	2013	JP-10	S.K. Naskar and Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar Odisha	High extractable starch (20-21%)

WEATHER DATA 2020

ICAR-CTCRI HQ, Sreekariyam,Thiruvananthapuram, Kerala

Month	Temperature (°C)		RH (%)		Wind velocity (km h^{-1})	Sunshine (h)	Rainfall (mm)	No. of rainy days
	Maximum	Minimum	FN	AN				
January 2020	32.78	22.39	97.94	53.78	1.04	8.11	8.3	3
February 2020	33.71	22.86	94.65	47.37	2.42	8.2	32.8	4
March 2020	34.24	24.50	95.39	53.47	2.41	8.0	125.7	6
April 2020	34.68	24.74	95.45	55.92	2.88	7.4	284.5	10
May 2020	32.19	24.51	99.10	72.33	4.41	6.4	182.1	13
June 2020	30.59	23.68	99.09	73.63	3.97	5.7	180.2	17
July 2020	30.46	23.46	99.26	73.04	3.52	5.1	348.3	16
August 2020	30.03	23.63	99.66	75.07	3.94	4.9	375.2	17
September 2020	29.63	23.23	100.00	77.98	2.31	6.5	250.5	13
October 2020	30.45	23.27	99.62	70.90	2.24	6.1	117.6	12
November 2020	32.22	23.28	99.79	64.78	0.78	6.0	52.6	7
December 2020	31.76	22.93	98.02	60.73	1.08	7.1	176.4	10

WEATHER DATA 2020

ICAR-CTCRI Regional Station, Bhubaneswar, Odisha

Month	Temperature (°C)		RH (%)		Sunshine (h)	Rainfall (mm)	No. of rainy days
	Maximum	Minimum	FN	AN			
January 2020	27.9	16.1	94	51	5.8	12.7	3.5
February 2020	28.5	16.2	91	48	5.2	94.2	3.5
March 2020	34.2	22.1	95	50	7.5	56.5	5.1
April 2020	36.9	24.7	93	50	7.7	103.3	6.4
May 2020	36.0	25.9	89	60	7.8	157.1	6.6
June 2020	34.9	26.7	93	68	4.9	95.3	5.6
July 2020	33.8	26.3	96	70	4.8	140.9	3.9
August 2020	32.7	26.0	95	76	3.5	95.3	2.9
September 2020	34.1	26.2	95	70	5.9	158.9	3.3
October 2020	31.9	24.4	95	76	4.7	585.4	3.1
November 2020	31.4	19.6	90	53	6.5	211.7	3.5
December 2020	29.8	14.3	94	41	6.5	247.6	3.6

'Produce Tuber
Ensure food, nutrition and
livelihood security'

For further details please contact
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Website : http://www.ctcri.org

भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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