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वार्षिक प्रतिवेदन
ANNUAL REPORT
2019

भाकृअनुप-केन्द्रीय कंद फसल अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
श्रीकारियम तिरूवनंतपुरम 695 017 केरल भारत

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

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ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE
SREEKARIYAM THIRUVANANTHAPURAM 695 017 KERALA INDIA

ICAR–Central Tuber Crops Research Institute
Sreekariyam, Thiruvananthapuram 695 017
Kerala, India

Tel.No. (91) (471) 2598551 to 2598554
Fax: (91) (471) 2590063
E-mail: director.ctcri@icar.gov.in
Website: http://www.ctcri.org

Published by
Dr. V. Ravi
Director (A)

Compiled and Edited by
Dr. A. Asha Devi
Dr. M.L. Jeeva
Dr. A.N. Jyothi
Dr. V. Ramesh
Dr. D. Jaganathan
Dr. K.M. Senthilkumar
Dr. Sanket J. More
Dr. V.B.S. Chauhan
Dr. S. Karthikeyan
Shri. B.S. Prakash Krishnan

Design & Printing
Directorate of Knowledge Management in Agriculture, ICAR, New Delhi

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PREFACE

The ICAR-Central Tuber Crops Research Institute (CTCRI), in its 56th year of service, is spearheading with 67 improved varieties, besides farmer-friendly production, protection and value addition technologies in tropical tuber crops, a group of climate-ready crops that can sustain food, nutritional, health and livelihood security. Roots and tubers are nutraceutical-rich health foods rich in dietary fibres, minerals, vitamins and anti-oxidants. In this background, I take pride to present the research accomplishments, technological advancements and development activities for the year 2019 documented in the form of 'Annual Report of ICAR-CTCRI'.

The field gene bank constituting 5651 accessions, continued to be enriched and conserved with valued traits. One CMD resistant cassava line was recommended for submission of proposal for central release in the states of Kerala, Manipur and Chhattisgarh based on AICRP trials. Two short duration CMD resistant lines were identified. A new greater yam variety, 'Sree Hima' was recommended for release by AICRP (TC) for Kerala State. One white yam line suitable for growing under non trailing conditions was also identified. Three sweet potato genotypes were identified as high yielders under drought stress condition. DUS guidelines were developed for greater yam and yam bean.

The sustainable resource management technologies like feasible cropping systems involving tuber crops and pulses, water saving techniques in elephant foot yam, water scheduling for taro, drip fertigation for greater yam + maize system, soil test based INM and nutrient use efficient cassava genotypes for saving NPK fertilizers will help to enable 'Doubling of Farmers Income by 2022', the most important mission-mode programme of the Govt. of India. Crop model for future projections of cassava, Aqua Crop model for cassava and sweet potato, WOFOST for predicting yield of cassava in India and climate smart agricultural practices for cassava with reduced carbon emission and increased carbon efficiency were all addressed.

IDM package for the management of anthracnose in greater yam and taro, identification of a new strain of entomopathogenic nematode, CMD resistant lines through OFTs at Salem and LAMP based diagnosis of S*weet potato feathery mottle virus* (SPFMV) were the other major research highlights. A few notable value addition technologies/products comprise anthocyanin and β-carotene rich cake from sweet potato flour, papad from cassava based composite flour, rice analogue from sweet potato based composite flour, crackers from cassava-sago-wheat flour, weaning food mixes from sweet potato flour, millet flour, pulse flour and cereal flours, ready to use laddu mix from sweet potato and Bengal gram composite flour. Continuous screw press type machine for dewatering of cassava mash for the production of high quality cassava flour, prototype for continuous steaming machine for sago papad/sago wafer production, thermoplastics starch sheets and RS4 type cassava and sweet potato starches were other important achievements.

Technology commercialisation strategies assessment model, modified methodology for assessing the sustainable livelihood analysis of tuber crop farmers using DFID methodology, bioinformatic tools like machine learning method for plant microRNA identification and SNP prediction in plants were developed.

'The Techno-Incubation Centre' is extending hand holding support to young entrepreneurs. Three technologies on production and value addition were commercialized. The Institute is moving forward with the twin flagship programme of the Govt. of India, '*Mera Gaon Mera Gaurav*'' and '*Swachh Bharath Mission*'. The quality research publications numbering to 189, including those in high impact national and international journals have improved the scientific credibility. To ensure the economic, educational and human development as well as the security and social dignity of the Scheduled Castes for achieving equality with the non-Scheduled Caste population in a time bound manner, the Scheduled Caste Sub Plan (SCSP) for the Scheduled Castes was initiated by the Central Government. Under this programme various activities were carried out viz., supply of planting material and transfer of viable technologies to SC farmers. Also for the livelihood improvement of tribal farmers through tuber crops technologies various activities were taken up both at the HQ and RC under the NEH programme and Trial Sub Plan.

For strengthening the R & D activities of the institute, RAC and IMC meetings were also convened. Besides, ICAR-CTCRI participated in 22 exhibitions and organized 87 trainings with the mission to reach the unreached. The Institute also observed World Environment Day, International Yoga Day, World Soil Day, National Science Day and Tuber Crops Day.

I express my deep sense of gratitude to Hon'ble Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his invaluable guidance and support. I sincerely acknowledge the timely guidance and support provided by the most respected Dr. Anand Kumar Singh, DDG (Horticulture Science) and Dr. T. Janakiram, ADG (HS-I).

The support extended by PPV&FRA, Indo-Swiss collaboration, RKVY-Government of Kerala & Government 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. My sincere thanks to all our staff. I also appreciate and congratulate the editorial team for bringing out this publication on time.

24 April 2020

V. Ravi
Director

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EXECUTIVE SUMMARY

The genetic wealth conserved with newer collections, varieties released, processes, protocols, technologies, methods, high value compounds and post-harvest machineries developed under eight Institute projects, two flagship projects as well as 22 external funded projects are given below:

Crop Improvement

- A total of 5651 accessions, comprising 1216 cassava, 1124 sweet potato, 1110 yams, 683 edible aroids, 271 minor tuber crops and 1247 collections from Regional Centre were maintained and conserved in the field gene bank.
- Sixty-one new collections of tuber crops, cassava (1), sweet potato (5), yams (11), edible aroids (18) and minor tuber crops (26) were added to the germplasm.
- In cassava, 14 indigenous accessions which grouped under a single core morphologically when subjected to molecular analysis using SSR markers, two accessions viz., CI-161 and CI-296 were found 100% similar and will be pooled after confirmation using more number of markers.
- One CMD resistant cassava line, 9S-125 (TCa13-7) was recommended for submission of proposal for central release in the states of Kerala, Manipur and Chhattisgarh based on AICRP trials conducted during 2013-2019. It is a hybrid, having 8-9 months duration with high yield (35 t ha^{-1}), dry matter (40.06%), starch (25.9%) and good culinary quality having an organoleptic score of 6.47.
- Many cassava lines having desirable traits were identified. Two cassava lines resistant to CMD with good culinary properties viz., 15S-436 (57.61 t ha^{-1}) and 15S-433 (54.32 t ha^{-1}); Two early bulking high yielding lines viz., D-36 (60.08 t ha^{-1}) and D-48 (55.96 t ha^{-1}) which yielded higher than the control, Vellayani Hraswa (37.86 t ha^{-1}) at six months after planting; Lines with high dry matter content, 16-5 (51.6%), D-48 (46.4%) and 8N-154 (45.6%) and lines having high starch content, 16-5 (42.2%) and 8N-134 (34.2%).
- Nutrient rich CMD resistant lines viz., 16-5 with high crude protein content (5.67%); 17S-84 with high sugar content of 7.9% and 1.69%, on dry weight and fresh weight basis, respectively; D-48 with high Fe content (230 ppm); 7W-10 x MT-4 with high manganese (15.40 ppm); 14-S-17 with high Zn content (36.0 ppm); 17S-84 and 8S-501 with high potassium content 0.63% and 0.72%, respectively were identified in cassava.
- Cassava variety, Sree Suvarna had the lowest cyanogen content in tuber flesh (29.4 ppm) and mature leaves (14.61 ppm).
- Based on Drought Tolerance Index and loading plot studies, the cassava genotypes 8S-501 and CR-43-7 were identified as highly drought tolerant. The high dry matter content of 8S-501 (25.98%) makes it the most preferable genotype over CR-43-7 (16.35%).
- Eleven MQTLs for CMD resistance and 10 MQTLs for CBSD-RN resistance were identified in cassava through Meta-analysis.
- Thirteen early maturing sweet potato accessions, four white flesh colour lines viz., SPH 19, SPH 61, SPH 60 and SPH 65 with high yield ranging from 22 to 25 t ha^{-1}, four orange flesh colour lines viz., SPH 44, SPH 21, SPH 52 and SPH 40 with high yield ranging from 20 to 22 t ha^{-1} and five purple flesh hybrid lines viz., SPH 31,

SPH 30, SPH 29, SPH 15 and SPH 14 with high yield ranging from 20 to 22 t ha^{-1} having crop duration of 75 to 80 days with very less (>5%) weevil infestation were identified at RC, ICAR-CTCRI.

- Three sweet potato genotypes viz., Dhenkanal local-2 (8.30 t ha^{-1}), S-783 (7.78 t ha^{-1}) and 84 x 14 (8.53 t ha^{-1}) were identified as high yielders under drought stress condition.
- Six sweet potato genotypes viz., Kanhangad, Kamala Sundari, Bhu Ja, Bhu Krishna, S-1712 and Gowri were found best for boiling and mashing.
- In greater yam germplasm, the tuber yield ranged from 0.45 kg $plant^{-1}$ (Da-265) to 8.0 kg $plant^{-1}$ (TCR-226). Five accessions viz., Da-5, Da-24, Da-52, Da-67 and TCR-226 were identified as high yielding (>5 kg $plant^{-1}$).
- Greater yam genotypes with high micronutrient content was identified. DaH-66 had the highest Fe (183.40 ppm) content followed by Da-340 (136.20 ppm). Sree Nidhi and GY14-11 had the highest manganese (13.20 ppm) and zinc content (85.80 ppm), respectively.
- In white yam germplasm, the tuber yield ranged from 0.10 kg $plant^{-1}$ (Dr-35) to 10.5 kg $plant^{-1}$ (Dr-44). Five accessions viz., Dr-44, Dr-96, Dr-118, Dr-1403 and Dr-332 were found to be high yielding (>5 kg $plant^{-1}$).
- In lesser yam, the number of tubers/plants ranged from 8 (De-266) to 68 (De-3). The tuber yield per plant ranged from 0.3 kg (CTDe-266) to 5.4 kg (De-64). Higher number of tubers/plant (>50) was recorded in De-3, De-39, De-80B, De-83, De-115, De-178A, De-230 and De-303. High tuber yield (>4.5 kg $plant^{-1}$) was recorded in De-64, De-147, De-303 and De-115.
- In the advanced yield trial of greater yam hybrids, DaH-10-24 (72.83 t ha^{-1}) yielded the highest followed by DaH-10-43 (54.32 t ha^{-1}) and DaH-66 (48.31 t ha^{-1}). The pre-breeding lines of greater yam were screened for resistance to anthracnose and three hybrids viz., DaH-9/196, DaH-22-2-3 and DaH-58FG showed high field tolerance resistance to anthracnose disease. In the evaluation of anthracnose resistant lines for yield, DaH-9/196 yielded the highest (51.84 t ha^{-1}).
- In white yam hybrid clones, DrH-1047 had the highest tuber yield (53.33 t ha^{-1}) followed by DrH-1150 (50.61 t ha^{-1}) and DrH-658 (49.38 t ha^{-1}). Among the new bushy white yam genotypes, two hybrids (Drd-9495 had the highest yield (35.43 t ha^{-1}) followed by Drd-835 (34.56 t ha^{-1}).
- In the on-farm trials of non-trailing white yam, SD-15 produced significantly higher yield (35.88 t ha^{-1}) than Sree Dhanya (23.45 t ha^{-1}). Two SSR primers viz., Dab2C05 and Dab2DO6 were found to be associated with dwarfness in white yam.
- Molecular characterization of 24 taro accessions collected from various locations in India were characterized using ISSR markers. The mean percentage polymorphism of 90.5% showed that high percentage of polymorphism exists in this set. Similarity coefficient ranged from 0.51 to 0.92. Similarity coefficient of 0.51 was seen between C-618 (collection from NEH region) and C-685 (collection from Kerala), while 0.92 was observed between C-294 (collection from Karnataka) and C-464 (collection from Kerala). No duplicates were identified in this set. However, one divergent accession, IC032986 could be identified which can be used in future breeding programmes.
- Taro pollen was successfully cryo-stored to overcome the problem of asynchronization in flowering during hybridization programme. Cryo-stored taro pollen recorded 80.65% staining, 19.41% *in vitro* germination and normal fruit set when used for hand pollination.
- An *in vitro* regeneration protocol was developed in taro. Among the different concentrations and combinations of growth regulators used for regeneration, 4.0 mg^{-l} BAP along with 1.0 mg^{-l} NAA resulted in the highest number of shoots (3.50/explant) in the variety Muktakeshi.
- Fifteen flowering lines viz., Am-7, Am-14, Am-37, Am-150, Am-155, AmH-136, AmH-139, AmW-4, H-64, NL-3, NL/2014-3, TCR-35, TCR-56, TCR-97 and Navasari were identified in elephant foot yam for breeding programmes.
- In attempts on bio-prospecting for novel traits in tuber crops, water extract of tubers and leaves of *I. batatas* var. Bhu Krishna, and tubers of *D. alata* acc. Da-605 and *D. rotundata*, acc. DrD-968 showed anti-bacterial activity.

- In Chinese potato, five accessions were identified for high dry matter content viz., JAS/2015-17 (30.18%), ASAKI/2019-5 (30.40%), TCR-137 (31.24%), ASAKI/2019-1 (31.45%) and TCR-138 (32.08%).

Crop Production

- The sustainable yield index (SYI) of package of practices (PoP: FYM @ 12.5 t ha^{-1} + NPK @ 100:50:100 kg ha^{-1}) (0.846) was established over absolute control (0.484) with mean values of 0.826 and 0.474, respectively, after 14 years of continuous experimentation in cassava.
- On farm validation studies of cassava genotypes for nutrient use efficiency in different parts of Kerala has shown that Sree Pavithra followed by CI-905 and 7-III-E3-5 produced an yield of 53.0, 48.0 and 42.0 t ha^{-1}, respectively and the acceptability was best for Sree Pavithra and CI-905.
- In sweet potato, the optimum levels of foliar application of nutrients viz., Mg, Zn and B was found to be 19.2, 6.3 and 3.0 kg ha^{-1}, respectively whereas, in the case of elephant foot yam, it was 14.4, 4.73 and 1.48 kg ha^{-1}, respectively.
- Sree Reksha (CR-24-4) responded well to organic farming. Of the 12 cassava varieties tested, Sree Reksha produced higher yield (36.57 t ha^{-1}), profit (₹ 179,839 ha^{-1}) and B:C ratio (2.07) followed by Sree Vijaya (₹ 45,161 ha^{-1} profit and 1.27 B:C ratio).
- Evaluation of soil ameliorants viz. polysulphate @ 1.5-2 t ha^{-1} along with either lime or dolomite in AEU 9 regions in Kerala State resulted in higher tuber yield of cassava variety Sree Pavithra (50.29 t ha^{-1}) besides improvements in soil and tuber qualities.
- On farm evaluation of SSNM in Kerala using customized fertilizers in cassava resulted in higher yield over farmer's practice (by 50.57 %) and POP (by 19 %). In greater yam, SSNM performed better than farmers practice with 17.35% higher yield.
- Application of lower and balanced doses of NPK fertilizers along with organic manure (FYM @ 10 t ha^{-1} + $N_{40}P_{15}K_{40}$) sustained soil quality and enhanced the productivity of *Colocasia* in marshy and lowlands of eastern India.
- Short-duration cassava intercropped with leguminous vegetables and oilseed in rice based cropping system during first year indicated that rice-short-duration cassava + cluster bean was productive as compared with French bean and groundnut. A minimum reduction in the yield of intercropped cassava (21.92 t ha^{-1}) was observed as compared to sole cassava (23.50 t ha^{-1}) besides considerable savings of nutrients.
- Dwarf white yam intercropped with soybean at reduced fertility level was the most productive during the second year with a yield of 26.69 t ha^{-1}, followed by green gram (25.22 t ha^{-1}) and black gram (25.16 t ha^{-1}).
- Sole taro produced significantly greater cormel equivalent yield of 21.55 t ha^{-1} as well as gross and net returns of ₹ 3,23,300 and ₹ 2,09,700 per ha respectively, followed by taro + maize (5:1) (18.99 t ha^{-1}).
- Application of Pendimethalin (PE) + Glyphosate (45 DAP) + Glyphosate (90 DAP) resulted in less weed dry biomass production in elephant foot yam and higher corm yield (56.80 t ha^{-1}).
- Among the ten cassava varieties tested, Sree Reksha variety performed well under irrigated and water deficit stress conditions by maintaining higher mean photosynthetic efficiency, stomatal conductance and transpiration.
- In sweet potato (var. Sree Arun), highest tuber yield was achieved with spraying of $CaCl_2$ (0.2%) during 4-12 weeks after planting, at fortnightly intervals under polychamber with humidification (18.00 t ha^{-1}), open field (14.70 t ha^{-1}) and polychamber without humidification (12.26 t ha^{-1}). It also enhanced photosynthetic rate to the maximum (17-28 µmol $m^{-2}s^{-1}$ CO_2) as compared to other chemical treatments viz., salicylic acid (0.2%) and BA (1000 ppm).
- Fumigation treatment of elephant foot yam corms with carbon disulphide @ 80 ml per 100 kg resulted in maximum uniform sprouts, increased growth and significantly higher corm yield.
- In greater yam + maize intercropping system, fertigation of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} at the rate of 40 split dose of fertilizer applied in two days interval produced higher maize yield (3.30 t ha^{-1}) as against soil application/no

application of fertilizers (with a yield of 2.50 and 1.20 t ha^{-1}, respectively).

- Irrigation of taro crop upto 24 weeks @ IW/CPE ratio 1.5 resulted in maximum cormel yield (22.78 t ha^{-1}) which was on par with irrigation for 24 weeks under different irrigation levels of 0.75, 1.0 and 1.25 and also furrow irrigation. Water productivity was found to be 2.6 to 4.5 kg m^{-3} under different irrigation levels.
- Optimal gross irrigation requirement estimates using FAO-CROPWAT model for cassava and sweet potato over the 23 agro-ecological units (AEUs) of Kerala was found to range from 158 to 816 mm and 145 to 469 mm, respectively.
- Mass multiplication of disease-free planting material of popular varieties of tuber crops viz., cassava, elephant foot yam, yams including greater yam, lesser yam and white yam, sweet potato, taro and Chinese potato was performed in 4.10, 1.00, 2.70, 0.20, 0.10 and 0.30 acres respectively, totaling to 8.40 acres in the different blocks of ICAR-CTCRI farm.
- Under RKVY-RAFTAAR project, 1,05,000 sweet potato vine cuttings were supplied to 44 ST contact farmers in five tribal panchayats of Thiruvananthapuram district.
- A total of 364 demonstrations in eight districts of Odisha under RKVY were laid out covering 33.8 ha area under six major tuber crops. In addition, 10 lakhs sweet potato vine cuttings were given for further multiplication and distribution to the farmers. The sweet potato + red gram intercropping system was demonstrated in 1.0 ha covering 12 farmers in Pappadahandi block of Nabarangpur district of Odisha.
- Tuber crops based farming system (0.2 ha model) was demonstrated for a total of 35 tribal households spread over two districts of Odisha.

Crop Protection

- Seven isolates of endosymbiotic bacteria associated with whiteflies, infesting cassava and yam bean, viz., *Bacillus cereus, Lysinibacillus fusiformis, Pseudomonas aeroginosa* from *Aleurodicus dispersus* of cassava; *Acinobacter baumannii* and *Pseudomonas aeroginosa* from *Bemisia tabaci* of cassava and *Acinobacter baumannii* from *B. tabaci* of yam bean were identified through molecular characterization.
- Residue analysis of different cassava plant parts using LC-MS and GC-MS, after the application of two promising insecticides, viz., Imidacloprid and Dimethoate against sucking pests at recommended dose showed that Imidacloprid is safe to use in cassava at recommended dose, whereas, Dimethoate could be used in spraying but not in drenching.
- A new strain of entomopathogenic nematode (EPN) isolated from a soil sample of cassava field in Ucchakada, Thiruvananthapuram was identified as *Steinernema siamkayai* (MH091332).
- Analysis of major trophic group of nematodes in cassava ecosystem from a farmer's field in Pravachambalam, Thiruvananthapram showed herbivores (*Tylenchus* sp., *Helicotylenchus* sp., *Pratylenchus* sp. and *Hemicycliophora* sp.) as the dominant group with 41%, followed by bacterivores (*Rhabditis* sp.) with 21%, predators (*Mylonchus* sp. and *Mylonchulus* sp.) with 19% and fungivores (*Aphelenchus* sp.) with 12% and omnivores (*Dorylaimus* sp.) 7%.
- In elephant foot yam fields of ICAR-CTCRI, root knot nematode, *Meloidogyne incognita* and lesion nematode, *Pratylenchus coffeae* were the predominant species. In soil solarisation experiment, second stage infective juveniles of *M. incognita* were reduced by 50% over control.
- The expression of insect resistance genes, viz., cysteine protease inhibitor, proteinase inhibitor and kunitz trypsin inhibitor related to sweet potato weevil infestation were validated with the gene specific primers in sweet potato varieties and related *Ipomoea* sp.
- Sweet potato plants treated with Imidacloprid at 0.01% showed no weevil infestation at the collar region and tuber of sweet potato except mild (5%) sweet potato vine borer infestation. The next best treatments were *Nanma* and Imidacloprid combinations (1:1 and 1:3) which is followed by *Nanma* 3% alone.
- Flight activity of the sweet potato weevils showed that the activity started from 5.00 pm and reached a peak by 9.00 pm; the maximum numbers were collected from the ground level followed by 1 and 2 m and no weevil was noticed in the trap kept at 3 m above from the ground.

- Based on production of diffusible metabolites and volatiles against the pathogen, induction of chitinase and β-1, 3-glucanase production and effect of volatile organic compounds (VOCs) on plant growth, isolates of *Trichoderma*, viz., T2, T15, T32, T34 (*T. asperellum*) and T40 (*T. erinaceum*) were identified as the most effective bio- agents against *Sclerotium rolfsii*.
- Screening of microbes from rhizosphere of cassava, sweet potato, elephant foot yam and yams against *Sclerotium rolfsii* showed that the majority of the isolates (75%) which showed excellent antifungal property were associated with sweet potato varieties. The isolates were identified as *Bacillus siamensis, B. amyloliquefaciens, B. pumilus, B. halotolerans, B. subtilis* and *B. altitudinis* based on 16s rDNA amplification.
- *Piriformospora indica*, an endophytic mycorrhiza like fungus successfully colonized elephant foot yam root cells and promoted growth characters like shoot length, root length, biomass, girth, leaf area etc of host plant, 12 days after inoculation.
- Tuber treatment along with foliar spraying of *Bacillus cereus*, seven times of which, the first three were done at fortnightly intervals and the rest at monthly intervals, showed highest reduction (41%) in anthracnose intensity in greater yam.
- Spraying *Bacillus licheniformis,* a non pathogenic endophyte, isolated from *Aloe vera* on greater yam var. Orissa Elite resulted in highest yield (24.22 t ha^{-1}) in greater yam by reducing anthracnose disease in greater yam. Dimethyl sulfoxoniumformyl methylide, a secondary metabolite compound identified from ethyl acetate fraction of cell free culture filtrate of *B. licheniformis* by GC-MS had antifungal activity against the anthracnose pathogen *Colletotrichum gloeosporioides.*
- The fungicides, viz., Propiconazole, Tebuconazole, Thiphanate methyl and combination of Tebuconazole and Trifloxystrobin were screened against *Colletotrichum gloeosporioides* causing greater yam anthracnose *in vitro*. Thiphanate methyl showed 100% inhibition even at 2.5 ppm concentration followed by Propiconazole.
- *Yam mild mosaic virus* (YMMV) infection in different ICAR-CTCRI germplasm lines of *Dioscorea alata* was diagnosed using partial coat protein primer YMMV 1S and YMMV 1C. The molecular characterization showed that the sequence got maximum similarity with the isolates from China (NCBI Ac NO. KJ125474.1) and Papua New Guinea (AB022424.1).
- The incidence of dasheen mosaic disease caused by DsMV was 4.3% at ICAR-CTCRI farm and yield reduction was 25.5% during 2019 in elephant foot yam var. Gajendra. Calli were obtained from meristem culture of elephant foot yam (cvs. *Karunakizhangu* and Gajendra) from corm tips and multiple shoots were induced to produce 75 disease free planting material.
- Tobacco (*Nicotiana benthamiana*) was transformed with hairpin gene construct of DsMV coat protein gene for evaluating their level of protection against DsMV infection. Transformants were obtained and are being multiplied.
- Small RNA sequencing was done with healthy and CMD infected cassava plants which gave unique small RNAs in H226 (C-control) as 2,627,476 reads while in H226 (I1 - infected1) and H226 (I2 - infected2), library consisted of 1,116,532 and 977,318 unique reads, respectively. Four novel miRNAs were predicted from these library data. Mes-miR2118 showed eight-fold increase in expression in the infected leaf. Meanwhile, mes-miR395a and mes-miR156h showed significant down regulation in the infected leaf. Altogether, 0.19% of the total reads from both the infected leaf library reads combined were mapped to SLCMV genome.
- Molecular marker analysis of nine cassava mosaic disease resistant genotypes were evaluated in replicated yield trial along with Sree Reksha as check variety using CMD resistance linked markers viz., SSRY28 and SSRY44 which confirmed the resistance in these genotypes.
- In the evaluation trial for development of CMD resistant varieties, Sree Reksha had the highest number of tubers $plant^{-1}$ (20.3) followed by 17S-234 (15.7) which also produced highest yield (67.2 t ha^{-1}) followed by KBH-18 (65.23 t ha^{-1}). 17S-247 had the highest dry matter (40.8%) followed by 17S-48 (38.4%). Excellent cooking quality along with CMD resistance was recorded

in genotypes, 17S-36,17S-40, 17S-48 and 17S-209.

- The pyramiding of different sources of CMD resistance genes was undertaken using cryo-preserved pollen of different sources of resistance through marker assisted breeding. The crosses involving nine elite genotypes viz., Sree Padmanabha, KBH-26/18, CR-43-8, 8W-5, CI-1301, 15S-103, 15S-106, 17S-234 and 17S-143. The percentage seed set ranged from 0 to 75%. The cross CI-1301 x 17S-143 resulted in the highest percentage of fruit set (75%) followed by CI-1301 x 17S-234 when cryo-preserved pollen was used for pollination. In total, 264 seedlings were transplanted to evaluate for CMD resistance.
- Twelve *Cassava mosaic virus* responsive *NAC* genes i.e. *MeNAC22, MeNAC28, MeNAC38, MeNAC59, MeNAC62, MeNAC63, MeNAC79, MeNAC99, MeNAC113, MeNAC116, MeNAC120* and *MeNAC121* were found under regulation of ten miRNAs (*MemiR156, MemiR157, MemiR159, MemiR167, MemiR169, MemiR172, MemiR319, MemiR394, MemiR395* and *MemiR1030*).
- A field trial to standardize the nutrient requirement of six new CMD resistant pre release clones, viz., CR-43-2, 15S-59, 15S-409, 15S-154, CR-43-7, 8S-501-2 along with the released variety CR-24-4 (Sree Reksha) with three nutrient doses viz., 75-50-75, 100-50-100 and 125-50-125 kg N, P_2O_5 and K_2O. The interaction effects of the treatments indicated that 75-50-75 kg N, P_2O_5 and K_2O was sufficient for all the varieties except 8S-501-2 and Sree Reksha. Sree Reksha responded to higher level of nutrients and produced maximum tuber yield (51.1 t ha^{-1}).
- Field experiment on effect of nutrients on cassava mosaic disease showed a sharp decline in symptom expression over a period of time with an overall mean percentage of 92.61, 71.87, 61.17, 39.05 and 19.69, respectively at 20, 45, 60, 120 and 180 DAP, respectively. The order of nutrients in manifesting the CMD symptom was Devirus<P<Zn<B<Ginger mixture<Mg<Si <K<Ca with mean intensity as 50.7, 52.6, 52.1, 53.2, 54.3, 55.5, 55.8, 56.8 and 57.2% compared to 66.0 and 71.4% for absolute control and PoP, respectively.
- *Cassava mosaic virus* free planting materials of cassava varieties viz., Sree Vijaya (5000 stems), Sree Jaya (4000 stems) Sree Pavithra (2000 stems) and Sree Reksha (500 stems) were produced. The rate of re-infection of virus was nil up to two months which gradually increased upto 26% and 28% at 8th month after planting the varieties of Sree Vijaya and Sree Jaya, respectively using virus free stems. Whereas, planting of virus infected materials of the same varieties showed symptoms at first month itself which gradually increased upto 62% and 74% at 8th month after planting.
- The fecundity of whitefly, *Bemisia tabaci* in six different cassava genotypes, viz., CMR-9, CMR-128, CMR-1, CMR-102, H-226 and H-165 showed the highest number of egg laying in susceptible cassava genotypes, H-165 (virulent) and H-226 (non virulent). Whiteflies deposited significantly fewer eggs on virus infected plants as compared to healthy plants. Regarding longevity, the highest was observed in susceptible genotypes H-226 (12.73 and 10.93 days, respectively) followed by H-165 (11.87 and 59.90 days, respectively) in both virulent and non virulent female and male whiteflies. The longest life cycle of both female and male insects of non-virulent and virulent female was in resistant cassava genotype CMR-128 except virulent male, which lived longest in infected but recovering genotype CMR-1.
- The polyclonal antibody was developed against *Dasheen mosaic virus* (DsMV) using recombinant protein (DsMV-IgG) the sensitivity and specificity of the polyclonal antibody (DsMV-IgG) were determined through DAC-ELISA and DIBA and the results showed that optimum titre value of the polyclonal antibody is 1:10000 dilutions and specificity was also good. Dipsticks for DsMV detection were prepared using this antibody and tested using the leaf samples (infected with DsMV as well as healthy samples)
- A one step LAMP assay was developed for detection of *Sweet potato feathery mottle virus* (SPFMV).The detection limit of the LAMP assay was found to be 100 times sensitive than conventional PCR method.

Crop Utilization

- Processes and formulations were standardized for the preparation of papads from cassava based composite flour, anthocyanins enriched cake using the purple fleshed sweet potato flour, β-carotene rich cake with orange fleshed sweet potato and ready-to-use laddu mix from different combinations of sweet potato flour and Bengal gram flour. Ready-to-use weaning food mixes were prepared from sweet potato flour, arrowroot flour, malted ragi flour and rice flour along with other ingredients. Tannia chips, cassava-sago-wheat semolina flour based pop-ups and cassava composite flour based traditional Indian flat bread (Poori) also were prepared. The process conditions and composition of the ingredients were optimized for the production of rice analogue from sweet potato flour.
- The effect of steaming and roasting treatments on the physicochemical and functional properties of cassava based reconstituted dry starch sago was studied. The resistant starch content in cassava and sweet potato tubers subjected to different cooking methods has been determined by *in vitro* technique. Among the different cooking methods, the *in vitro* starch digestibility of the tubers was least for steaming, followed by baking and microwave heating, while it was highest for boiling. Steaming, baking and microwave cooking increases RS content in all tubers than the conventional boiling method
- Microwave assisted solvent free chemical synthesis of cassava starch by esterification with octenyl succinic anhydride, citric acid and sodium orthophosphate has been standardized for producing cassava resistant starch (RS4 type) and the process more effectively brought down the percentage digestibility of starch when compared to those synthesized by conventional method.
- The *in vitro* studies have shown that simulated gastric digestion did not interfere with the overall stability of purple sweet potato anthocyanins, while during the intestinal digestion (pH 7.5), a clear degradation of anthocyanins was observed.
- Particle boards were prepared from cassava stem using acid modified cassava starch as well as cashew nut shell liquid as adhesives, characterized the boards and the process was optimized in each case. Thermoplastic starch sheets were prepared from cassava starch-saw dust composite and cassava starch with sorbitol as plasticizer and the conditions were optimized.
- Molecular docking study has been conducted for the anticancer activity of sweet potato tuber and leaf anthocyanins using three cancer target proteins, 4FA2 (breast cancer), 4FLH (colon cancer) and V226F (cervical cancer). *In silico* analysis have shown that the major anthocyanin in sweet potato, peo-3-O-(6″-caffeoyl-6‴-p-hydroxybenzoylsoph)-5-O-glc exhibited good binding energy with breast cancer and cervical cancer target proteins indicative of their anticancer potential.
- Two sweet potato varieties, Sree Arun and Sree Kanaka were evaluated for their growth performance in pots under different levels of biochar application. Wax coating of cassava was developed and tested for extending the shelf-life of cassava roots.
- A continuous screw type pressing machine was developed for dewatering of cassava mash for the production of high quality cassava flour. A continuous steaming machine was designed and fabricated for sago wafers/sago papad production.
- The techno incubation centres at headquarters and regional centre were actively involved in imparting hands on trainings and providing incubation facilities on preparing various tuber crops based food products to several groups of people. Thirty-five training programmes were organized at the Techno Incubation Centre of ICAR-CTCRI on value added products from tuber crops, which were attended by 940 people including farmers and young entrepreneurs from different districts of the Kerala. The incubation centre was used by 48 entrepreneurs for the production of snack foods.

Extension & Social Sciences

- Ten frontline demonstrations on improved varieties of cassava viz., Sree Jaya, Sree Vijaya, and Sree Pavithra each in an area of 50 cents were established in Kanyakumari district of Tamil Nadu. The yield of improved varieties of cassava was higher by 14.7 % over that of the local varieties. The net income realized

from improved varieties of cassava was ₹2.49 lakhs per ha which was 41.48 % higher over that obtained from local varieties (₹1.76 lakhs). Benefit Cost ratio was higher for improved varieties (2.88) than the local varieties (2.47) of cassava.

- Demonstrations on Fertilizer Best Management Practices (FBMP) in elephant foot yam var. Gajendra established in East Godavari and West Godavari districts of Andhra Pradesh, indicated that there was 8.21 % yield increase in FBMP treatment over farmers' practices. Similar trend was observed in FBMP treatment for gross income (8.21%), net income (8.73 %) and benefit cost ratio (11.11 %) in comparison to farmers' practices. Farmers opined that FBMP treatment resulted in robust vegetative growth of the plants, absence of nutrient deficiencies, higher yield, good shape and size of corm and increase in the weight of corm.
- Sustainable livelihood analysis of tuber crop farmers was conducted among 50 taro growers and 50 paddy growers from two taluks viz., Ranpur and Khandapada in Nayagarh district of Odisha. The study revealed that rural livelihood sustainability index was marginally more for paddy (60) than taro growers (59). The mean values of different capitals of taro and paddy growers are in the decreasing order with respect to physical, natural, social, human and financial capitals. Major sources of livelihood as reported by both the farmers were, agriculture, employment in government/private sector and small business. The vulnerability factors were price fluctuation, climatic variations, and increased labour cost. The trends observed were, high input cost, climate change and labour shortage.
- Variety Finding Tool (VFT): A mobile app for identifying sweet potato varieties from the images of leaves is being developed and the app uses the Convolutional Neural Network (CNN) image classification model using deep learning algorithm of artificial intelligence. Web interface of eCrop was modified and it was made more user friendly. Online version of the sweet potato model SPOTCOMS was developed using PHP/ MySQL for developing real-time agro advisories in response to user demand.
- The machine learning package 'HuntMi' tool was used and predicted 28 pre-miRNAs in cassava. A molecular marker based SNP-ML was applied as an efficient method to predict single nucleotide polymorphism (SNPs) in sweet potato genotypes viz., Bhu Sona and Bhu Swami and a total of 771,963 SNPs was extracted. Using BLAST2GO gene finding module, about 59,653 genes were identified for the predicted SNPs.
- A conceptual framework for assessing the success of commercialization of tuber crops technologies (varieties, mineral nutrient mixture, eco-friendly pesticides, novel foods and industrial products) was developed. The tuber crops entrepreneurial ecosystem was assessed in the dimensions of human capital, culture, finance, policy and markets. Markets were highly rated by scientists and entrepreneurs followed by support institutions and availability of funds for creating new tuber crops based businesses was rated lowest.
- Decadal compound growth rates for cassava, sweet potato and tuber crops based products viz., fresh tubers and its derivatives were estimated. Cassava productivity showed significant growth in all the decades except during 2011-17 and non-significant during 1971-80. Sweet potato productivity showed significant growth in all the decades except during 1971-80. Among different forms, cassava and substitutes (1971-2018); sago starch (1995-2018); sweet potato tubers (1996-2018) and flour meal of sago (1987-2018) individually had significant growth in exports from India both in quantity and value of exports. Cassava starch had significant decline in quantity of exports while significant growth in cassava starch imports both in terms of the quantity (32.5%) and value (43.9%) was observed during 2003-2018 in India. Revealed Symmetric Comparative Advantage (RSCA) was estimated for various forms of tuber crops exports from India. India has comparative 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, export of sweet potato and roots and tubers nes; in the case of BRICS region, export of cassava dried products and in the case of IOR-ARC, export of sweet potato, flour roots and roots and tubers nes.

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

- Two technologies for the production of tuber crops based fried snack products were transferred to two entrepreneurs in Kerala and two processing units started functioning during 2019. One MoU on protein enriched pasta was signed with an entrepreneur in Kerala. A total of ₹ 65.80 lakhs was generated as revenue through technology commercialization, farm sales, sale of technological products, students fee, analytical charges and other professional service functions.
- ICAR-CTCRI is an approved Research Centre for undertaking Ph.D. programme on tuber crops. During the period, the Institute has offered exposure training to B.Sc./B.Tech. students, project work of M.Sc. students, imparted technical guidance for Ph.D. and PDF programme totaling to 287. Three students were awarded Ph.D. and 15 students received M.Sc. degrees.
- A total of 1050 farmers, 2031 students and 210 officials from different parts of the country were imparted training by ICAR-CTCRI.
- ICAR-CTCRI participated in 22 exhibitions and bagged first prizes in the category of 'Best Exhibition Stall Award' in National Horticultural Fair, Krishidham Expo and Kanakolsavam.
- The Institute had a total of 189 publications: Research papers: 56; Symposia: 53; Book chapters: 7; Popular articles: 26; Folders/ leaflets/pamphlets: 19; Course/training manuals: 3; Chapters in course/training manuals: 17; Institute publications: 8.
- Radio talks: 6; TV talks: 2.

INTRODUCTION

ICAR-CTCRI, Headquarters, Thiruvananthapuram (48.19 ha)

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

ICAR-CTCRI (1963-2019)

The ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) was established during the Third Five Year Plan for intensification of research on tuber crops (other than potato). The Institute started functioning in July 1963 with its headquarters (HQ) at Sreekariyam, Thiruvananthapuram. It has one Regional Centre (RC) at Bhubaneswar. The All India Coordinated Research Project on Tuber Crops (AICRP-TC) was started at ICAR-CTCRI in 1968 for testing and popularizing the location specific tuber crop technologies in various parts of India. It has presently 21 centres including ICAR-CTCRI HQ and Regional Centre. The Institute is also one of the centres of the All India Coordinated Research Project on Pre and Post Harvest Technology. The ICAR-CTCRI is conducting basic, strategic and applied research on various edible tropical tuber crops.

Vision

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

Mission

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

Mandate

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

- Basic, strategic and applied research on genetic resource management, crop improvement, sustainable production and utilization of tropical tuber crops.
- Co-ordinate research and validation of technologies through AICRP on Tuber Crops.

General Achievements

The ICAR-CTCRI is a premier research organisation in the world dedicated solely to the research on

tropical tuber crops. The Institute celebrated its golden jubilee during 2013 and 56 years of concerted research have led to the development of several sustainable production, protection and processing technologies for tuber crops, besides release of 67 improved varieties. The target group of most of the technologies being marginal and resource poor farmers, adequate emphasis is also given for on-farm evaluation and popularisation of the technologies. In addition, several technologies were also developed in the recent past enabling resource generation through consultancies and commercialization. ICAR-CTCRI has a wealth of germplasm of tuber crops, totalling 5651. The pioneering role of ICAR-CTCRI in the area of classical breeding of tropical tuber crops attracted international collaborations in the breeding and genetic improvement of these crops. Now, works on molecular based improvement are also being continued. The ICAR-CTCRI has released 67 varieties with various quality traits and preferences. The cassava starch and sago production in the country is mostly dependent on two major industrial varieties of cassava released from ICAR-CTCRI, viz., H-165 and H-226. Two triploid cassava varieties, viz., Sree Athulya and Sree Apoorva are promising and acceptable to farmers as well as industries. The two latest cassava varieties, Sree Reksha and PDP CMR1 are resistant to CMD and are high yielding. The β carotene rich sweet potato varieties, Bhu Sona, Bhu Kanti and Bhu Ja, anthocyanin rich Bhu Krishna and mid season drought tolerant Bhu Swami have gained wide popularity among the rural and tribal people. Three varieties in yams viz., Sree Nidhi, Sree Haritha and Sree Swetha were also recently released. The domestic and international training received in the use of biotechnology in conservation, characterisation and genetic improvement of tuber crops has contributed to a great extent in development of facilities and formulation of programme using this advanced technology for the improvement of tuber crops. The Institute has strong programme on biotechnology, which includes the development of diagnostic tools for viral and fungal diseases and transgenic plants for conferring resistance to cassava mosaic disease and to enhance the starch content and waxy starch.

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

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

The ICAR-CTCRI bagged the Sardar Patel Outstanding Institution Award for the year 2005, Instituted by the ICAR for outstanding contributions made in the improvement of tropical tuber crops and development of low cost production technologies.The Institute also bagged many national and international recognitions in the past that include: J. Chinoy Gold Medal (1970), ICAR Team Research Awards (1985, 1996, 1998, 2014), D.L. Plucknett Award for Tropical Root Crops, Hari Om Ashram Trust Award (1993), Jawaharlal Nehru Award (1975, 1995, 1998, 2000 and 2003), Young Scientist Award Instituted by Deseeya Sasthra Vedi (1996), NRDC cash reward for biodegradable plastics (2000), Pat Coursey Award (2000, 2006), Vasantharao Naik Memorial Gold Medal (2002), Samantha Chandrasekhar Award (2013), International Potash Institute (IPI)-Fertilizer Association of India (FAI) Award (2014), Shri. L.C. Sikka Endowment Award (2014), IZA (International Zinc Association)-FAI Award (2017) and Panjabrao 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 to 15 November

2006. The Institute bagged several prizes in National and International Agricultural Exhibitions. The Best Annual Report Award (1997-98) and (2017-18) among the category of small Institutes was conferred to ICAR-Central Tuber Crops Research Institute for succinctly presenting the research results.

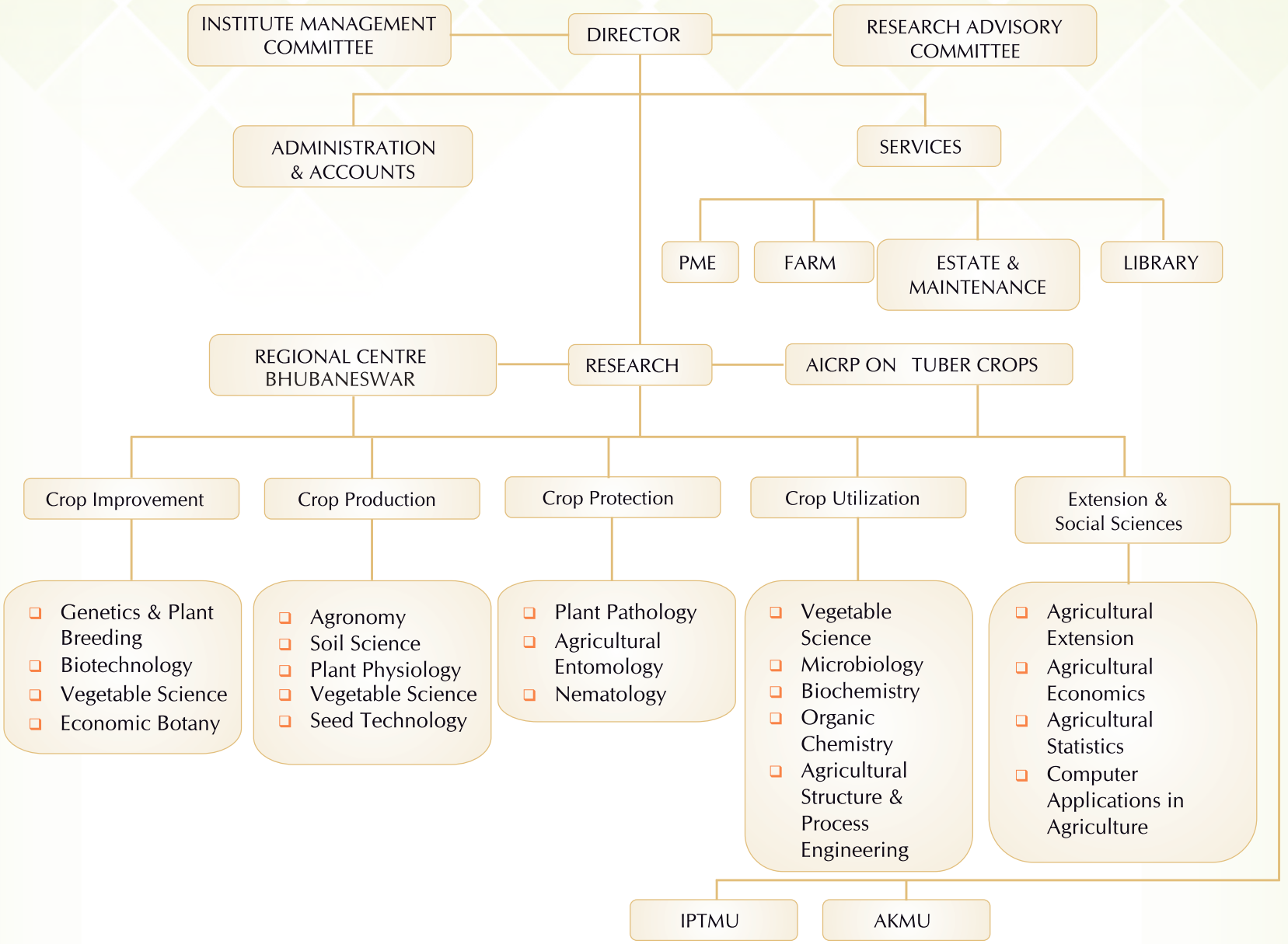
The Institute has conducted more than 20 national and international symposia / seminars / workshops. The Institute is well equipped to conduct basic, strategic and applied research with its state-of-art laboratories. The infrastructural facilities of the Institute have increased during the X and XII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

Extramural support by way of research schemes from both international (like CIAT, CIP, CIRAD, European Union, IFAD, Indo –Swiss etc.) and national agencies like DBT, DIT, DST, DRDO, DSIR, ICAR, JNU, KSCSTE, LSRB, MOEF, DoA, Kerala, KSPB, NABARD, PPIC, RKVY, PPV&FRA, SHM, CDB, UGC, Network and Consortia projects of ICAR, are enriching the research activities. Institute Technology Management Unit (ITMU) of the Institute has been active in carrying out IP activities. Various technologies related to value addition have been commercialised through ITMU under consultancy, licensing and contract research mode. The Institute has established a full fledged Local Area Network connecting various Divisions, Administration, Accounts, and farm sections of ICAR-CTCRI through a strong fiber optic backbone. The entire campus is now wi-fi enabled through access controlled wi-fi devices and controllers. VPN connectivity is established for global access to the servers. The home page can be accessed as ICAR-CTCRI at http://www.ctcri.org, which provides a comprehensive information about the various activities of the Institute and various online facilities like sales counter, discussion forum etc.

Mandate Crops

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

ORGANISATIONAL SETUP



Staff Position

Category	Sanctioned	Filled	Vacant
RMP	1	0	1
Scientists	49	48	1
Technical	47	37	10
Administration	31	26	5
Skilled support staff	38	31	7
Total	**166**	**142**	**24**

Progressive Expenditure 2019-20

Sl. No.	Head of Account		Amount (₹)	
	Capital		**RE 2019-20**	**Expenditure**
1.	Works			
	Office building	- Institute	2.36	2.36
2.	Equipments	- Institute	21.70	21.70
		- NEH	5.00	2.32
3.	Information Technology		1.00	0.99
4.	Library books and Journals		1.31	0.91
5.	Furniture & Fixtures		1.63	1.63
6.	Fani		135.00	135.00
	Total Capital		**168.00**	**164.91**
	Revenue			
1.	Establishment Expenses		1825.00	1809.01
2.	Pension & Other Retirement Benefits		187.00	186.49
3.	Traveling Allowance			
	a. Domestic TA/Transfer TA		39.47	39.43
	b. Foreign TA			
	Total TA		39.47	39.43
4.	Research & Operational Expenses			
	a. Research Expenses			
	i. Institute Expenditure	- Institute	29.81	29.81
		- SCSP	11.54	11.54
	b. Operational Expenses			
	i. Institute Expenditure	- Institute	66.55	66.55
		- SCSP	27.46	27.46
	ii. TSP Expenditure		10.00	10.00
	iii. NEH Expenditure		21.98	21.98
	Total Research & Operational Expenses		167.34	167.34
5.	Administrative Expenses			
	a. Infrastructure	- Institute	69.86	69.86
		- SCSP	21.53	21.53
	b. Communication	- Institute	4.31	4.31
		- SCSP	0.11	0.11
	c. Maintenance			
	i. Equipment, Vehicles & Others	- Institute	12.63	12.63
		- SCSP	1.27	1.27
	ii. Office building	- Institute	0.03	0.03
		- SCSP	0.12	0.12
	iii. Residential building	- Institute	0.51	0.51
		- SCSP	0.02	0.02
	iv. Minor Works	- Institute	4.37	4.37
		- SCSP	6.09	6.09
	d. Others (excluding TA)	- Institute	67.62	67.62
		- SCSP	6.86	6.86
	Total Administrative Expenses		195.33	195.33
6.	Miscellaneous Expenses			
	a. HRD		1.07	1.07
	b. Other Items (Fellowships, Scholarships etc.)		---	---
	c. Publicity & Exhibitions		0.98	0.98
	d. Guest House – Maintenance		1.07	1.07
	e. Other Miscellaneous		1.74	1.74
	Total Miscellaneous Expenses		4.86	4.86
	Total Revenue		**2419.00**	**2402.46**
	Grand Total (Capital + Revenue)		**2587.00**	**2567.37**
	P. Loans		**15.00**	**13.33**

RESEARCH ACHIEVEMENTS

INSTITUTE PROJECTS

CROP IMPROVEMENT

Conservation and Utilization of Germplasm of Tuber Crops for Sustaining Production

Field gene bank

Cassava

In cassava, one landrace from Kozhikode was added to the existing germplasm. The existing 1216 accessions of cassava comprising of indigenous, exotic, landraces and breeding lines were planted in the field during June-July 2019 for maintenance, characterization and preliminary evaluation. Fourteen indigenous accessions which grouped under a single core group under morphological characterization using a combination of IPGRI/ NBPGR/IITA descriptors for 51 traits (31 above ground and 20 below ground tuber traits), were subjected to molecular analysis using ISSR/SSR markers to find out the genetic variability existing within this set and also to identify the duplicates, if any, among these accessions.

The ISSR markers produced a total of 80 scorable bands out of which 67 were polymorphic (83.75) while, SSR markers produced a total of 29 scorable bands of which, 21 were polymorphic (72.41%). The percentage polymorphism based on ISSR primers ranged from 94.11 (UBC 836) to 66.66 (UBC 807 and UBC 811). The similarity coefficient based on ISSR markers ranged from 0.10 (between CI-296 and CI-161) to 0.23, whereas, the similarity coefficient based on SSR markers ranged from 0.00 (again between CI-296 and CI-161) to 0.28. The value of expected heterozygosity ranged from 0.92 (UBC 807) to 0.98 (UBC 808, UBC 817 and UBC 836) and from 0.00 (SSRY 102) to 0.97 (SSRY 45 and SSRY 100). The Polymorphic Information Content values ranged from 0.133 (UBC 808, UBC 836) to 0.180 (UBC 845) and from 0.000 (SSRY 102) to 0.500 (SSRY 9, SSRY 147, SSRY 148 and SSRY 161).

UPGMA cluster analysis and dendrogram using ISSR primers grouped the 14 accessions into three clusters with 2 accessions each and the rest 8 accessions as separate entities. Cluster I comprised of CI-703 and CI-304; Cluster II comprised of CI-688 and CI-615; Cluster III of CI- 296 and CI-161 and the rest 8 accessions viz., CI-1002, CI-766, CI-581, CI-530A, CI-391, CI-373, CI-700 and CI-124 as separate entities.

Dendrogram based on SSR primers also grouped the accessions into three clusters with 2 accessions as separate entities. Cluster-I comprised of 6 accessions viz., CI-766, CI-581, CI-530A, CI-296, CI-161 and CI-373, which was further sub-grouped into cluster IA of CI-766 and CI-581 and IB of CI-296 and CI-161 in which, CI-296 and CI-161 showed 100% similarity. The accessions CI-530A and CI-373 got separated. Cluster-II comprised six accessions viz., CI-1002, CI-703, CI-688, CI-615, CI-391 and CI-304 in which, CI-304 existed as a separate entity. Cluster- III comprised 2 accessions CI-700 and CI-124.

The present study revealed that genetic variability existed amongst the 14 accessions of cassava which had grouped under a single core using morphological characterization. Amongst them two accessions, namely, CI-161 and CI-296 were confirmed to be 100% similar using SSR markers. These will be confirmed using more number of markers and duplicates will be pooled.

Sweet potato

A total of 1124 accessions are being maintained in the field gene bank. Five accessions were added to the existing germplasm (Fig. 1) during this year from Idukki and Thrissur districts, Kerala. Morphological characterization of germplasm of sweet potato based

on IPGRI descriptors (CIP, 1991) (17 vegetative characters) and DUS guidelines for 85 accessions was done. Preliminary evaluation was done for 102 accessions of germplasm for yield and tuber traits in augmented design with six blocks and five controls during May 2019 and harvested in August after 120 days. During the season, the vine yield, tuber yield and tuber characters were recorded. The vine yield was very high whereas the tuber yield was very poor.

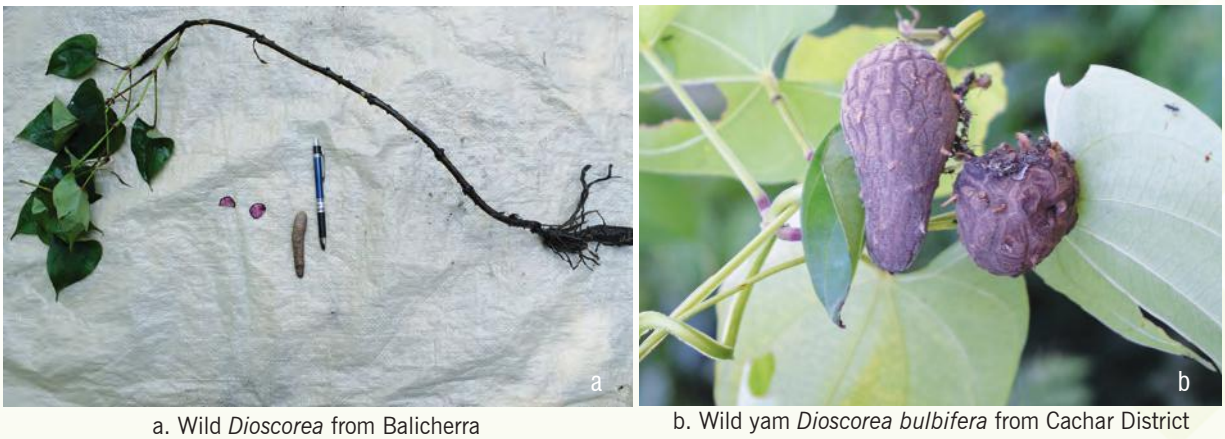
Fig. 1. New accessions of sweet potato collected

In a second set of 42 accessions, morphological characterization was done with CIP (CIP, 1991) (17 vegetative characters) and DUS guidelines. Here, molecular characterisation was also attempted using 11 ISSR markers and is in progress. Based on morphological descriptors, a dendrogram was constructed using MVSP3.1 package which divided the accessions into two major groups based on Euclidean similarity index, one cluster comprising of 11 accessions and the remaining accessions grouped together in the second cluster. In the principal component analysis, the first principal component accounted for 42% of the variation and the characters like predominant vine colour, secondary vine colour, leaf lobe shape and number were the highly significant characters. Petiole pigmentation was the highly loaded character in the second principal component which accounted for 15% of the variation. The first four principal components accounted for 78% of the variation and secondary vine colour showed high values in all the principal components.

Yams

A total of 1110 accessions of yams comprising greater yam (591), white yam (158), lesser yam (220), potato yam (6) and wild yams (135) are being maintained in the field gene bank. Five accessions of greater yam, two accessions of lesser yam; three wild yams and one wild *Dioscorea bulbifera* from Mohanpur, Assam were added to the field gene bank (Fig. 2). The lesser yam accession collected from Kottur forest of Thiruvananthapuram district was unique with very long tubers (16.5 cm). The greater yam germplasm was characterized based on 38 descriptors and database was updated.

The germplasm was planted during April 2019 at ICAR-CTCRI, Sreekariyam as rainfed crop and harvested after nine months during January 2020. Among 591 greater yam accessions, the tuber yield ranged from 0.45 kg plant^{-1} (Da-265) to 8.0 kg plant^{-1} (TCR-226). Five accessions viz., Da-5, Da-24, Da-52, Da-67 and TCR-226 were found to be high yielding



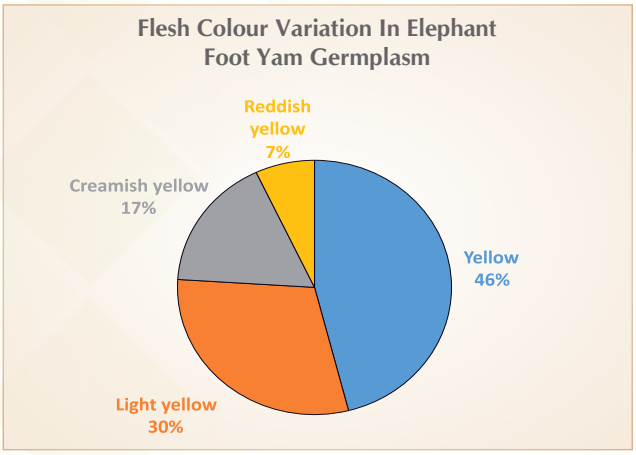
a. Wild *Dioscorea* from Balicherra

b. Wild yam *Dioscorea bulbifera* from Cachar District

Fig. 2. Wild yams collected from Assam

(>5 kg plant^{-1}) during 2019-2020. The genotypes exhibited wide variation in the micronutrient content of the tubers. DaH-66 had the highest Fe (183.40 ppm) content followed by Da-340 (136.20 ppm). Sree Nidhi and GY14-11 recorded the highest manganese (13.20 ppm) and zinc content (85.80 ppm), respectively. Molecular characterization of 40 accessions of greater yam was carried out using 15 ISSR and 10 SSR primers.

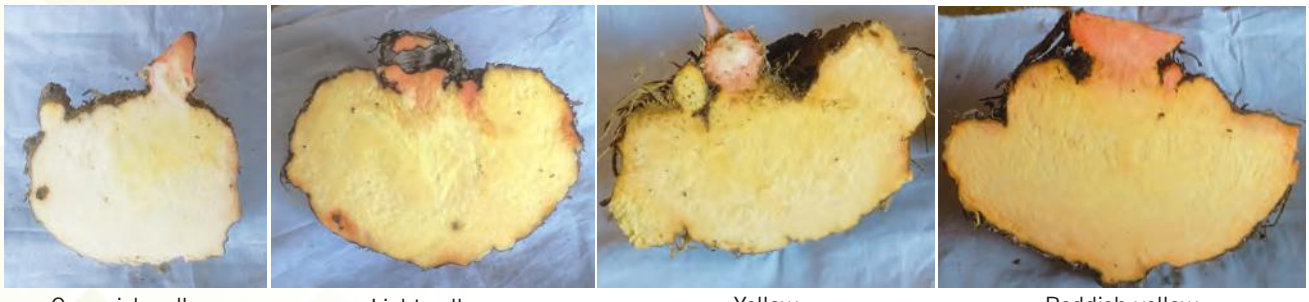
Among 158 white yam accessions, the tuber yield ranged from 0.10 kg plant^{-1} (Dr-35) to 10.5 kg plant^{-1} (Dr-44). Five accessions viz., Dr-44, Dr-96, Dr-118, Dr-1403 and Dr-332 were found to be high yielding (>5 kg plant^{-1}). Among 220 accessions of lesser yam, the number of tubers/plant ranged from 8 (De-266) to 68 (De-3). The tuber yield per plant ranged from 0.3 kg (CTDe-266) to 5.4 kg (De-64). Higher number of tubers/plant (>50) was recorDed in accessions viz., De-3, De-39, De-80B, De-83, De-115, De-178A, De-230 and De-303. High tuber yield (>4.5 kg plant^{-1}) was recorDed in accessions viz., De-64, De-147, De-303 and De-115.



Edible aroids

The edible aroid germplasm was augmented with a total of 17 edible aroids comprising six taro, four tannia, one elephant foot yam and six *karunaikizhangu* collected from Tamil Nadu (Tirunelveli, Thenkasi, Sengottai and Madurai), Kerala (Thrissur) and Karnataka (Joida). 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 of ICAR-CTCRI, HQ. DNA from 24 taro and 30 tannia accessions were isolated and stored in the DNA bank. Fifteen flowering lines (viz., Am-7, Am-14, Am-37, Am-150, Am-155, AmH-136, AmH-139, AmW-4, H-64, NL-3, NL/2014-3, TCR-35, TCR-56, TCR-97 and Navasari) were identified in elephant foot yam germplasm which can be used for future breeding programmes.

Under morphological characterization in elephant foot yam, flesh colour of 92 accessions were recorded along with photographs. The flesh colour ranged from creamish yellow (17%) to light yellow (30%) through yellow (46%) to reddish yellow(7%) (Fig. 3).



Creamish yellow | Light yellow | Yellow | Reddish yellow

Fig. 3. Flesh colour variation in elephant foot yam germplasm

Morphological characterization of 30 tannia accessions for 19 underground tuber traits comprising 14 qualitative and five quantitative traits were done and photo database created. Variation was observed in tuber shape (Fig. 4), size, tuber exterior colour and flesh colour in this morphologically less distinct crop. Traits like, time of harvest and position of cormel apex were similar for all the accessions tested.

Fig. 4. Tuber shape variation exhibited in tannia germplasm
a. Elliptical rough corm b. Elliptical scaly cormel
c. Ovate rough corm d. Cylindrical scaly cormel

Molecular characterization of 24 taro accessions collected from various locations in India were characterized using ISSR markers. The concentration of DNA samples ranged from 394.4 ng/µl (C-618) to 4347.4 ng/µl (C-218) and the purity from 1.82 (SSK/2017-3) to 2.26 (IC032986). The mean percentage polymorphism of 90.5% showed that high percentage of polymorphism exists in this set. Similarity coefficient ranged from 0.51 between C-618, an accession from the NEH region and C-685, an accession from Kerala to 0.92 between C-294, an accession from Karnataka and C-464, an accession from Kerala. No duplicates were identified in this set. However, one divergent accession (IC032986) could be identified which can be used in future breeding programmes.

Minor tuber crops

During April to September 2019, 34 new minor tuber crops accessions comprising edible canna (8), tikhur (2), starchy *Costus* spp. (16) and other starchy curcumas (8) were collected and conserved in the field gene bank, in addition to the existing 209 accessions. Apart from this, a collaborative germplasm exploration was conducted in Cachar district of Assam along with ICAR-NBPGR during the October 2019 and 16 accessions of minor tuber crops were collected. The collection included edible canna (14) from different locations, wild *Homalomena aromatica* (2) from Mohanpur, Assam (Fig. 5). All these accessions were planted during the month of October 2019 in the field gene bank. IC Numbers were assigned to two accessions of *Homalomena aromatica*, a minor tuber crop with multipurpose utilities which was conserved in the field gene bank of ICAR-CTCRI. In Chinese potato, ten new accessions collected from Kozhikode (5), Ernakulam (2) Malappuram (1), Wayanad (1) and Thiruvananthapuram (1) districts of Kerala were added to the existing germplasm. At present, a grand total of 271 minor tuber crops germplasm accessions are maintained at ICAR-CTCRI field gene bank.

a. Edible Canna collection b. *Homalomena aromatica* from Balichera c. Wild *Homalomena aromatica* from Chilchar

Fig. 5. Minor tuber crops collected from Assam

A preliminary evaluation was done in Chinese potato using top shoot cuttings of twenty-four accessions planted during July 2019 in three replications under rainfed conditions. The accessions were characterized and the crop was harvested in January 2020. Dry matter content of the tubers indicated that 16 accessions had values above the check variety Sree Dhara (27.48%). The percentage ranged from 21.17% in TCR-138 to 32.08% in TCR-110 (Fig. 6). Five accessions with dry matter content above 30% were JAS/2015-17 (30.18%), ASAKI/2019-5 (30.40%), TCR-137 (31.24%), ASAKI/2019-1 (31.45%) and TCR-138 (32.08%).

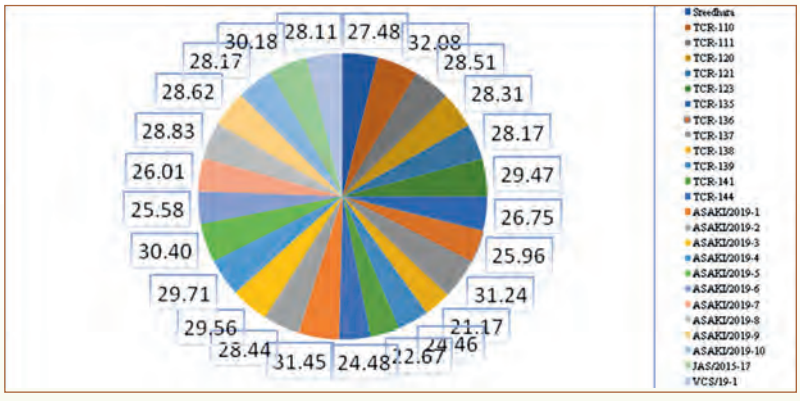


Fig. 6. Dry matter content (%) of 24 accessions of Chinese potato

Germplasm at Regional Centre

A total of 1247 accessions of tropical tuber crops comprising cassava, sweet potato, taro, elephant foot yam, yam, yam bean and minor tuber crops are maintained at the Regional Centre. One taro line was collected from Keonjhar district of Odisha. Fifty accessions of sweet potato germplasm were planted at Regional Centre research farm during September, 2019 for characterization of yield and flesh colour of the tubers. Out of these, 17 had white colour, 12 had cream and yellow colour each, 3 had cream with orange spots, 3 had yellow with orange spots and one line was found light orange in colour. Seven lines were recorded as good yielders producing around 500-700 g plant^{-1} (accession 7, 17, 19, 27, 31, 46 and 48). Fourteen high yielding lines of sweet potato selected during 2018 were planted at Regional Centre research farm during September, 2019 for re-evaluation of yield. Irrigation is given at an interval of 7-10 days and tubers of sweet potato harvested during December, 2019. Out of these 14 accessions, accessions 47 and 52 (1 kg plant^{-1}) were the high yielders followed by accession 73 (900 g plant^{-1}) and accession 56 (700 g plant^{-1}) (Fig. 7). Two accessions, accession 80 and 88 had good shape and may be used for fried chips making. Ten high yielding lines of yam bean selected during 2018 were sown at Regional Centre research farm during September, 2019 for re-evaluation of yield. Irrigation is given at an interval of 7-10 days and tubers of yam bean harvested during December 2019. Out of these, accession 39 (1.25 kg plant^{-1}) was the highest yielder followed by accession 9 (1.2 kg plant^{-1}) accession 10 (1 kg plant^{-1}) and accessions 54 and 57 (900 g plant^{-1}) (Fig. 8). Fifty taro accessions were planted during June 2019 and leaves were harvested during August 2019 for testing their acridity level in the leaf and petiole. Out of these, 35 showed high acridity levels, 10 medium and 5 showed low acridity.

Fig. 7. Few promising sweet potato lines identified

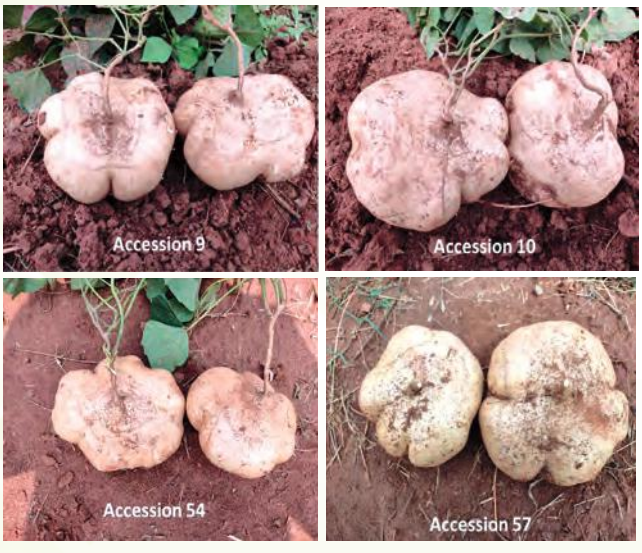


Fig. 8. Few promising yam bean lines identified

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 subcultured and maintained in the *in vitro* gene bank of Division of Crop Improvement, ICAR-CTCRI. *In vitro* cultures of released, pre-released and exotic lines including sweet potato - 58 accessions, yams - 62 accessions (includes accessions received from ICAR-NBPGR), cassava - 13 accessions, taro - 5 accessions and minor tuber crops - 5 accessions were maintained at the *in vitro* gene bank facility at the headquarters.

At the *in vitro* gene bank facility of the Regional Centre, 600 cultures of released, pre released and exotic lines including 10 varieties in cassava, 11 varieties in sweet potato, five varieties in taro, four varieties in yam, two varieties in elephant foot yam and four varieties of Chinese potato were maintained *in vitro* (Fig. 9).

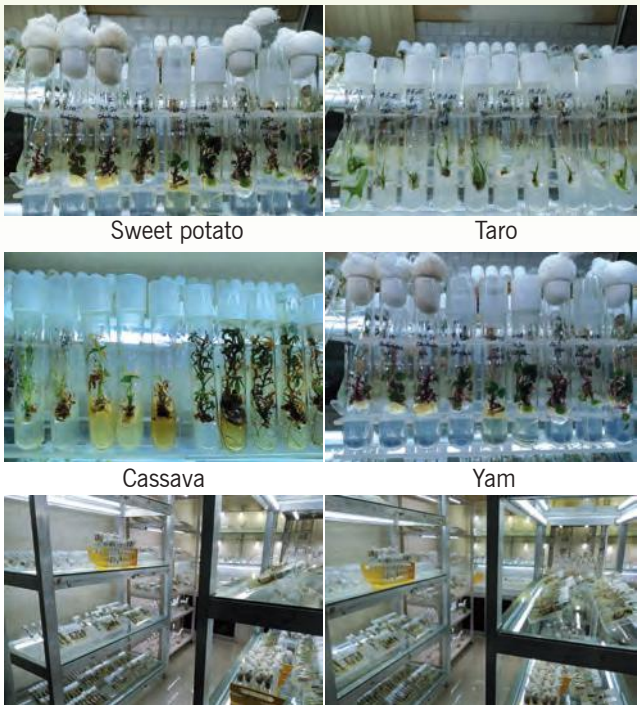


Fig. 9. *In vitro* gene bank of tuber crops at Regional Centre, ICAR-CTCRI

Cryopreservation of taro pollen

Male portion with staminate flowers of taro variety Muktakeshi were collected one day before anther dehiscence and kept overnight under laboratory conditions. Next day morning, pollen grains were separated from the male flowers with gentle tapping and immediately stored in liquid nitrogen (-196°C) after placing them in cryo-vials. Viability of the fresh pollen as well as stored pollen was tested by acetocarmine staining and *in vitro* pollen germination tests. Freshly collected taro pollen had 89.76% staining and 51.50% germination under laboratory conditions. Taro pollen cryo–stored for a week, on the other hand, showed 80.65% staining using acetocarmine staining and 19.41% *in vitro* germination under *in vitro* pollen germination tests (Fig. 10). Hand pollination in the field was done on the female flowers of same parent (Muktakeshi) using fresh pollen as well as stored pollen (Fig. 11) and normal fruit set was observed in both the treatments (Fig. 12).

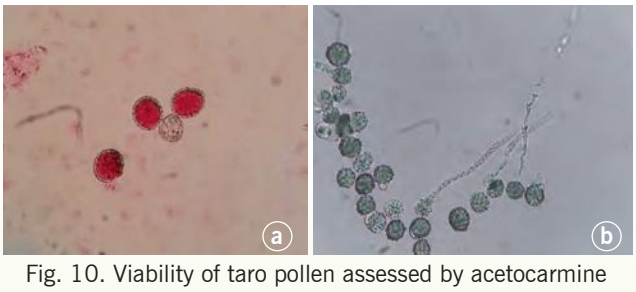


Fig. 10. Viability of taro pollen assessed by acetocarmine test (a) and *in vitro* germination test (b)

Fig.11. Pollination of female parent, (a) emasculation, (b) pollinated female flower

Fig.12. Successful hybridization with cryopreserved taro pollen (a) immature fruit, (b) ripped fruit

Gene bioprospecting for novel traits in tuber crops

Water extract was prepared from sweet potato variety, Bhu Krishna - tubers and leaves; tubers of *Dioscorea alata* accessions, viz. Da-605 and Da-86; *D. rotundata* accession, DrD-968 and taro, RNCA-1. The anti-bacterial screening was done using extracts prepared from these tuber crops. Water extract of Bhu Krishna tubers and leaves; tuber extracts of *D. alata*, Da-605 and *D. rotundata*, DrD-968 showed anti-bacterial activity against *S. aureus* strain of bacteria through disc diffusion assay. The effect was most prominent in water extracts of sweet potato variety, Bhu Krishna tuber and *D. rotundata*, DrD-968 tuber which was effective even at a dose of 100 µg.

Genetic Improvement of Tuber Crops through Conventional Breeding and Molecular Approaches

Cassava

Development of cassava mosaic disease (CMD) resistant varieties with different traits of interest

In the trial on development of early bulking lines with CMD resistance, ten early bulking lines were tested in replicated yield trial with Vellayani Hraswa

as control. The experiment was planted in June 2019 at ICAR-CTCRI, Sreekariyam farm and harvested during November 2019. The highest tuber yield was recorded by D-36 (60.08 t ha^{-1}) followed by D-48 (55.96 t ha^{-1}) as compared to control, Vellayani Hraswa (37.86 t ha^{-1}) at six months after planting. In the replicated yield trial of CMD resistant varieties for culinary purpose, 15S-436 yielded the highest (57.61 t ha^{-1}), followed by 15S-433 (54.32 t ha^{-1}).

Fifty CMD resistant breeding lines were evaluated for dry matter content. The experiment was planted in June 2019 at ICAR-CTCRI, Sreekariyam farm as rainfed crop and harvested during February 2020. The line, 16-5 had the highest dry matter (51.6%) followed by D-48 (46.4%) and 8N-154 (45.6%). The highest starch content was recorded in the line 16-5 (42.2%) followed by 8N-134 (34.2%). 17S-84 had the highest sugar content of 7.9% and 1.69%, on dry weight and fresh weight basis, respectively. Line 16-5 also had the highest crude protein content (5.67%) in the tubers. The micronutrient content of tubers of eighteen cassava breeding lines were analysed. The highest Fe content (230 ppm) was recorded in D-48 (Fig. 13). The genotype, 7W-10 x MT-4 had the highest manganese (15.40 ppm) while, 14-S-17 had the highest Zn content (36.0 ppm) in the tubers. Highest potassium content in tubers (0.72%) was recorded by 17S-84 followed by 8S-501 (0.63%).

Fig. 13. Tuber of promising pre-release variety D-48

Ten cassava genotypes were evaluated for cyanogen content of which Sree Suvarna recorded the lowest cyanogen content in tuber flesh (29.4 ppm) and mature leaves (14.61 ppm). The experiment was planted in June 2019 at ICAR-CTCRI, Sreekariyam farm as rainfed crop and harvested during February 2020. Two hundred and fifty five hybrid seedlings identified through molecular marker assisted selection were transplanted and are being screened for resistance to cassava mosaic disease caused by ICMV and SLCMV.

One Cassava line, 9S-125 (TCa13-7) was recommended for submission of proposal for central release in the states of Kerala, Manipur and Chhattisgarh based on AICRP trials conducted during 2013-2019. It had high yield (35 t ha^{-1}), dry matter (40.06%), starch (25.9%) and good culinary quality having an organoleptic score of 6.47. It is tolerant to cassava mosaic disease.

Identification of molecular markers linked to postharvest physiological deterioration in cassava

In the activity on identification of molecular markers associated with Postharvest Physiological Deterioration (PPD) in cassava, the hybrid seeds collected from 2018-19 crosses between parents (Sree Padmanabha, Co-1 and 9S 127) contrasting for PPD tolerance were raised in pots after germination. The germination percentage of the hybrid seeds from the crosses was found to be 82.28%. The average seedling length and seed vigor index (SVI-I) was 19.97 cm and 1640.19, respectively. The seedlings were then transplanted to the main field during May 2019 and planted along with the parents for evaluation. Hybridization between the parents was continued during October-November 2019 to increase the population size and hybrid seeds were collected. The parental polymorphism study to identify polymorphic markers was carried out using 40 new microsatellite markers in addition to the 67 markers already screened and is being continued. The genotyping of the parents and progenies using polymorphic markers is in progress.

Selection of drought tolerant clones in cassava

Twenty cassava genotypes were evaluated for drought tolerance for two years 2017-18 and 2018-19 consecutively under field conditions. For control condition, the stakes were planted in May with the onset of monsoons and harvesting was done in February. This crop was under irrigation continuously six months as it received the significant amount of SW and NE monsoon rainfall which was sufficient to attain full growth of cassava. For water deficit stress treatment, the stakes were prepared and planted in the soil in the last week of August. Irrigation was

provided up to 3 months after planting. By the end of November, after completion of the NE monsoon rainfall, irrigation was withdrawn, the dry period begun and continued up to the harvesting of the crop in May.Various symptoms exhibited by cassava plants under drought stress are presented in Fig. 14. There were significant differences between control and water deficit-stress conditions in the case of sprouting percentage, Leaf Area Index (LAI), tuber yield, harvest index and dry matter. The Leaf Area Index (LAI) at 1 month after stress induction ranged from 0.53 to 2.23 with a mean value of 1.17 ± 0.10 under water deficit stress conditions. When compared with the control conditions, a significant reduction of 48.5% was noticed under water deficit stress conditions in LAI. The overall mean tuber yield was 1.48 ± 0.18 kg plant^{-1} under control conditions and it was reduced to 0.55 ± 0.07 kg plant^{-1} under water deficit stress conditions, suggesting a great reduction of 62.8%. The genotypes 8S-501 (1.02 kg plant^{-1}, 0.54) and CR-43-7 (1.02 kg plant^{-1}, 0.43) had high tuber yield and harvesting index under water deficit stress conditions, respectively. A percent reduction of 38.7% was found in the dry matter content under water deficit stress conditions (18.78 ± 0.98%) akin to control conditions (30.64 ± 0.88%).

Fig. 14. Various symptoms exhibited by cassava plants under drought stress: A. Dead cassava stake B. Sparse sprouting in the field C. Shortening of internodes D. Leaf rolling E. Leaf abscission

Factor analysis revealed that sprouting at 3 weeks after planting (0.570), Yield Per Plant (YPP) (0.963), gross mean productivity (0.907), Drought Tolerance Index (DTI) (0.868), harvesting index (0.780) and dry matter (0.544) were major contributors of variation (33.6%). Sprouting percentage and DTI were positively correlated with YPP suggesting that selection should be based on these parameters. DTI and loading plot of the genotypes clearly indicated that the clones 8S-501 and CR-43-7 were highly drought tolerant. They outperformed the check cultivar H-226 in terms of yield. The high dry matter content of 8S-501 (25.98%) makes it the most preferable genotype than CR-43-7 (16.35%).

A set of 8 EST-microsatellite markers were used to screen the 20 accessions of cassava. The AMOVA (Analysis of Molecular Variation) revealed that the variation among populations, individuals and within individuals was 4, 56 and 40%, respectively. Mantel test was done to study the correlation between morphological and molecular Genetic Distances (GD). The results revealed that there was no significant correlation between morphological and molecular GD as evidenced by the low R^2 value of 0.0752. It means only 7.5% variation was explained by them and the remaining 92.5% was unexplained attributing the factors that were not included in the study.

Sweet potato

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

Fifteen hybrid lines (white-5, orange-4 and purple-6) developed during 2014-15 were planted in September, 2019. Eleven hybrid lines (white-5, orange-5 and purple-1) developed during 2015-16 were planted in September 2019. Seven hybrid lines (white-4, orange-2 and purple-1) developed during 2016-17 were planted in September 2019. Total 33 hybrid lines (14 white, 11 orange and 8 purple) developed during 2014-2017 were planted at Regional Centre farm in the month of September 2019 for evaluation of yield, maturity, weevil resistance and other qualitative traits and harvested during December 2019. Irrigation was given at an interval of 7-10 days. Out of 33 hybrid lines, four best white flesh colour lines were selected based on yield and maturity (SPH 65, SPH 19, SPH 61 and SPH 60; yield ranged from 22-25 t ha^{-1}) (Fig. 15). Early maturing lines had no weevil infestation. Four orange flesh hybrid lines were selected based on colour, yield and maturity (SPH 44, SPH 21, SPH 52 and SPH 40; yield ranged from 20-22 t ha^{-1}) (Fig. 16). Biochemical estimation of β carotene is in progress.

Fig. 15. White flesh sweet potato hybrid SPH 65

Fig. 16. Orange flesh sweet potato hybrid SPH 44

Five purple flesh hybrid lines selected based on colour and yield (SPH 31, SPH 30, SPH 29, SPH 15 and SPH 14: yield ranged from 22-24 t ha^{-1}) (Fig. 17). All the hybrids showed very less (<5%) weevil infestation. SPH 29 had no weevil infestation whereas, SPH 30 had good shape and may be used for fried chips making. It also showed deep purple colour and could be used for colour extraction. SPH 14, 15 and 31 had less amount of latex which are good for table purpose. Biochemical estimation of anthocyanin is in progress.

Fig. 17. Promising purple flesh sweet potato hybrids

Breeding for drought tolerance in sweet potato

A total of 14 sweet potato genotypes were selected based on field and *in vitro* screening for drought during 2018-19. The selected 14 germplasms were further screened in field and *in vitro* conditions during 2019-20 at the Regional Centre of ICAR-CTCRI, Bhubaneswar for drought tolerance along with control (irrigation). The genotypes were planted during September 2019 and harvested during January 2020. During drought condition, among the 14 genotypes the high drought resistance index coupled with high yield under drought stress condition recorded in the genotype Dhenkanal local-2 (1.85 and 8.3t ha^{-1}) followed by S-783 (1.5 and 7.78 t ha^{-1}) and 84 x 14 (1.45 and 8.53 t ha^{-1}). The selected 14 lines were also screened *in vitro* for drought tolerance. The explants were taken and inoculated in culture medium containing different concentration of PEG. At 10g l^{-1} of PEG treatment the genotype Dhenkanal local-2 has recorded maximum shoot weight (56 g), shoot length (8.5 cm) and root length (23.5 cm) followed 84x1 for shoot weight (48 g) and shoot length (4.5 cm). At 15 g l^{-1} PEG treatment the genotype SB21/57 had maximum root length (22.5 cm) and shoot weight (39.5 g) followed by Dhenkanal Local-2 for number of leaves (13) and shoot length (4 cm). There is no definite relation between field performance and *in vitro* tolerance.

Developing sweet potato hybrid clones for processing

Twenty-five sweet potato genotypes including released varieties and germplasm accessions were evaluated for processing traits. The tuber physical traits affecting sweet potato processing was also observed. There was significant variation observed for tuber flesh colour ranging from cream to dark yellow, light to dark orange and strong pigmentation of anthocyanin except in S-27 which had white flesh colour. The length, width and individual tuber weight ranged from 9.23-15.97 cm, 7.57–19 cm and 0.02-0.39 kg, respectively. Tuber cortex thickness influencing the chips making process ranged from very thin to thick among the studied genotypes. The major kinds of surface defects observed on tubers according to IPGRI descriptors were presence of alligator-like skin (Kamala Sundari, 526/7, S-27 and Bhu Sona), veins (Sree Arun) and shallow horizontal constrictions (Bhu Ja and Sree Varsha). Few tuber cracking was observed for four genotypes namely, Sree Arun, Sree Kanaka, Sree Vardhini and Sree Varsha. Although the tuber shape variability ranged from uniform to moderate, most of the genotypes exhibited uniformity in tuber shape which is critical for processing into chips using various equipments and machines. The boiled tuber consistency, presence of undesirable colour and texture was also studied to identify the genotypes best suited for boiling and mashing as these are the most commonly used methods of processing in sweet potato. The consistency of boiled tuber exhibited wide variability from watery to hard with intermediates and most of the genotypes were found to possess desirable consistency on boiling. The presence of undesirable slightly green or grey colour of boiled tubers was found in Sree Rethna,

Sree Arun, Sree Vardhini, 526/7, SD-11, SP-18-SP, and S-27 whereas, grey colour was seen on tubers of Kishan and Sree Varsha. The tubers of JAS-12-pink exhibited purple spots on boiling. Based on boiled tuber traits, genotypes such as Kanchangad, Kamala Sundari, Bhu Ja, Bhu Krishna, S-1712 and Gowri were found to be highly desirable. The biochemical analysis for the estimation of different processing traits such as total starch, sugar, crude fibre, flour content of the studied genotypes is in progress.

Yams

In yams, the evaluation trials were planted during April 2019 at ICAR-CTCRI, Sreekariyam as rainfed crop and harvested after nine months during January 2020. In the advanced yield trial of greater yam lines conducted at ICAR-CTCRI during 2019-2020, DaH-10-24 (72.83 t ha^{-1}) yielded the highest followed by DaH-10-43 (54.32 t ha^{-1}) and DaH-66 (48.31 t ha^{-1}). The pre-breeding lines of greater yam were screened for resistance to anthracnose, and three hybrids viz., DaH-9/196, DaH-22-2-3 and DaH-58FG had high field tolerance/resistance to anthracnose disease. In the evaluation of anthracnose resistant lines for yield, DaH-9/196 yielded the highest (51.84 t ha^{-1}).

Among the white yam hybrid clones evaluated, DrH-1047 had the highest tuber yield (53.33 t ha^{-1}) followed by DrH-1150 (50.61 t ha^{-1}) and DrH-658 (49.38 t ha^{-1}). Among the new bushy white yam genotypes, Drd-9495 had the highest yield (35.43 t ha^{-1}) followed by Drd-835 (34.56 t ha^{-1}). In the on-farm trials of non-trailing white yam lines conducted at Thiruvananthapuram and Pathanamthitta districts, SD-15 (Fig. 18) produced significantly higher yield (35.88 t ha^{-1}) than Sree Dhanya (23.45 t ha^{-1}). The association of molecular markers that are linked with dwarfness in *Dioscorea rotundata* Poir was studied using ISSR and SSR markers. The results identified two SSR primers viz., Dab2C05 and Dab2DO6 that recorded association with dwarfness in white yam.

Fig. 18. Tubers of white yam pre-release variety, SD-15

Edible Aroids

Taro

For introgression of TLB resistance in taro, OP seedlings produced during the previous years were raised and morphological traits recorded. Many of the taro tubers showed the presence of stolons. These were further planted to raise the next generation. The previously identified taro genotypes showing resistance to TLB viz., Colocasia Nicobar Chukchukia village, C-717 and IC310104 were multiplied for initiating a trial along with other high yielding lines showing good tuber shape.

In the trial on taro planted during February 2019 and harvested in October 2019, grown as a rainfed crop, with four accessions and Sree Rashmi as the check, the average cormel yield ranged from 2.31 (IC526654) to 4.36 t ha^{-1} (IC310104) and the total yield from 3.78 (IC526654) to 5.90 t ha^{-1} (IC310104). Check Sree Rashmi yielded 4.18 and 5.44 t ha^{-1} cormel and total yield, respectively.

Breeding for quality improvement in taro

Corms of all the crosses of taro comprising, 18 × TCR-369, Nycle × 224, 12 × TCR-369, 12 × TCR-429, 12 × IC022067, TCR-369 × TCR-429 and TCR-813 × IC419746 were planted in last week of July 2018 and harvested in January 2019. Field trials and nutritional analysis of taro samples were done at ICAR-CTCRI, Regional Centre. During the experiment dry spell experienced from October and irrigation were given at 7-8 days interval. Corms were harvested, cleaned and chopped for drying and fine dry powder prepared for evaluation of their nutritional attributes such as antioxidant activity (DPPH and CUPRAC), total phenolics, sugar, starch, crude protein, phosphorous, potassium, iron, copper, zinc and manganese in corms. Free radical scavenging ability against DPPH assay ranged from 42.27 to 73.08% dry weight; CUPRAC assay from 18.13 to 31.29 µ mol trolox/g dry weight; total phenolics content from 3.15 to 7.26 mg gallic acid/g dry weight; sugar from 1.85 to 2.64%; starch content from 18.51 to 61.22%; crude protein content from 4.13 to 18.89 g 100 g^{-1} dry weight; phosphorous from 215.31 to 458.17 mg 100 g^{-1} dry weight; potassium content from 843.07 to 1208.76 mg 100 g^{-1} dry weight; iron content from 6.22 to 17.13 mg 100 g^{-1} dry weight; copper content from 0.89 to 1.51 mg 100 g^{-1} dry weight; zinc content from 7.91 to 15.35 mg 100 g^{-1} dry weight and manganese content from 4.34 to 6.91 mg 100 g^{-1} dry weight.

Clones of all the crosses were planted in field during July 2019 and leaf were collected in the month of September 2019 for nutritional analysis. Leafs were properly cleaned, chopped and dried to make fine powder and nutritional analysis were done at ICAR-CTCRI, Regional Centre. DPPH assay ranged from 58.72 to 97.22%; CUPRAC assay from 56.45 to 98.16 µ mol trolox/g and total phenolics content from 27.13 to 66.25 mg gallic acid/g dry weight in leaf. Sugar content ranged from 1.32 to 2.21%; Starch from 12.18 to 44.45%; Crude protein content 8.16 to 23.82 g 100 g^{-1}; Phosphorous content from 114.65 to 324.47 mg 100 g^{-1}; Potassium content from 890.36 to 1269.27 mg 100 g^{-1}; Iron content from 7.75 to 20.65 mg 100 g^{-1}; Copper content from 0.69 to 1.95 mg 100 g^{-1}; Zinc content from 4.86 to 8.11 mg 100 g^{-1} and Manganese content from 2.69 to 7.54 mg 100 g^{-1} dry weight in leaf. During the experiment, dry spell was experienced from October and irrigation were given at 7 to 8 days interval. Corms of all the crosses were harvested in December 2019, fine powder was prepared after drying for analysis of their nutritional values and it is under progress.

Elephant foot yam

Under the genetic improvement of elephant foot yam programme, the hybrid corms from previous years crosses Am 159 x Am158, Gajendra x Local, Am156 x Am158, Am157 x Gajendra, Am158 x Gajendra were harvested during November 2019 and the corm and cormel numbers, corm and cormel weight, shape of corm and cormel were recorded (Fig. 19). The corm and cormel weight ranged between 15 to 310 g. All the corms had cormels and number of cormels per corm ranged from 1 to 26. The hybrid corms were replanted for further evaluation during *rabi* 2019-20. Seeds obtained from pollination during April 2019, between ADS/2019-1 as female parent and Am158 as male parent, were harvested and shade dried and sown during February 2020. The seeds germinated within two weeks and germination per cent was 46%.

Fig. 19. Hybrid corms of elephant foot yam

In elephant foot yam, a new trial was initiated during *rabi* 2019-20 with 14 high yielding genotypes and Sree Padma as the check and the trial is in progress.

Tannia

In the second year advanced yield trial in tannia, Xa-13 and Xa AD/2014-15 produced the maximum cormel yield which was at par yielding 2.23 and 1.48 t ha^{-1}, respectively and a total yield of 3.55 and 2.84 t ha^{-1}, respectively. For initiation of polyploids, tubers of three tannia genotypes (VHAK/2015-5; Xa-AD/2014-15 and SSK/2017-2) were subjected to ploidy manipulation using colchicine (0.05, 0.5 and 1.0%) by spray method at intervals of one day, three times. The buds were then washed, scooped out and planted in sand: soil mixture, but the buds decayed.

Arrowroot

Biochemical evaluation of tubers was done for moisture, total starch, sugar, crude fibre, ash and dry matter. All the 7 genotypes of arrowroot had values of the dry matter content of tubers above 30%. The percentage ranged from the lowest of 30.49% in M-7 to the highest of 33.30% in M-6 (Fig. 20). Advanced yield trial of seven arrowroot genotypes for the second consecutive year is under progress.

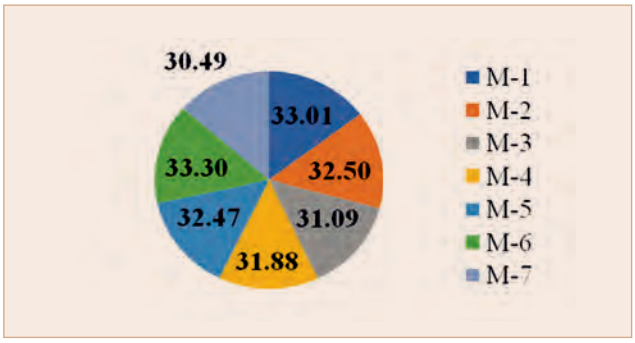


Fig. 20. Dry matter content (%) of arrowroot

Yam bean

The F5 generation of five best F1 hybrids along with check variety (RM-1) were sown at research farm of Regional Centre during September, 2019

for evaluation of yield and other yield contributing traits. Irrigation was given at an interval of 7-10 days. Yam bean tubers harvested during December 2019. Tuber yield in F5 generation of best F1 hybrids ranged from 30.0 (3 x 10) to 32.0 t ha^{-1} (3 x 8) as compared to 22.5 t ha^{-1} in RM-1, the check variety (Fig. 21). Another ten F5 generations, which had good yield in F1 generation was also maintained for successive generations. Out of these, five lines had 25.0 t ha^{-1} to 30.0 t ha^{-1} yield. Another set of five F5 generations were raised for the production of seeds for further evaluation and distribution. Biochemical estimation of starch and sugar is in progress.

Fig. 21. Promising hybrids of yam bean

Developing breeder seed standards and precocity of genetic vigour for yam bean

For developing breeder seed standards in yam bean, 53 accessions of yam bean were maintained in the field gene bank including RM1 and RM2. Out of these, ten accessions namely, Rajendra Local, Nepal, EC100550, IC025112, IC025117, DL-14, DL-16, DL-17, DL-20 and DPH-5 were evaluated for field emergence. Seedling emergence and vigour of seedlings were evaluated for 10 genotypes. The preliminary results showed that DPH-5 showed significantly high field emergence, seedling vigour and precocity of flowering and pod set which showed positive correlation with seed quality results obtained in the lab. Significant differences in terms of seed germination and seedlings vigour were recorded in the seed colour categories viz., black, dark brown, brown and green in yam bean varieties, RM1 and RM2.

Marker assisted breeding

Identification of molecular markers linked to high starch content in cassava

For identification of molecular markers linked to high starch content in cassava, the contrasting parents, 9S-127 and Sree Padmanabha (MNga-1) along with 145 F1 clonal progenies in field, were evaluated for starch content and gene mapping study. 25 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 needs to be sequenced for the identification of sequence variation among the parents. This information can be used for the identification of SCAR or CAPS markers. The polymorphic SSR markers were screened with 145 clonal progenies. The starch content estimated in both the parents and progenies indicated wide variation in the clonal progenies.

Genetic modifications for quality improvement in cassava

Cassava varieties viz., Sree Sakthi, Sree Reksha, Sree Suvarna, Sree Swarna, Sree Sahya, Sree Pavithra, Sree Rekha, Sree Vijaya, Sree Prakash, Sree Prabha, H226, Sree Padmanabha were raised *in vitro* and the genetic fidelity of these *in vitro* raised plants were analysed using molecular markers. The plants raised *in vitro* were true to type with variation ranging from 0-14%. The variations observed can be attributed to epigenetic variations and were genotype dependent. For developing transgenic cassava plants with increased starch content, the CMD resistant cassava accession, 9S-127 was multiplied and maintained. Embryogenic calli was raised from cassava accessions 9S-127, CR-501-2 and cassava variety H-226. The embryogenic calli as well as nodes of 9S-127 were co-cultivated with *Agrobacterium* having *glgC* gene construct.

Characterization of *MeHSP70* family genes in cassava

Genome-wide HMM based-analysis led to the identification of 22 *MeHSP70* family genes in cassava. Out of 18 chromosomes of cassava, only 11 chromosomes viz., 1, 2, 3, 4, 7, 8, 9, 10, 11, 14 and 15 encodes for *MeHSP70* genes. Promoter analysis of 22 *MeHSP70* 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 *MeHSP70* family genes with *HSP70* family of Malpighiales genomes grouped the members into nine sub-groups. The data obtained from this study contribute to a better understanding of the complexity of *MeHSP70* 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.

Statistical tools and technologies for tuber crops research and development

Meta-analysis of QTLs associated with disease resistance in cassava

Meta-analysis is a statistical analysis for integrating information from multiple scientific studies and can be performed when there are multiple studies addressing the same question, with each individual study reporting measurements that are expected to have some degree of error. The aim then is to use approaches from statistics to derive a pooled estimate closest to the unknown common truth based on how this error is perceived. QTL meta-analysis involves combining results of individual QTL studies and detecting major and constant QTLs. The pooling of results from several studies allow greater statistical power for QTL detection and a more precise estimation of their genetic effects. The QTLs identified by a meta-analys is from a stack of QTLs at a confidence interval of 95% are called meta-QTLs (MQTLs). The MQTLs, with small confidence interval (CI), consistency and large effect on a trait are useful for marker-assisted selection.

Eight published QTL mapping studies conducted at different countries including African countries like Nigeria, Tanzania and at Indian institutes including Tamil Nadu Agricultural University (TNAU) and ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram from 2003 to 2017 for disease resistance in cassava were selected. Detailed information of the genetic maps, types of mapping population, population size, number and type of marker and genetic distances in the linkage groups were collected. A total of 61 QTLs in which 39 QTLs were associated with resistance to Cassava Mosaic Disease (CMD) and 22 QTLs were associated with resistance to Cassava Brown Streak Disease (CBSD) were used. For each QTL, name, trait, experiment location, year of experiment, names of chromosome and linkage group, LOD score, R^2 value (proportion of phenotypic variance explained), most likely position of QTL (in cM) and confidence interval (CI, in cM) were collected. These QTLs were distributed on 13 chromosomes with a range of 1-13% QTLs per chromosomes (Fig. 22). The phenotypic variance explained by the initial QTLs varied from 0.03 to 50.37% and the confidence interval (CI) of markers varied from 1.5 to 60.4 cM. These QTLs had an average CI of about 9.56 cM and LOD scores between 1.76 and 45.59.

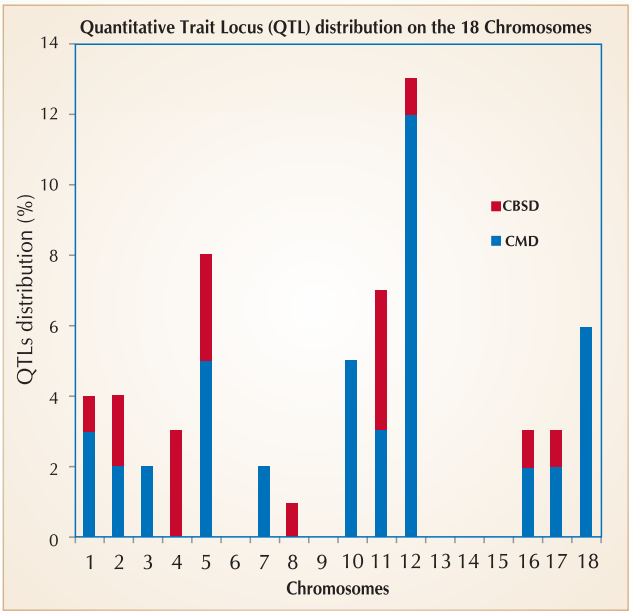


Fig. 22. Distribution of QTLs associated with disease resistance genes in Cassava

Biomercator V-4 (http://moulon.inra.fr/index.php/fr/seminairedoc/doc_download/64-biomercator-v4) was used to integrate the QTL information. A composite genetic linkage map for cassava harbouring 22,403 markers with map length of 2,412 cM from International Cassava Genetic Map Consortium (ICGMC) developed by International Institute of Tropical Agriculture (IITA) was used as a reference map for anchoring all individual genetic linkage maps used in this study. A consensus map in the name of 'CMAP' was constructed which had 18 LG with 22,621 markers. The length of Consensus map was 2,412.35 cM. In the consensus map chromosome 1 harboured more number of markers i.e about 2,387 markers and Chromosome 7 had the least number of markers i.e. about 310 markers. Map length of chromosome 1 was highest among all (164.78 cM) and chromosome 18 had the lowest map length (90.99 cM). The summary of consensus map is given in Table 1. Meta-Analysis of 58 QTLs projected in the consensus map was performed in Biomercator V.4 software using Goffinet and Gerber method. Meta - analysis of CMD and CBSD resistance QTLs were done separately. After Meta -analysis QTLs were fixed into 4 models, the model with lowest AIC criterion was selected as best model and it was used for visualization. Eleven MQTLs for CMD resistance and

10 MQTLs for CBSD-RN resistance were obtained. For mining candidate genes and for identifying their functional information, the QTLs within the MQTLs with confidence interval less than 2 cM and physical length less than 1 Mb were selected.

Table 1. Summary of integrated consensus map

Chromosome no.	No. of markers	Length (cM)
1	2387	164.78
2	1450	164.22
3	1368	155.60
4	1470	148.73
5	1392	146.87
6	1468	144.73
7	310	141.96
8	1217	137.48
9	1252	137.35
10	1221	133.31
11	1362	132.16
12	845	128.85
13	892	125.09
14	1362	120.26
15	1597	117.89
16	1127	117.13
17	837	104.95
18	1064	90.99
Total	22,621	2,412.35

The most recent annotated version of the *Manihot esculenta* (cassava) reference genome V.6.1 in Phytozome was used to identify the physical position of the meta-QTL and genes contained in these regions.

A total of 73 candidate genes were identified for QTLs associated with CMD resistance and a total of 51 candidate genes were identified for QTLs associated with CBSD-RN resistance. Functional annotation of these candidate genes was carried out by using Phytomine. Defence related proteins like Leucine Rich Repeats (LRR), Jasmonic acid, Receptor like kinases, protein kinases, Heat shock protein and trascription factors like Zinc finger and Leucine Zipper were found to be associated with these annotated genes.

Modeling of cassava-*Cassava Mosaic Virus* interaction

The protein sequence data of inbred line-AM560-2, the whole genome assembly (approx. 221.2 MB arranged on 18 chromosomes) and whole genome annotation (33,033 genes) of AM560-2 genotype of *Manihot esculenta* v6.1 (cassava) were downloaded from Phytozome, the Plant Comparative Genomics Portal of the Department of Energy's Joint Genome Institute (https://phytozome.jgi.doe.gov). *Cassava Mosaic Virus* (CMV) proteome were downloaded from UniProt database (https://www.uniprot.org/). There are many computational methods for identification of Protein Protein Interaction (PPI) which include, domain-based methods, structure-based methods and machine learning methods. Here, the interlog method, a domain based method, was applied to construct the PPI between cassava and cassava-CMV. The logic behind this method is the assumption of conserved interactions between a pair of proteins which have interacting homologs in another species. The conserved interaction is called as 'Interlog'.

Firstly, the Interlog method which relies on existing data was adopted for PPI prediction in cassava. Seven plant species were selected as templates, based on one of the three criteria: the model plant, *Arabidopsis*-has abundant PPI information; potato, rice and maize are starch-storing crops; castor bean, poplar and soybean are closely related to cassava. The PPI information from various databases includes *Arabidopsis thaliana* which contains: 235,215 interactions of 17,962 proteins (it has the most abundant PPI information), *Oryza sativa* (rice) contains: 76,829 interactions of 5,219 proteins, *Solanum tuberosum* (potato) contains: 42 interactions of 48 proteins, *Zea mays* (maize) contains: 25 interactions of 29 proteins, *Glycine max* (soybean) contains: 10 interactions of 12 proteins, *Ricinus communis* (castor bean) contains: 10 interactions of 10 proteins and *Populus trichocarpa* (poplar) contains : 8 interactions of 10 proteins.

To infer PPI information for cassava from each template plant, BLASTp search of the cassava genome sequence database was carried out. The cassava orthologous proteins that showed identity percentage $\geq$ 60, coverage percentage $\geq$ 80% and e-value $\leq 10^{-10}$ were identified. Interactions were inferred as orthologous PPIs in cassava if those orthologous proteins matched the proteins of template plants that had previously been identified to have protein-protein interaction. Based on the results obtained, majority of the PPIs were from *Arabidopsis thaliana*.

The resulting interolog-based PPI network of cassava consists of 90,173 interactions interconnecting 7,209 proteins, which accounted for about 21% of proteins in the whole genome. The predicted interacting pairs of proteins visualized in the form of a network (interactome) using Cytoscape v3.7.1.

To predict the genome wide interactions, all proteins of cassava and CMV were paired up, which constituted 351 protein pairs. A total of 351 probable protein pairs were predicted using Interolog-based method. After filtering of 351 protein pairs in VirusHostPPi prediction tool, 114 protein pairs were found to be interacting which included 114 cassava proteins and 10 CMV proteins. Cytoscape was utilized for the visualization of PPIN. Details of the predicted genes in cassava, CMV are shown in Table 2.

Table 2. Details of the predicted genes in CMV interacting with genes in cassava

Virus gene	No. of interaction	No. of host genes	No. of host proteins
AR1, AV1	44	37	44
ORF4	22	21	22
AC1	16	14	16
AC4	9	8	9
AC2, AL2	7	6	7
AV1	6	6	6
BC1	6	5	6
AC3	2	2	2
ORF2	1	1	1
ORF3	1	1	1
Total	114	101	114

The effectors of CMV with the highest number of edges (hubs) were AR1, ORF4 and AC1 with more than 10 PPIs in the Cassava-CMV interactome. There are effectors with less than 10 predicted PPIs. These were AC4, AC2, AV1, BC1, AC3, ORF2 and ORF3. These hub proteins play an important role in pathogenesis, and hence can be further investigated for deciphering virulence mechanism.

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

Production of disease-free planting materials in tropical tuber crops

Mass multiplication of virus free planting materials of cassava was done through procedures involving indexing, micropropagation, hardening and minisett multiplication under protected environment. Large scale multiplication of disease free planting materials was done in selected areas of Kerala, Tamil Nadu, Odisha and North East India in a farmer's participatory mode together with farmer's training programmes for mass multiplication and popularization of disease free planting materials. The planting material production of all tuber crops was done as per the seed procedure standards. The planting material was monitored for pest and disease occurrence from standing crop at different intervals. The field inspection, rogueing and intercultural operations were carried out as and when required and planting materials were harvested at maturity stage. Mass multiplication of disease-free planting materials of cassava (Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Reksha); elephant foot yam (Gajendra and Sree Padma); yams viz., greater yam (Sree Keerthi, Sree Roopa, Sree Karthika and Sree Shilpa), lesser yam (Sree Latha) (planted in the month of April 2019 and harvested during January 2020) and white yam (Sree Priya and Sree Dhanya); sweet potato (Bhu Sona and Bhu Krishna); taro (Muktakeshi) and Chinese potato (Sree Dhara) was done in 4.10, 1.00, 2.70, 0.20, 0.10 and 0.30 acres respectively, totaling to 8.40 acres in the different blocks of ICAR-CTCRI farm (Fig. 23). The details of quality planting material production of tuber crops at ICAR-CTCRI, Thiruvananthapuram and Regional Centre, Bhubaneswar and distribution to farmers are given in Table 3.

Table 3. Quality planting material production of tuber crops during the crop season 2019-20

Sl. No.	Name of the crops	Varieties	Quantity of planting material produced
1.	Cassava (No. of stems)	Sree Vijaya	40,000
		Sree Jaya	35,000
		Sree Pavithra	15,000
		Sree Reksha	5,000
		Total	**95,000**
2.	Elephant foot yam (ton)	Gajendra	11.50
		Sree Padma	0.50
		Total	**12.00**
3.	Greater yam (ton)	Sree Shilpa	4.5
		Sree Nidhi	3.0
		Orissa Elite	3.0
		Sree Keerthi	2.5
		Sree Roopa	1.5
		Sree Karthika	1.0
	White yam (ton)	Sree Priya	0.5
		Sree Dhanya	0.5
	Lesser yam (ton)	Sree Latha	0.5
		Total	**17.00**
4.	Taro (ton)	Muktakeshi	1.0
5.	Sweet potato (No. of vine cuttings)	Bhu Sona	3,50,000
		Bhu Krishna	3,50,000
		Kishan	4,00,000
		Total	**11,00,000**
6.	Chinese potato (No. of vine cuttings)	Sree Dhara	20,000
7.	Yam bean (kg)	RM-1	150

Cassava

Sweet potato

Elephant foot yam

Greater yam

Fig. 23. Field view of quality planting material production of tuber crops

Multiplication through minisett technique in cassava: Mass multiplication of virus free planting materials was carried out through minisett technique in cassava with the varieties of Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Reksha. The minisetts were planted inside the net house for one month and then transplanted in the net house as well as in field (Fig. 24).

Fig. 24. Net house view of quality planting material production of cassava

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

Planting material of cassava varieties viz., Sree Vijaya, Sree Jaya, Sree Swarna and Sree Pavithra that were treated by soaking in hot water resulted in zero cassava mosaic virus symptoms for two months and it was 3, 5, 7 and 9% at 3rd month and 32, 33, 39 and 36% at 8th month after planting under field conditions.

Induction of early and uniform sprouting in elephant foot yam

A field experiment was conducted during summer (second season) of 2019 at ICAR-CTCRI,

Thiruvananthapuram, to study the effect of different growth regulators and chemical treatments on induction of early and uniform sprouting in elephant foot yam var. Gajendra. The corms were treated using sixteen treatments, replicated thrice and arranged in a randomized block design. The crop was planted in the month of April, 2019 with 90 x 90 cm spacing. The standard recommended package of practices was followed in the field trial. Corms subjected to fumigation method are given in Fig. 25. The results revealed that elephant foot yam corms treated with carbon disulphide @ 80 ml per 100 kg resulted in maximum uniform sprouts with 80.96 and 99.98% at 15 and 40 days after planting (DAP), followed by GA_3 (200 ppm) treated corm which produced 74.56% and 96.75% sprouting at 15 and 40 DAP. The plant growth parameters revealed that higher plant height (72 cm), stem girth (26 cm) and canopy spread (84 cm) were recorded in plants from corms treated with carbon disulphide followed by GA_3 (200 ppm) treatment at 90 days after planting. Harvesting was done in the month of January 2020. The corm yield data revealed that treatment with fumigation of carbon disulphide solution @ 80 ml per 100 kg of corm resulted in significantly higher corm yield (32.68 t ha^{-1}) followed by GA_3 (200 ppm) treatment (28.75 t ha^{-1}) (Fig. 26).

a. Fumigation of corm b. Before fumigation c. After fumigation: Corm with uniform sprout d. Single corm with sprout

Fig. 25. Fumigation treatment for uniform sprouting of elephant foot yam

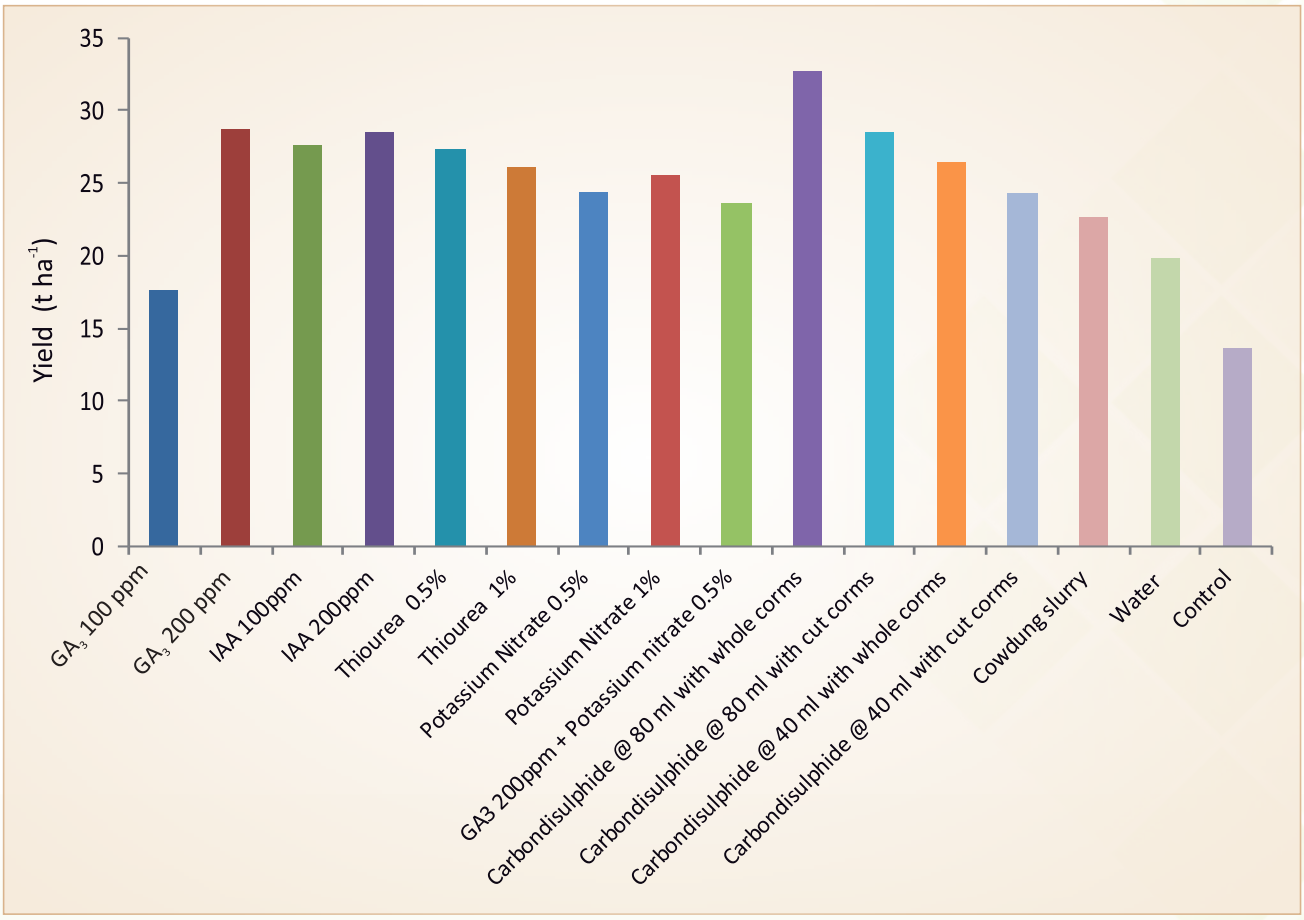


Fig. 26. Effect of growth regulators on corm yield in elephant foot yam

Cropping systems involving tuber crops and legumes

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

The field experiment to evaluate the feasibility of intercropping short-duration cassava with leguminous vegetables and oilseed in rice based cropping system was carried out for the first season. Short-duration rice var. Manu Ratna was taken up as the first crop followed by short-duration cassava (var. Sree Vijaya and Vellayani Hraswa), intercropped with leguminous vegetables (cluster bean (var. Gloria), French bean (var. Crystal) and oilseed crop (groundnut var. Co-7) at two fertility levels of cassava (full FYM, N and K; half FYM and N, full K) (FYM @ 12.5 t ha^{-1}, NK @ 100:0:100 kg ha^{-1}; FYM @ 6.25 t ha^{-1}, NK @ 50:0:100) (Fig. 27). Sole crops of the two varieties under full fertility levels were also included for comparison.

The grain yield and straw yield of rice were 2.25 t ha^{-1} and 7.08 t ha^{-1}, respectively. There was yield reduction (20.33%) in cassava under intercropping (18.58 t ha^{-1}) compared to sole cropping (23.50 t ha^{-1}) (Fig. 28). Both the varieties of cassava were suitable for intercropping. Among the legumes, cluster bean was more suitable as the cassava yield under intercropping with cluster bean was significantly higher than that with French bean and groundnut. Sole cropping produced highest yield but was on par with cassava (both the varieties) intercropped with cluster bean. Thus, intercropping short-duration cassava either of the varieties with cluster bean, irrespective of fertility level was preferred due to cassava tuber yield (21.92 t ha^{-1}; yield reduction of 7%) on par with sole cassava (23.50 t ha^{-1}) and saving of nutrients. Nutrient saving to cassava to the extent of half FYM and N and full P was possible. Rice-short-duration cassava + cluster bean was productive in the first year.

First crop of rice (var. Manu Ratna)

Short-duration cassava + cluster bean

Short-duration cassava + French bean

Short-duration cassava + groundnut

Fig. 27. View of the field experiment on rice-short-duration cassava + legumes

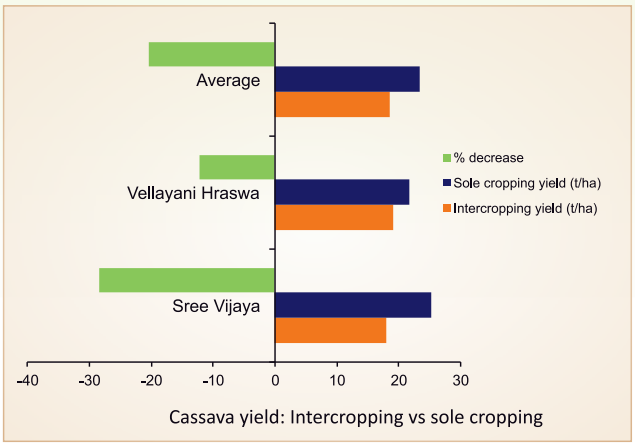


Fig. 28. Cassava: Intercropping vs sole cropping

Intercropping system involving dwarf white yam and pulse crops

The field experiment to evaluate the feasibility of intercropping dwarf white yam with pulse crops was carried out for the second season. Dwarf white yam var. Sree Dhanya was intercropped with pulse crops, green gram (var. Co-8), black gram (var. Co-6) and soybean (var. NRC-37) at two fertility levels of white yam (full FYM, N and K; half FYM and N, full K) (FYM @ 10 t ha^{-1}, NPK @ 100:0:100 kg ha^{-1}; FYM @ 5 t ha^{-1}, NPK@ 50:0:100 kg ha^{-1}) during May 2019 (Fig. 29). Sole crop of dwarf white yam under full fertility level was also included for comparison.

Fig. 29. Dwarf white yam intercropped with soybean, green gram and black gram

Pulse, pulse x fertility level and control vs treatment did not impart significant effect on the productivity of dwarf white yam. The insignificant effect of control vs treatment obtained indicates that intercropping treatments remained on par with sole cropping. Intercropping pulse crops in dwarf white yam (20.86 t ha^{-1}) enhanced yield of dwarf white yam by 16.92 % over sole cropping (17.84 t ha^{-1}) (Fig. 30). Nutrient saving to the extent of half FYM and N and full P was possible, which was superior to full nutrient management. Dwarf white yam intercropped with soybean at the reduced fertility level (26.69 t ha^{-1}) was the most productive, followed by green gram (25.16 t ha^{-1}) and black gram (25.22 t ha^{-1}) at the lower fertility level.

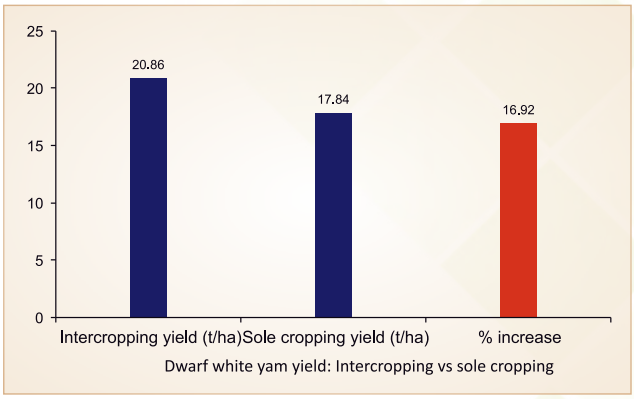


Fig. 30. Dwarf white yam: Intercropping vs sole cropping

Studies on intercropping in taro

A field experiment was conducted during 2019 at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar to study the effect of taro intercropping on yield potential, biological efficiency and economics. The experiment was laid out in randomized block design with three replications (Fig. 31). The experiment consisted of seven treatments, 1-sole taro, 2-sole maize, 3-sole pigeonpea, 4-taro + maize (5:1), 5-taro + maize (5:2), 6 - Taro + pigeonpea (5:1) and 7- taro + pigeonpea (5:2). All the crops in intercropping were planted at 45 x 30 cm spacing. Sole taro was maintained at 45 x 30 cm spacing, whereas sole maize and pigeon pea at 60 x 30 cm spacing. The variety Muktakeshi (taro), H 4226 (maize) and CORG 9701 (pigeonpea) were used in this study. The experiment was planted/sown on 10 June 2019. 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.

Fig. 31. Field view of experiment taro + maize (5:1)

The results revealed that sole taro produced significantly higher cormel equivalent yield of 21.55 t ha^{-1}. This was due to higher yield potential of taro. The next best treatment was taro + maize (5:1) (18.99 t ha^{-1}). Sole pigeonpea and maize recorded lower cormel equivalent yield of 6.78 and 4.80 kg ha^{-1}, respectively. This was due to the 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 >1 (Fig. 32). This indicated that all the above intercropping systems were biologically efficient. The LER is the most popular method of assessing intercropping systems. Economic analysis indicated that the sole taro was resulted in higher gross and net returns of ₹3,23,300 and ₹2,09,700 per ha, respectively. This was mainly due to the higher yield. The gross and net returns of taro + maize (5:1) and taro + pigeonpea (5:1) were statistically on par and were next best to the sole taro. Sole pigeonpea and maize resulted in lower gross and net returns. This was due to lower yield of pigeonpea and maize. The treatment, sole taro, resulted in greater B:C ratio (2.85) followed by taro + maize (5:1) (2.53) and taro + pigeonpea (5:1) (2.44). 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.

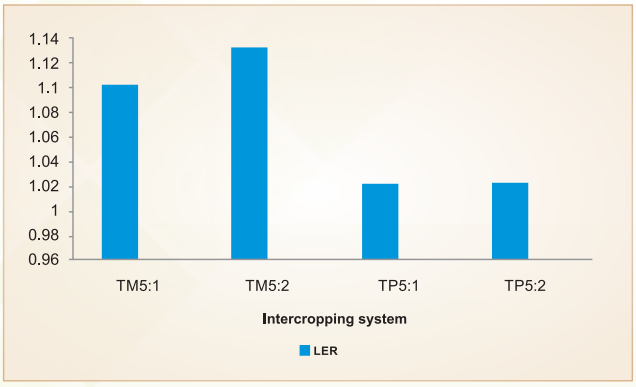


Fig. 32. Effect of taro intercropping system on LER

Weed management with new generation herbicides in tropical tuber crops

A field experiment was conducted during 2019 at ICAR-CTCRI, Thiruvananthapuram to study the effect of new generation herbicides on weed management in elephant foot yam. The crop was planted in the month of March 2019. The experiment was laid out in randomized block design with three replications. The experiment had nine treatments viz., T_1 - Imazethapyr (PE) + Propaquizafop (45 DAP) + Propaquizafop (90 DAP), T_2 - Imazethapyr (PE) + Clodinofop propargyl (45 DAP) + Clodinofop propargyl (90 DAP), T_3 - Imazethapyr (PE) + Propaquizafop (45 DAP) + Clodinofop propargyl (90 DAP), T_4 - Tembotrion (PE) + Propaquizafop (45 DAP) + Propaquizafop (90 DAP), T_5 - Tembotrion (PE) + Clodinofop propargyl (45 DAP) + Clodinofop propargyl, T_6 - Tembotrion (PE) + Propaquizafop (45 DAP) + Clodinofop propargyl (90 DAP), T_7 - Pendimethalin (PE) + Glyphosate (45 DAP) + Glyphosate (90 DAP), T_8 - Weed free control (weeding at 30, 60, 90 and 120 DAP) and T_9 - Un-weeded control. Initial soil samples were taken for soil physical, chemical and microbiological studies prior to experiment. Dry weed biomass was recorded at 30, 60, 90, 120 days after planting and at harvesting stage. Weed control efficiency was done by using standard procedure. The crop was harvested at 8 months after planting. Maximum dry weight of weeds was recorded in the control plot, where no weeding was done. The treatment, T_7 resulted in lowest dry weed biomass at 45, 90, 120 days after planting and at harvesting stage. This was due to complete suppression of weeds due to the chemical residue for more periods in the soil (Fig. 33). The next best treatment for less dry weed biomass was weeding free control (T8) viz., weeding at 30, 60, 90 and 120 DAP. Significant higher plant growth, canopy spread, pseudo-stem height, fresh and dry weight of shoot portion was recorded in plants under the treatment T_4 followed by T_5. Significantly higher corm yield was recorded in plants under the treatment T_7 (56.80 t ha^{-1}), which was due to best weed control efficiency and less weed dry matter production, followed by T_8 (49.13 t ha^{-1}) and T_4 (45.84 t ha^{-1}).

Fig. 33. Effect of different herbicides on weed management in elephant foot yam at 4 MAP (top) and 6 MAP (bottom)

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

A field experiment was laid out in split plot on 15 April 2019 at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar to study the effect of fertigation interval and number of splits in greater yam + maize intercropping system (Fig. 34). The experiment was laid out in split plot design with fertigation interval in main plots (I_1-2 days, I_2-3 days and I_3-4 days) and number of splits in sub plots (S_1-40 splits, S_2-50 splits and S_3-60 splits). Control/Check (1): (soil application of N-P_2O_5-K_2O @ 140-90-140 kg ha^{-1} at basal (40%), 45 (30%) and 90 (30%) days after planting) and control/check (2): (No fertilizer) was also included to compare the treatments. The treatments were replicated thrice. In fertigation treatments, water soluble N, P and K was applied in 5 splits (basal, 30, 60, 90 and 120 DAP @ 20% each). In control/check 1, P_2O_5 was applied in the last plough. N and K was applied in 3 splits at basal (40%), 45 DAP (30%) and 90 DAP (30%). FYM @ 10 t ha^{-1} was incorporated in the last plough in all the treatments except control/check (2). The greater yam weighing 200 g cut tubers were planted on ridges formed at 90 cm spacing. The plant to plant distance of 90 cm was maintained. In the intra-rows, in between two greater yam plants 3 maize seeds were sown on the same day at the spacing of 30 cm. The irrigation was withheld 10 days before harvesting in all the treatments. The crop was harvested 280 days after planting. Maize cobs were harvested 90 days after sowing (14 July 2019) and the greater yam is yet to harvest.

The results revealed that the treatment I_1 (2 days interval) resulted in significantly higher maize yield (3.0 t ha^{-1}) as compared to other treatments. Significantly lower yield (1.7 t ha^{-1}) was recorded in I_3. It indicated that maize requires fertilizers in quick succession for its robust growth and development. Among number of split applications, the treatment S_1 (40 splits) resulted in significantly higher maize yield (2.7 t ha^{-1}). Increasing number of splits decreased maize yield. Significantly lower maize yield of 2.2 t ha^{-1} was recorded in plants under treatment S_3 (60 splits). This indicated that maize plant has not used the fertilizers which were applied after 80 days. The interaction effect of fertigation interval and number of splits indicated that 40 split dose of fertilizer applied in two days interval (I_1S_1) was very effectively utilized by the crop and produced higher yield (3.3 t ha^{-1}) as against the control/check 1 and 2 treatments with a yield value of 2.5 and 1.2 t ha^{-1}, respectively. Increasing fertigation interval and number of splits decreased the maize yield. The treatment I_3S_3 (fertigation at 4 days interval with 60 number of splits) resulted in lower maize yield (1.4 t ha^{-1}). This may be due to non-availability of fertilizers during the crop growth period. The greater yam crop is yet to be harvested.

Fig. 34. Field experiment on fertigation in greater yam + maize intercropping system

Water management studies in tropical tuber crops

Water management studies in taro

The field experiment to standardise irrigation scheduling on upland taro was carried out at ICAR-CTCRI, Thiruvananthapuram for the third season. The

experiment was laid out in 3 x 4 factorial design along with two controls, furrow irrigation and a rainfed crop and the crop was planted during November 2018. The treatment factors included three periods (irrigation upto 8 weeks after planting (WAP), upto 16 WAP, upto 24 WAP) and four levels of drip irrigation (IW/CPE ratio 0.75(I_1), 1.0 (I_2), 1.25 (I_3) and 1.50 (I_4). The crop took 33-42 days for initiating sprouting and 48-55 days for achieving 50% sprouting. Furrow irrigation and rainfed crop took 32 and 55 days for first sprouting, and 56 and 72 days for 50% sprouting respectively. Soil moisture content recorded at monthly intervals indicated the significant variation at different intervals. The moisture content varied from 6.1 to 18.6% under drip irrigation treatments, 6.9 to 16.1% under furrow irrigation and 5.3 to 7.7% under rainfed control.

The crop was harvested during May 2019. There was significant difference in both cormel yield and total yield (corm + cormels) among the periods of irrigation, but different levels of irrigation did not result in significant variation in yield. Irrigation upto 24 weeks resulted in maximum yield and the yield decreased when irrigation was confined to 16 weeks and 8 weeks. Irrigation upto 24 weeks @ IW/CPE ratio 1.5 resulted in maximum cormel yield (22.78 t ha^{-1}) among the interaction effects of the two factors, which was on par with irrigation for 24 weeks under different irrigation levels of 0.75, 1.0 and 1.25 and also furrow irrigation. Furrow irrigation and rainfed crop resulted in cormel yield of 19.01 and 3.47 t ha^{-1}, respectively. Total yield was also maximum when irrigation was given for 24 weeks @ IW/CPE ratio 1.50 and was statistically on par with the other three levels of drip irrigation and the furrow method.

Pooled analysis of three years yield data also indicated that both cormel yield and total yield varied with respect to the period of irrigation and not with the different levels of irrigation. Drip irrigation upto 24 weeks at IW/CPE ratio of 1.25 and 0.75 resulted in maximum cormel yield and total yield (corm + cormel) respectively. However, the yields were on par among the different irrigation levels and furrow irrigation. Hence, it was concluded that upland taro needs continuous irrigation upto 24 weeks after planting at IW/CPE ratio of 0.75 for producing optimum cormel yield as well as total yield.

Based on the data collected over three seasons, water requirement of upland taro was worked out to be 2.9 to 3.3 mm per day for producing optimum cormel yield (Fig. 35). Water productivity ranged from 2.6 to 4.5 kg m^{-3} under different irrigation levels.

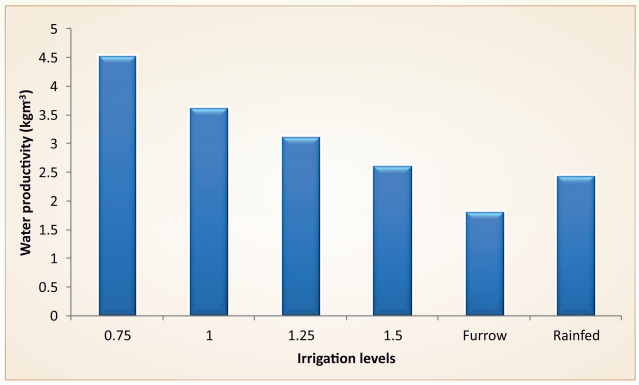


Fig. 35. Water productivity of taro under different irrigation treatments

Long term fertilizer cum manurial experiment in cassava

To determine the effect of continuous application of manures and fertilizers including secondary and micronutrients for the 14th season crop, an experiment was conducted with 20 treatments using the cassava variety H-1687 (Sree Visakham). These treatments include levels of fertilizers (6), different organic manures (5) and secondary nutrient (Mg) and micronutrients (Zn, B) in single nutrient, two nutrients and three nutrients combination (7). The effect of these treatments were studied mainly on tuber yield, tuber quality parameters like cyanogenic glucosides and starch, soil physical properties, chemical parameters *viz*., pH, organic carbon, available N, P, K, Ca, Mg, S, Fe, Cu, Mn, Zn and B, plant nutrient uptake of major, secondary and micronutrients and soil microbiological biological properties.

The levels of fertilizers include a soil test-based fertilizer recommendation as FYM @ 2.5 t ha^{-1} and NPK @ 75:0:54 kg ha^{-1} based on the soil organic carbon and available P, K to the tune of 1.56%, 255.14 and 275.30 kg ha^{-1}, respectively and an absolute control where no manures and fertilizers were applied. The other levels include NPK @ 125:50:125, 100:50:100, 50:25:100, 50:25:50 kg ha^{-1}. The different organic manures tried were FYM @ 12.5 t ha^{-1}, green manuring *in situ* with cowpea, vermicompost @ 3.91 t ha^{-1}, coirpith compost @ 4.6 t ha^{-1} and crop residue. The application rate of vermicompost and coirpith compost was based on N equivalent basis. In the green manuring *in situ* treatment, the average green biomass of cowpea added was 15.13 t ha^{-1}. Similarly, the residue of the crop incorporated included the leaf and stem remains after taking the tubers which in turn

was to the tune of 3.2 and 3.5 t ha^{-1} containing N as 3.7 and 1.05%, respectively.

With regards to the secondary and micronutrients, nutrients viz., Mg, Zn and B were applied based on soil test to the tune of $MgSO_4$, $ZnSO_4$ and borax @ 5, 2.5, 7.5 kg ha^{-1} based on the mean status of Mg, Zn and B as 0.788 meq 100 g^{-1}, 5.6 and 0.312 ppm, respectively.

Sustainable Yield Index (SYI)

The sustainable yield index (SYI) worked out for PoP and absolute control for this season crop was 0.846 and 0.484 and over these 14 years it was 0.826 and 0.474, respectively. The influence of levels of fertilizers on SYI during the 14th crop season and over these years are presented in Fig. 36.

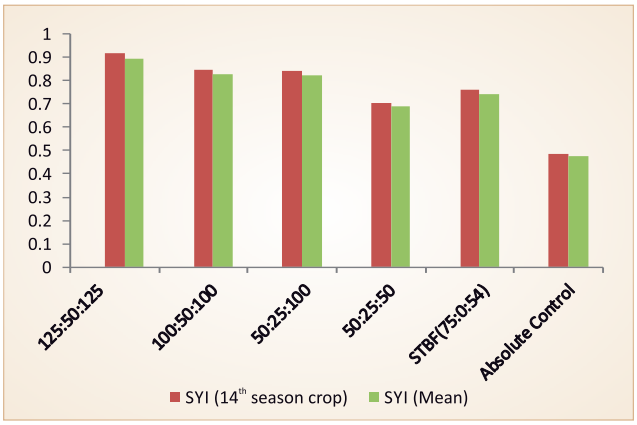


Fig. 36. Effect of levels of fertilizers on Sustainable Yield Index (SYI)

Tuber yield

The different levels did not significantly affect the tuber yield except for absolute control. However, application of NPK @ 125:50:125 kg ha^{-1} resulted in the highest tuber yield of 26.07 t ha^{-1} statistically on par with all other levels. Absolute control resulted in tuber yield of 12.93 t ha^{-1}. Among the different organic manures, green manuring *in situ* with cowpea (27.90 t ha^{-1}) resulted in a significantly higher tuber yield over other organic manures and all others were on par (Fig. 37). Tuber yield under PoP (25.71 t ha^{-1}) was significantly higher compared to different combination of secondary and micronutrients which in turn were on par.

Quality parameters

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

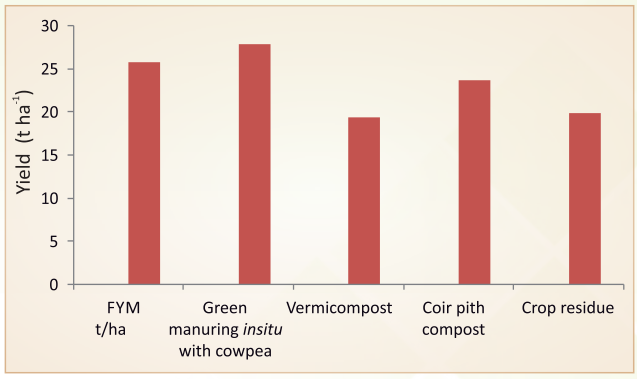


Fig. 37. Effect of continuous application of organic manures on tuber yield of cassava

However, there was comparatively low HCN (47.58 ppm) and high starch (24.06%) with NPK @ 50:25: 100 kg ha^{-1}. Among the different organic manures, green manuring *in situ* with cowpea and vermicompost resulted in comparatively low HCN to the tune of 47.58 and 46.29 ppm, respectively over FYM (139.51 ppm) and green manuring *in situ* with cowpea, coirpith compost and vermicompost resulted in comparatively high starch content to the tune of 24.06, 24.83 and 24.48%, respectively compared to FYM @ 12.5 t ha^{-1} (21.02%) application. In the case of the effect of secondary and micronutrients, application of Mg alone (23.27%) and along with Zn (24.81%) resulted in comparatively higher starch over PoP (21.02%). Similarly, the cyanogenic glucoside content of cassava tubers sharply declined under these treatments compared to PoP (139.51 ppm) with single nutrient application resulting in lower content compared to two nutrients and three nutrients combination.

Soil physical properties

Based on the analysis of soil samples collected on 11 July 2019 from six different organic manures application treatments, it was observed that, soil bulk density (1.28 ± 0.07 Mg m^{-3}), porosity (51.70 ± 3.80 %) and maximum water holding capacity (48.90 ± 5.40 %) was found to be higher under the treatment consisting of combination of organic materials viz., vermicompost, coirpith compost, ash and crop residue compared to the rest of the treatments. The soil bulk density was the maximum (1.58 ± 0.04 Mg m^{-3}) in absolute control among the six treatments studied.

Soil chemical properties

During this season, significant effect of treatments was noticed in the case of soil parameters like pH,

EC, P, Ca, Zn and B. Fertilizer levels significantly influenced pH, P, Ca and Zn. NPK @ 125:50:125 (5.37) and 100:50:100 (5.26) kg ha^{-1} resulted in a significantly higher pH compared to other levels. Soil test-based application of fertilizers (STBF) caused significant reduction in soil P (165.4 kg ha^{-1}) over PoP (288.3 kg ha^{-1}). PoP resulted in a significantly higher Ca (1.92 meq 100 g^{-1}) and Zn (7.50 ppm) compared to other levels.

As regards to the effect of different organic manures, pH was found significantly improved under the organic manure alone treatment (6.47) with ash as one of the components as well as FYM @ 12.5 t ha^{-1} (5.26). EC also followed the same trend. Application of FYM resulted in a significantly higher P (288.3 kg ha^{-1}) over other organic manures. Exchangeable Ca also followed the same trend as pH with a post-harvest soil status of 2.89 meq 100g^{-1} under purely organic treatment having ash as one of the components and with FYM @ 12.5 t ha^{-1} (1.924 meq 100g^{-1}). In the case of Zn and B, FYM @ 12.5 t ha^{-1} and coir pith compost @ 4.6 t ha^{-1} significantly increased the soil Zn status (7.50 ppm) and B status (0.467 ppm) compared to other treatments.

In the case of the effect of secondary and micronutrients, post-harvest soil properties like P, Zn and B were significantly affected with treatments as Zn (103.8 kg ha^{-1}), Mg (97.6 kg ha^{-1}) and Zn along with Mg (93.2 kg ha^{-1}) registering significantly lower soil P status compared to other nutrient combinations including PoP (288.3 kg ha^{-1}). The Zn content was significantly higher in PoP (7.50 ppm) on par with treatments except Mg alone treatment (2.45 ppm). Over PoP (0.381 ppm), the post-harvest soil B was found significantly higher in B (0.575 ppm), Mg along with B (0.540 ppm) and B along with Mg and Zn (0.561 ppm) treatments. The effect of continuous application of Mg, Zn and B on the status of these nutrients after 14th season crop is presented in Fig. 38.

Total plant nutrient uptake

The treatments did not produce any significant effect on the total plant uptake of major, secondary and micronutrients.

Microbial population

In the case of fungal and actinomycetes population, no significant effect of treatments was seen. In the case of bacterial population, application of coir pith compost significantly increased the bacterial population (63.44 × 10^6 cfu/g soil) over other organic manures. Similarly, Mg application (33.22 × 10^6 cfu/g soil) resulted in a significantly higher bacterial population on par with other secondary and micronutrient combinations.

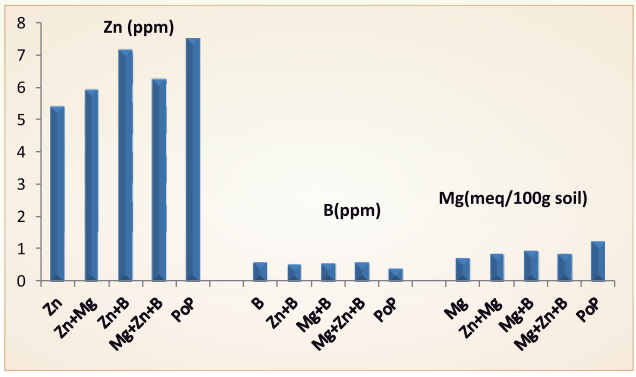


Fig. 38. Effect of continuous application of Mg, Zn and B on the post harvest soil Mg, Zn and B (after 14th season crop)

Screening nutrient use efficient cassava genotypes for low input management

The objective was to identify nutrient use efficient (NUE) genotypes in cassava which require lesser levels of chemical fertilizer inputs. Crop was planted during May 2019 and harvested in March 2020. In this regard, during this period, a total of four NPK use efficient genotypes were identified after conducting preliminary screening of 300 elite genotypes based on their physiological efficiency of N, P, K coupled with other desirable attributes like tuber yield, tuber quality, plant stature and cassava mosaic disease tolerance. Out of a total of 15 selected genotypes, four genotypes viz., CI-905, CI-906, 7-III-E3-5 and Sree Pavithra were tested for its NPK use efficiency in a split plot experiment with four levels of NPK viz., 25, 50, 75 and 100% of package of practices (PoP) to see how much percent of NPK can be reduced when these genotypes are used. The trials conducted for three years on station revealed no significant effect among levels of fertilizers on tuber yield indicating that the NPK level can be reduced to 25% if these genotypes are used. These were tried during the ensuing year in 24 farmers' fields of the different agro ecological units of Kerala with 25% application of the recommended PoP and were found acceptable. Large scale multiplication of these four genotypes was initiated at ICAR-CTCRI to see the sustainability of these genotypes for continuous cultivation with lower dose of NPK (25%). The average yield of the genotypes viz., Sree Pavithra, 7-III-E3-5, CI-905 and CI-906 were 38.3, 43.21, 39.26 and 39.50 t ha^{-1}, respectively.

Pooled analysis of the three years data with respect to tuber yield, tuber quality parameters like starch, cyanogenic glucosides, nutrient use efficiency parameters viz., agronomic efficiency, physiologic efficiency, agro physiologic efficiency, apparent recovery efficiency, utilization efficiency, harvest index, NPK harvest index, NPK uptake ratio, NPK utilization ratio and NPK utilization for biomass and physiological parameters like crop growth rate (CGR), relative growth rate (RGR) and tuber bulking rate (TBR). Results showed that, with respect to the parameters indicated for the K efficient, N efficient and NPK efficient genotypes, confirmed the superiority of the K efficient genotypes viz., Sree Pavithra and 7-III -E3-5 at low levels of K (0, 50 kg ha^{-1}), N efficient genotypes viz., W-19 and CR-43-8 at low levels of N (0, 50 kg ha^{-1}) and NPK efficient genotypes viz., CI-905, CI-906, Sree Pavithra and 7-III-E3-5 at 25% of the recommended NPK as per PoP. Statistical analysis of the data of three years each of the three experiments indicated significant effect of years, genotypes, K levels/N levels and their interaction on the yield, quality, NUE and physiological parameters. In the case of NPK efficient experiment, the pooled data over three years did not show significant effect of levels of NPK on the above parameters further confirming the possibility to reduce NPK fertilizers to 25% of the recommended NPK when NPK efficient cassava genotypes are cultivated.

Apart from these, three genotypes viz., CI-905, 7-III-E3-5 and Sree Pavithra were taken for on farm validation at four KVK's of Kerala namely ICAR-KVK, Mithranikethan, Thiruvananthapuram, KAU-KVK, Kollam, KAU-KVK, Kottayam and ICAR-KVK, Kozhikode (Fig. 39).

The average yield reported for Sree Pavithra, CI-905 and 7-III-E3-5 at KVK Kollam at 25% NPK was 13.2, 9.1, 12.6 kg $plant^{-1}$, respectively where the local variety (Ariyan) produced an yield of 7.2 kg $plant^{-1}$ at the recommended PoP. Based on tuber yield, low NPK requirement and cooking quality, they have rated the genotypes Sree Pavithra as excellent followed by CI-905 and 7-III-E3-5. The trials conducted at KAU-KVK, Kottayam also showed good tuber yield and wider acceptability of the genotypes especially CI-905 due to its high yield and dark yellow colour of the flesh. At ICAR-KVK, Kozhikode, Sree Pavithra produced an average yield of 38.3 t ha^{-1} in farmers fields with 25% of the recommended NPK as per PoP at normal spacing of 90 × 90 cm. This variety was widely accepted by the farmers due to its excellent cooking quality and high yield under low levels of NPK. On farm testing of the three NUE genotypes at ICAR KVK-Thiruvananthapuram also indicated the acceptability of the three genotypes due to high yield at low levels of fertilizers coupled with good cooking quality and relatively low incidence of cassava mosaic disease. Sree Pavithra followed by CI-905 and 7-III-E3-5 produced an yield to the tune of 53.0, 48.0 and 42.0 t ha^{-1}, respectively and the acceptability was best for Sree Pavithra and CI-905.

Field view of NUE cassava at KAU-KVK Kollam

Tuber yield of the NUE cassava at KVK Kottayam

Field day conducted by ICAR-KVK, Kozhikode

Fig. 39. OFTs on NUE cassava genotypes in various parts of Kerala

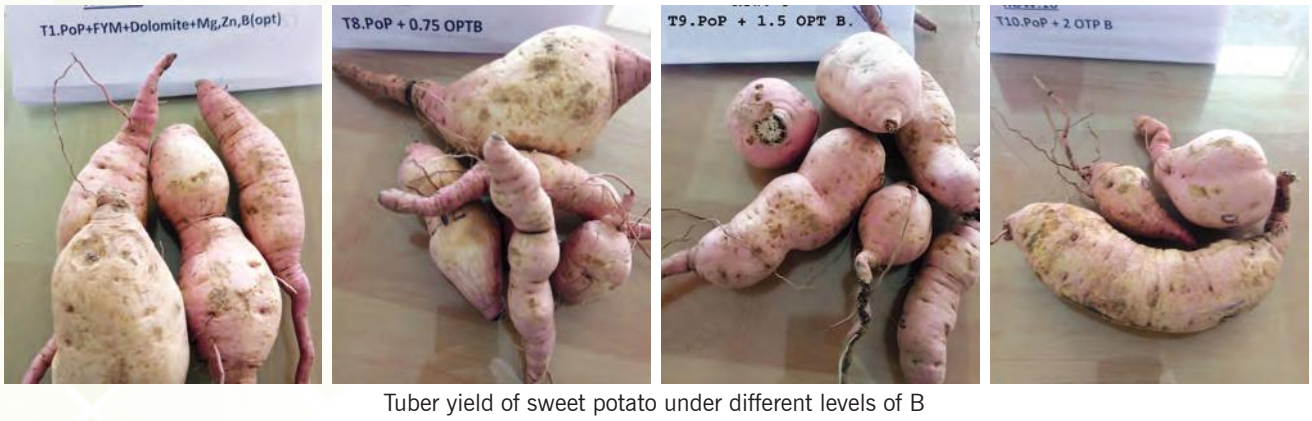
Response of tropical tuber crops to secondary and micronutrients under integrated nutrient management (INM) practice

The major objective was to find out the critical growth stage of elephant foot yam (EFY) and sweet potato (SP) for foliar nutrition. Elephant foot yam was planted in March 2019 and harvested in January 2020 both under field and lysimeter, while, sweet potato experiment was planted in both lysimeter, pots and field during June and harvested in October. During this year, in sweet potato, nutrient level experiment under field condition was conducted

to standardise the levels of dolomite, Mg, Zn and B. The eleven treatments consisted of a theoretical optimum comprising of optimum levels of dolomite (2 t ha^{-1}), Mg, Zn and B as 19.2, 6.3, 1.98 kg ha^{-1}, respectively along with PoP and FYM which in turn was fixed based on a previous experiment on evolving customized fertilizer formulations for elephant foot yam under intercropping in coconut. The other three levels were 0.5, 1.5, 2.0 times of optimum of each of Mg, Zn and B along with an absolute control. The tuber yield data indicated significant effect of levels of Mg affecting tuber yield with 2 times optimum (8.28 t ha^{-1}) giving an yield on par with optimum (6.93 t ha^{-1}). In the case of B, 1.5 times optimum B resulted in higher yield (12.54 t ha^{-1}) over optimum. Hence the optimum level of application of Mg, Zn and B for sweet potato can be fixed as 19.2, 6.3 and 3.0 kg ha^{-1}, respectively (Fig. 40).

Tuber yield of sweet potato under different levels of Mg

Tuber yield of sweet potato under different levels of Zn



Tuber yield of sweet potato under different levels of B

Fig. 40. Tuber yield of sweet potato under different levels of Mg, Zn and B

Another experiment was conducted with higher levels of liming materials to see its effect on tuberization along with changes in the soil parameters. Two experiments, one in the lysimeter tank and one in fibre glass pots were undertaken with higher levels of liming materials viz., lime, gypsum and dolomite @ 4, 8, 12, 16 t ha^{-1}. In the pots, lime application followed by gypsum and dolomite @ 8 t ha^{-1} resulted in good yield. The change in pH during the period from planting till 100 DAP under the influence of the liming materials indicated a

bearing of soil pH on tuberization as lime followed by gypsum and dolomite resulted in rise in pH which was reflected in tuber yield too (Fig. 41). The mean increase in exchangeable Ca with lime, gypsum and dolomite was 0.387, 0.408, 0.442 meq 100 g^{-1}, respectively where, the control had a value of 0.348 meq 100 g^{-1}. It was also observed that the increased soil Ca due to the application of the tested liming materials did not affect the tuber yield. Change in soil exchangeable Ca under the influence of different liming materials from planting till harvest of sweet potato is depicted in Fig. 42. Similarly, the mean exchangeable Ca (meq 100g^{-1} soil) under different liming materials at different rates is presented in Fig. 43. The mean pH under the different liming materials at various rates are depicted in Fig. 44.

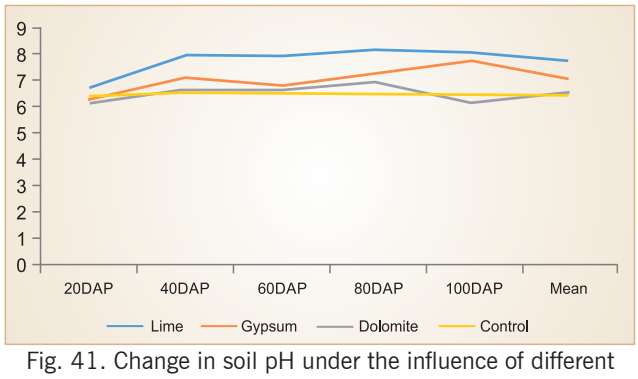


Fig. 41. Change in soil pH under the influence of different liming materials from planting till harvest

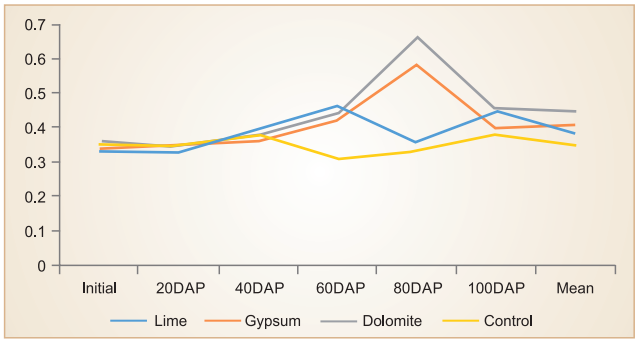


Fig. 42. Change in soil exchangeable Ca under the influence of different liming materials from planting till harvest of sweet potato

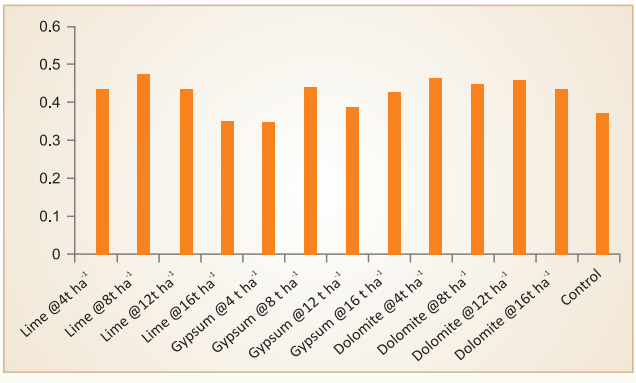


Fig. 43. Mean exchangeable Ca (meq 100g^{-1} soil) under different liming materials at different rates

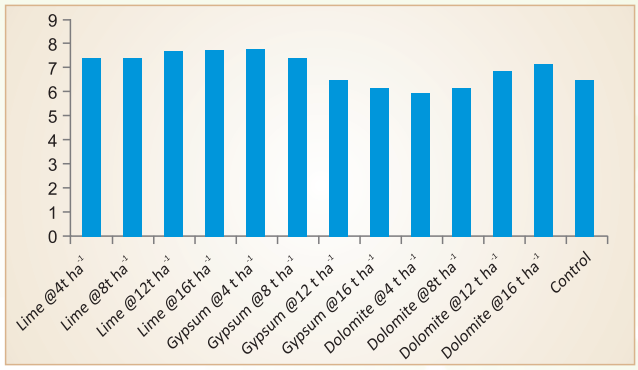


Fig. 44. Mean pH under different liming materials at different rates

In elephant foot yam, one experiment was conducted in the field to standardise the rates of dolomite, Mg, Zn and B. The experiment had 10 treatments replicated thrice in RBD comprising of three (0.75, 1.5, 2 times optimum) levels of optimum Mg (19.2 kg ha^{-1}) Zn (6.3 kg ha^{-1}) and B (1.975 kg ha^{-1}). The results indicated significantly higher tuber yield at 0.75 times optimum of all the three nutrients studied (33.8, 41.3 and 43.3 t ha^{-1}, respectively). Hence, the optimum of secondary (Mg) and micronutrients (Zn and B) for elephant foot yam could be fixed as 14.4, 4.73 and 1.48 kg ha^{-1}, respectively. The variations seen in the tuber yield of elephant foot yam due to additions of secondary and micronutrients (Mg and Zn) is depicted in Fig. 45.

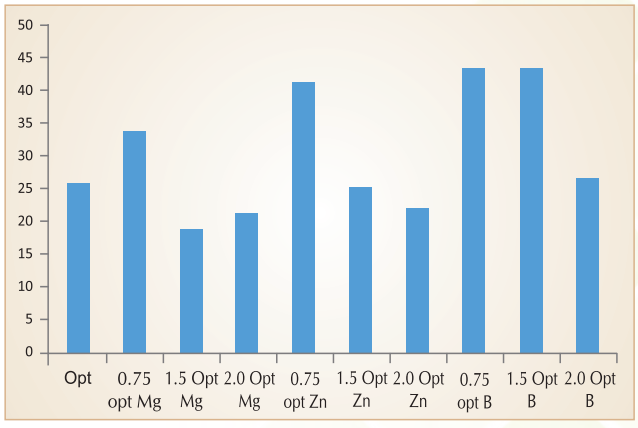


Fig. 45. Tuber yield of EFY (t ha^{-1}) under different levels of Mg, Zn and B

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. All five field experiments are ready for harvest. Soil and plant analysis to study the effect of site-specific nutrient management (SSNM) on yield, nutrient use efficiency and soil quality are being done.

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

A field experiment was laid out for second consecutive *kharif* season during 2019-20 with 14 treatment combinations (Control, N_{40}, N_{80}, N_{120}, P_{30}, K_{40}, K_{80}, K_{120}, $N_{80}P_{30}$, $N_{80}K_{80}$, $P_{30}K_{80}$, $N_{80}P_{30}K_{80}$, FYM @ 10 t ha^{-1}, FYM @ 10 t ha^{-1} + $N_{40}P_{15}K_{40}$) to study the impact of nutrients on soil microbes, enzyme activities and yield of elephant foot yam – black gram cropping system in an Alfisol. Elephant foot yam (cv. Gajendra) tubers were cut into a size of 250 g, and planted in 45 cm^3 pits at a spacing of 75 x 75 cm. Black gram (local cultivar) seeds were dibbled in between elephant foot yam as an intercrop and grown up to 70 days. Intercultural activities were followed as per the schedule. The crops were harvested at maturity during January 2020 and the data is under compilation. Plant and soil samples were collected at harvest for estimation of bio-chemical constituents and nutrient composition.

Post harvest soils from individual treatments during 2018-19 were analyzed for microbial activities. Higher dehydrogenase and urease activities (1.216 µg TPF $hr^{-1}g^{-1}$ and 172.28 µg NH_4-N g^{-1} h^{-1}, respectively) were found due to application of 80-30-80 kg ha^{-1} of N, P and K, respectively as against the control values of 0.937 µg TPF $hr^{-1}g^{-1}$ and 127.92 µg NH_4-N g^{-1} h^{-1}, respectively. However, integrated application of FYM and 40-15-40 kg ha^{-1} of N, P and K, respectively showed higher FDA and acid phosphatase activities (1.352 µg g^{-1} h^{-1} and 82.17 µg PNP g^{-1} h^{-1}, respectively) in Alfisols. Increased doses of N application recorded increased activity of urease whereas, increased doses of K application tended to increase the soil biological activities. Application of lower doses of NPK along with organic manure (FYM) produced sustainable crop yields with good quality tubers of elephant foot yam and grain yield of black gram over that of higher doses of chemical fertilizers alone.

Actinomycetes and bacteria had highly significant relationship with dehydrogenase, FDA, acid and alkaline phosphatase activities, indicating that actinomycetes and bacteria play major role in enzyme mediated reactions in the soil. Corm yield of elephant foot yam had positive and significant relationship with all the enzyme activities and the 'r' values 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 dehydrogenase (r=0.911**), urease (r=0.727**), acid phosphatase (r=0.685**), alkaline phosphatase (r=0.632*) and FDA (r=0.538*). Application of balanced inorganic chemical fertilizers combined with organic manures not only helps to augment the crop yields but also enhances the microbial activities and sustain the soil quality attributes.

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

The effects of three tillage [conventional (CT), deep (DT) and minimum (MT)] and mulch types in laterite soils on variations in soil physical constants viz., soil bulk density (BD), maximum water holding capacity (WHC) and porosity properties were investigated based on soil samples collected before cassava planting for final year of study at block I of ICAR-CTCRI during June 2019. Bulk density of soils under minimum tillage continue to register higher values under minimum tillage (1.68 ± 0.06 Mg m^{-3}) whereas, conventional and deep tillage showed more or less similar values of 1.48 to 1.52 ± 0.07 Mg m^{-3}. The response of Ultisols due to continuous adoption of different tillage and mulching indicated that the soil bulk density and texture as the most important variables influencing soil organic matter, saturated hydraulic conductivity and soil sorptivity, based on previous years of study. Increased soil porosity (48.0 ± 4.2%) under CT and maximum WHC (46.1 ± 5.7%) was observed under soils of DT. Surface soil moisture storage (volumetric) and soil temperature variations were also studied at different periods of the year 2019. The average soil water storage values were found to be 7.4, 8.2 and 6.8% (v/v) and the soil temperature values were 36.6, 36.1 and 37.0°C under CT, DT and MT practices, respectively. Among the mulch practices, GC showed high moisture content (8.6%, v/v) as compared to no mulch (6.9%, v/v). Rhizosphere soil samples collected during September 2019 showed that the impact of conventional tillage and weed control ground cover sheet mulch can be remarkably seen in soil dehydrogenases (1.25 ± 0.16 µg TPF g^{-1} h^{-1}) and was highly associated with soil organic matter (with a content of 0.78 ± 0.10 %). Correlation studies showed that bulk density had a significant negative relationship with soil organic carbon (r=0.72**) in conventional tilled and GC sheet applied plots.

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

A field experiment was initiated during August 2019 at Chinnamangalam village of Pachamalai hills (11°20.711' N latitude; 078°35.669' E longitude; 693 m ± 4 m elevation msl) in view of decline in content of soil organic carbon, glomalin content in the hill cassava production systems of Eastern Ghats of Tamil Nadu. The objective was to study the performance of scientific crop production packages especially C and soil test based addition of plant nutrients and its effects on soil carbon stocks, soil properties and tuber yield of cassava. The treatments employed consist of humic acid granules applied @ 3 kg ha^{-1}, FYM applied @ 12.5 t ha^{-1} and Vesicular Arbuscular Mycorrhiza (VAM) applied @ 5 g $plant^{-1}$ which has the potential of improving the carbon storage properties and a control (farmer's practice) (Fig. 46). The cassava variety Sree Athulya, which was recently introduced in the hill, was used for the experiment in a randomized block design. Soil samples collected during August was analyzed for pH, SOC and dehydrogenases enzyme activity. In addition, the dissolved organic matter (DOM) constituting the labile portion of soil organic carbon was investigated for its presence of redox contributing groups using electrochemical procedures, as a part of carbon quality studies. The organic carbon content varied from 0.71 to 1.03% and was maximum in soils received FYM followed by humic acid granules application (0.87%). The soil pH was non-significant during the tested stage whereas, considerable difference in soil biological activity was observed. The dehydrogenases in soil which received FYM had a content of 2.14 ± 0.26 µg TPF $g^{-1} h^{-1}$ whereas, least value was measured in control soils (1.08 ± 0.18 µg TPF $g^{-1} h^{-1}$). Differential Pulse Voltammetry (Fig. 47 (R)) indicates the presence of active redox moieties in the extracted labile fraction of SOM whereas, Cyclic Voltammetry (Fig. 47 (L)) identified the reversibility of active redox moieties present in the labile fraction (DOM). Results indicated that soils of agriculture land use is found to have few redox active moieties and are more liable for oxidation-reduction conditions. The samples need to be further confirmed with spectroscopic studies for the exact composition of such groups. The crop harvest is expected during June 2020 after the onset of rainfall.

Fig. 46: Location of field experiment at Pachamalai hills, Tamil Nadu

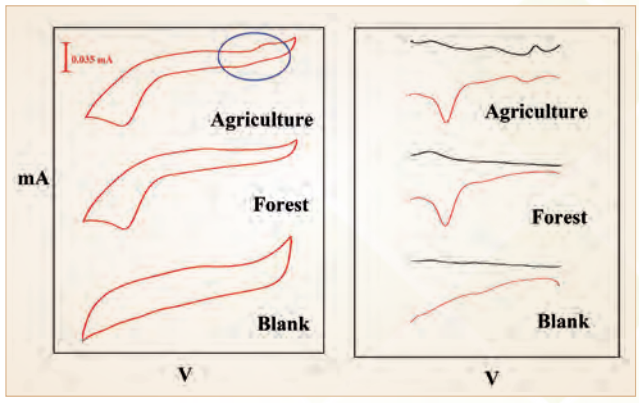


Fig. 47: Comparison of DPV and CV estimations of soil for agriculture and forest land use of Pachamalai hills

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

Studies on heat stress management in tropical tuber crops

With an objective to study the effect of induction of tolerance to high temperature stress (HTS) through chemical treatments in sweet potato, variety Sree Arun was planted during July 2019 in RBD with five replications under field conditions and the

growth and yield performance was recorded under HTS. Plants were harvested during October 2019. Sweet potato vine cuttings were planted under open field and polychamber conditions with and without humidification. Five foliar spraying treatments were given as follows (1) Control with water spray (2) Foliar spraying of 0.2% $CaCl_2$ during 4-12 weeks after planting, at fortnightly intervals (3) Foliar spraying of 0.2% Salicylic acid during 4-12 weeks after planting, at fortnightly intervals and (4) Foliar spraying of 1000 ppm Benzyl adenine (BA) during 4-12 weeks after planting, at fortnightly intervals. Prevailing weather conditions under open field and polychamber conditions with and without humidification were recorded. On bright sunny day, plants under open field conditions experienced 32-34°C temperature with 65-75% RH and 2189-2420 µmol $m^{-2}s^{-1}$ photosynthetic photon flux density (PPFD) during daytime. Inside the polychamber without humidification, sweet potato plants experienced HTS of 36 to 41.8°C with 42-55% RH and 780-1225 µmol m^{-2} s^{-1} photosynthetic PPFD during day time (10 am to 4 pm). Plants under humidified polychamber conditions experienced >65% RH with a temperature range of 34-37°C. On cloudy days, PPFD was 280-370 µmol m^{-2} s^{-1}, temperature 31°C and 67% RH under outside conditions and PPFD was 150 µmol m^{-2} s^{-1}, temperature 30°C and 68% RH under polychamber conditions. Plants under open field conditions were irrigated when there was water deficit stress whereas, plants under polychamber conditions were regularly irrigated. Photosynthetic rate, vine length, leaf area index, tuber yield per plant and per ha as well as harvest index were recorded under field as well as polychamber conditions. The crop was harvested at 16 weeks after planting (WAP). Highest photosynthetic rate (P_n) (23-28 µmol $m^{-2}s^{-1}CO_2$), vine length (214-248 cm $plant^{-1}$) tuber yield (120-179 g $plant^{-1}$, 14-18 t ha^{-1}), tuber number (2-3 $plant^{-1}$), were recorded in plants under polychamber conditions with humidification. Highest tuber yield was achieved with spraying of $CaCl_2$ (0.2%) under polychamber with humidification (18 t ha^{-1}), open field (14.7 t ha^{-1}) and polychamber without humidification (12.26 t ha^{-1}). Foliar spraying of $CaCl_2$ (0.2%) enhanced photosynthetic rate to the maximum (17-28 µmol $m^{-2}s^{-1}$ CO_2) compared to other treatments. Higher photosynthetic rate was achieved under polychamber with humidification (28 µmol m^{-2} s^{-1} CO_2) followed by open field (19 µmol m^{-2} s^{-1} CO_2) and polychamber without humidification (17 µmol m^{-2} s^{-1} CO_2). Photosynthetic rate increased up to 42-47% and 62-81% compared to open field and polychamber without humidification, respectively. Under field conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) increased tuber yield by 25%, 16% and 9%, respectively as compared to control plants under ~32°C day temperature. Under humidified polychamber conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) increased tuber yield by 25%, 14% and 8%, respectively as compared to control plants under 32-40°C day temperature and >80% RH (10 am-4 pm). Under polychamber conditions without humidification, foliar spraying of $CaCl_2$ (0.2%) and Salicylic acid (0.2%) increased tuber yield by 29% and 22%, respectively as compared to control plants under 32-40°C day temperature and ~50% RH (10 am - 4 pm).

Impact of nutrients on soil quality and yield of *Colocasia* under marshy/lowlands of eastern India

A field experiment was laid out for the second consecutive *kharif* season during 2019 at Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar with 14 treatment combinations (Control, N_{40}, N_{80}, N_{120}, P_{30}, K_{40}, K_{80}, K_{120}, $N_{80}P_{30}$, $N_{80}K_{80}$, $P_{30}K_{80}$, $N_{80}P_{30}K_{80}$, FYM @ 10 t ha^{-1}, FYM @ 10 t ha^{-1} + $N_{40}P_{15}K_{40}$) to study the impact of nutrients on soil microbes, enzyme activities and yield of *Colocasia* in the Alfisols. The experimental soil was slightly acidic in reaction (pH 6.09), non-saline (0.22 dS m^{-1}), very low in organic carbon (0.20%), low in available N (222 kg ha^{-1}), high in available P (67.1 kg ha^{-1}) and K (310 kg ha^{-1}). The soil had higher than the critical limits of S, Fe, Cu, Mn and Zn. *Colocasia* (cv. Muktakeshi) cormels were planted at a spacing of 45 x 30 cm, followed all the intercultural operations as per the schedule and will be harvested at maturity during January 2020. Plant (cormel) samples were collected for analyzing bio-chemical constituents, nutrient composition.

Soil microbial activities assessed in the post harvest soils during 2018-19 has showed that application of balanced doses of NPK ($N_{80}P_{30}K_{80}$) has shown higher dehydrogenase activity (1.226 µg TPF hr^{-1} g^{-1}) and acid phosphatase activity (64.35 µg PNP g^{-1} h^{-1}). However, highest fluorescein diacetate hydrolysis assay (1.125 µg g^{-1} h^{-1}) and urease activity (156.56 µg NH_4-N g^{-1} h^{-1}) were observed due to integrated use of FYM + 40-15-40 kg NPK ha^{-1}. The alkaline

phosphatase activity ranged from 21.84 to 77.18 µg PNP g^{-1} h^{-1} among different treatments. Soil bacterial population showed highly significant relationship with microbial activities followed by actinomycetes.

Organic C showed positive and significant relationship with all the enzyme activities and the 'r' values were found to be 0.847**, 0.719**, 0.876**, 0.760** and 0.881** in respect of dehydrogenase, FDA, urease, acid phosphatase and alkaline phosphatase activities, respectively. Increased available nutrient (N, P & K) status of the soil significantly influenced the multiplication of actinomycetes and bacteria rather than total fungi, which plays significant role in organic matter decomposition and nutrient transformations. Dehydrogenase, FDA, urease and phosphatase activities showed significant relationship with yield and bio-chemical constituents of *Colocasia*. The results indicated that application of lower and balanced doses of NPK along with organic manure enhances the productivity of *Colocasia* and sustain the soil quality.

Response of tuber crops to elevated CO_2

The relentless increase in atmospheric CO_2 is a major component of climate change. Previously, the potential increase in photosynthetic response of sweet potato, elephant foot yam and taro plants grown under field conditions to eCO_2 was studied. During the reporting year the net photosynthetic rate (P_n), stomatal conductance (g_s) and intercellular CO_2 (Ci) was studied in seven varieties of yam and six cassava genotypes under ambient (400 ppm) and eCO_2 (eCO_2) (600, 800 and 1000 ppm) at Photosynthetic Photon Flux Densities (PPFDs) viz., 200, 400, 600, 800, 1000, 1200 and 1500 µmol $m^{-2}h^{-1}$ at 30°C using portable photosynthesis system LI-6400, LICOR, USA.

Photosynthetic response of cassava varieties/ genotypes to eCO_2

The net photosynthetic rate (P_n), stomatal conductance (g_s) and intercellular CO_2 (Ci) were studied in six cassava genotypes (M-4, CMR-1, Black Thailand, Me-833 and Sree Reksha) under ambient (400 ppm) and eCO_2 (600, 800 and 1000 ppm), and the P_n at photosynthetic photon flux densities (PPFDs) viz., 200, 400, 600, 800, 1000, 1200 and 1500 µmol m^{-2} h^{-1} at 30°C and 400 ppm CO_2 using portable photosynthesis system LI-6400, LICOR, USA. With this 15 varieties were completed and the data is being analyzed.

Photosynthetic response of yam varieties to eCO_2

The net photosynthetic rate (P_n), stomatal conductance (g_s) and intercellular CO_2 (Ci) was studied in seven varieties of yam viz., Sree Dhanya, Sree Shwetha, Sree Shilpa, Sree Karthika, Sree Nidhi, Sree Priya, and Sree Haritha, under ambient (400 ppm) and eCO_2 (600, 800 and 1000 ppm), and the P_n at photosynthetic photon flux densities (PPFDs) *viz*., 200, 400, 600, 800, 1000, 1200 and 1500 µmol m^{-2} h^{-1} at 30°C and 400 ppm CO_2 using portable photosynthesis system LI-6400, LICOR, USA. The data is being analyzed. In general, the maximum P_n of seven yam varieties was recorded at PPFD of 1500 µmol $m^{-2}s^{-1}$. The P_n steadily increased due to short-term (ten minutes) exposure at eCO_2 concentrations between 400 ppm and 1000 ppm. Max increment was recorded between 400-600 ppm CO_2. In all varieties Ci steadily increased between 400 and 1000 ppm CO_2.

Climate smart agriculture (CSA) practices for tropical tuber crops

The on-station experiment to develop climate smart agriculture (CSA) practices for cassava is in progress and the crop is yet to be harvested. Soil and plant analysis are in progress to study the green house gas emission estimates of the two production systems *viz.* CSA and conventional practice (CP). Life cycle assessment studies are also in progress.

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

With an objective to quantify the relationship between $\delta^{13}C$, WUE_i, physiological, growth and yield parameters of cassava grown under normal and Water Deficit Stress (WDS) conditions, the experiment was undertaken. Results of the second year study showed that amongst the ten cassava varieties tested, Sree Reksha outperformed the other varieties in terms of plant height, number of leaves and leaf area index. Ten cassava varieties were planted during October 2018 and were harvested during September 2019. Physiological parameters like average net photosynthetic rate (P_n), average stomatal conductance (g_s), transpiration and intercellular CO_2 concentration (C_i) were analysed for these cassava genotypes under irrigated and WDS conditions and

it was found to vary considerably between these two sets of treatments.

This year, biometrical observations at final harvest revealed that plant height at final harvest ranged between 239.15-307.5 and 219.66-282.6 under irrigated and WDS conditions. Leaf retention index decreased significantly as cropping period advanced and ranged between 83.12 and 90.84, 75.75 and 83.92, 72.97 and 82.08 and between 17.14 and 26.50% at 3, 4, 5 MAP and final harvest, respectively, under irrigated conditions while, it ranged between 64.34 and 78.10, 55.49 and 72.08, 48.95 and 68.26 and between 20.42 and 39.52% at 3, 4, 5 MAP and final harvest, respectively under WDS conditions. Leaf area index was reduced ranging between 57.48 and 75.40, 46.14 and 47.77, 56.89 and 75.40 and between 39.36 and 56.71% at 3, 4, 5 MAP and final harvest, respectively. Further, harvest index was reduced up to 19.27 and 53.04% under WDS conditions as compared to irrigated conditions. In this experiment cassava tuber yield was ranged up to 41.97-67.90 (irrigated) and 23.26-52.77 t ha^{-1} (WDS) at 11 MAP. There was significant reduction in tuber yield (ranging between 20 and 53%) along with physiological parameters viz; photosynthesis (ranging between 30 and 47%), stomatal conductance (ranging between 47 and 63%) and transpiration (ranging between 33 and 60%) in the plants subjected to water deficit stress. It was revealed that Sree Reksha variety was able to maintain higher mean photosynthetic efficiency, stomatal conductance and transpiration under water deficit stress conditions ascertaining the capacity of this variety for efficient use of water. Basis for this inference corresponds with other morphological parameters like maintenance of higher mean plant height, leaf area index, leaf retention index, number of leaves, harvest index and tuber yield under water deficit stress condition. It is concluded that among ten varieties, Sree Reksha was found to be drought tolerant based on morpho-physiological parameters assessment. Considering the overall performance of the tested varieties, Sree Reksha was observed to perform better under irrigated as well as water deficit stress conditions.

Eco-friendly Strategy for the Management of Insect Pests in Tuber Crops

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

Isolation and characterization of endosymbionts of whiteflies

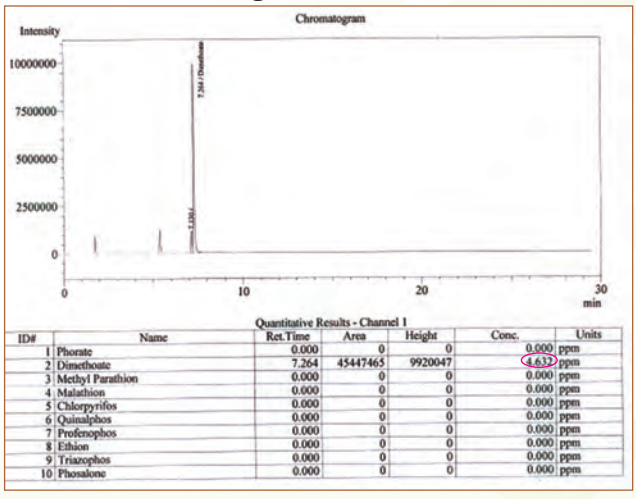
Endosymbionts are microorganisms present inside the body of insects including whiteflies in close association and perform many diverse functions like nutrition, communication, detoxification etc. Molecular identification of endosymbiotic bacteria associated with whiteflies infesting tropical tuber crops such as cassava and yam bean resulted in seven bacterial isolates. The bacterial isolates were *Bacillus cereus, Lysinibacillus fusiformis, Pseudomonas aeruginosa* from *Aleurodicus disperses* of cassava; *Acinobacter baumannii* and *Pseudomonas aeruginosa* from *Bemisia tabaci* of cassava and *Acinobacter baumannii* from *B. tabaci* of yam bean (Fig. 48). All these bacteria were reported to exhibit secondary endosymbiotic (facultative) relationship with host whiteflies.

Antibiotic susceptibility test of the isolated bacteria showed that, among two antibiotics tested Ciprofloxacin had inhibitory action towards all bacterial endosymbionts and all were resistant against Ampicillin.

Fig. 48. Bacterial colonies isolated from whiteflies on nutrient agar plates

Insecticide residue analysis in cassava

For the management of sucking pests like whitefly, mealybug and scales etc., many insecticides are recommended for drenching and spraying. Two most effective insecticides, Imidacloprid and Dimethoate at recommended doses were taken for residue analysis. The samples (cassava stems, leaves and tubers) were taken 1, 7, 14 and 30 days after drenching and spraying with Imidacloprid and Dimethoate. LC-MS and GC-MS were used for residue analysis. Results showed that, the tuber (edible part) is free from Imidacloprid residue even after 30 days of application but, 4.632 ppm Dimethoate residue was noticed in tubers of cassava 30 days after drenching (0.05 ppm is the limit) (Fig. 49). It indicated that Imidacloprid is safe to use in cassava at recommended dose; whereas, Dimethoate could be used in spraying and not in drenching.



ID#	Name	Ret.Time	Area	Height	Conc.	Units
1	Phorate	0.000	0	0	0.000	ppm
2	Dimethoate	7.264	45447465	9920047	4.632	ppm
3	Methyl Parathion	0.000	0	0	0.000	ppm
4	Malathion	0.000	0	0	0.000	ppm
5	Chlorpyrifos	0.000	0	0	0.000	ppm
6	Quinalphos	0.000	0	0	0.000	ppm
7	Profenophos	0.000	0	0	0.000	ppm
8	Ethion	0.000	0	0	0.000	ppm
9	Triazophos	0.000	0	0	0.000	ppm
10	Phosalone	0.000	0	0	0.000	ppm

Fig. 49. Residue in cassava tuber 30 days after insecticides drenching (GC-MS)

Isolation of entomopathogenic nematode

A new strain of entomopathogenic nematode, CTCRI EPN 01 was isolated from a soil sample in cassava field, Ucchakada, Thiruvananthapuram. It was identified as *Steinernema* sp. based on morphological characterization. Further, to confirm its specific identity, molecular characterization was done based on ITS region of ribosomal DNA (rDNA). The ITS sequence of CTCRI EPN 01 covering 18S and 26S rDNA region was of 672 bp length. The sequence has been deposited in the DNA GenBank under the accession number MN583000. The query sequence was compared with other *Steinernema* species in the NCBI database and the isolate was identical to *S. siamkayai* (MH091332) with maximum sequence identity of 99.7% (Fig. 50). The most closely related *Steinernema* species from the BLASTn search was aligned using ClustalW multiple alignment tool and the phylogenetic analysis in *MEGA 6* revealed that CTCRI EPN 01 is located in the same clade as that of *S. siamkayai* (MH091332), indicating that the strain CTCRI EPN 01 belongs to *S. siamkayai*. This is the first report of an entomopathogenic nematode from the rhizosphere of cassava.

Description	Max Score	Total Score	Query Cover	E value	Per. Ident	Accession
Steinernema siamkayai isolate PODAVUR small subunit ribosomal RNA gene, partial sequence; intern	1204	1204	100%	0.0	99.70%	MH091332.1
Steinernema siamkayai isolate Thayanur small subunit ribosomal RNA gene, partial sequence; internal	1204	1204	100%	0.0	99.70%	MH091330.1
Steinernema siamkayai isolate TNAU SS PKM18 small subunit ribosomal RNA gene, partial sequence;	1199	2399	100%	0.0	99.55%	MK977605.1
Steinernema siamkayai isolate CS44 small subunit ribosomal RNA gene, partial sequence; internal trar	1199	1199	100%	0.0	99.55%	MK692545.1
Steinernema siamkayai isolate CS46 small subunit ribosomal RNA gene, partial sequence; internal trar	1199	1199	100%	0.0	99.55%	MK692537.1
Steinernema siamkayai isolate CS45 small subunit ribosomal RNA gene, partial sequence; internal trar	1199	1199	100%	0.0	99.55%	MK692513.1
Steinernema siamkayai isolate CS36 18S ribosomal RNA gene, partial sequence; internal transcribed s	1199	1199	100%	0.0	99.55%	MF480759.1
Steinernema siamkayai isolate CS33 18S ribosomal RNA gene, partial sequence; internal transcribed s	1199	1199	100%	0.0	99.55%	KX886343.1
Steinernema sp. SGmtr16 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.	1199	1199	100%	0.0	99.55%	JN177514.1
Steinernema sp. SGrj5 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S	1199	1199	100%	0.0	99.55%	HQ003712.1
Steinernema sp. SGrj19 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S	1199	1199	100%	0.0	99.55%	GU354215.1
Steinernema siamkayai isolate CS37 small subunit ribosomal RNA gene, partial sequence; internal trar	1195	1195	100%	0.0	99.40%	KY311813.2
Steinernema siamkayai isolate CS13 18S ribosomal RNA gene, partial sequence; internal transcribed s	1195	1195	100%	0.0	99.40%	MK203844.1
Steinernema siamkayai strain Pak.S.S.10 18S ribosomal RNA gene, partial sequence; internal transcril	1195	1195	100%	0.0	99.40%	JF892544.1
Steinernema sp. SGgkp 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S	1195	1195	100%	0.0	99.40%	JN251021.1
Steinernema sp. SGrj17 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S	1195	1195	100%	0.0	99.40%	HQ317504.1

Fig. 50. Blast hits of *Steinernema siamkayai,* CTCRI EPN 01 with closely related species.

Sweet potato weevil management using pesticides

Impact of synthetic insecticide (Imidacloprid) and biopesticide (*Nanma*) on the infestation of pests in sweet potato at different spray schedule

Efficacy of biopesticides *Nanma* at 3 and 5% was tested and compared with Imidacloprid @ 0.01% against sweet potato weevil (*Cylas formicarius* F.). The treatment was given in the field of sweet potato (var. Sree Arun). Treatments with Imidacloprid @ 0.01% and the biopesticide *Nanma* at 3 and 5% were sprayed in the sweet potato field at weekly interval after 15, 30, 45 and 60 days after planting (DAP). The number of weevil, irrespective of sex, collected from the 5 treated and control plants were recorded daily until harvest (110 days). It was observed that there was a significant decrease in the weevil incidence in the field treated with Imidacloprid, and the total number of weevil collected until harvest was 20, 25, 66 and 99 when weekly spraying started at 15, 30, 45 and 60 DAP, respectively as against 202, 448, 590 and 780, respectively in the control. There was no significant difference in weevil collection in the treatment with *Nanma* between 3 and 5% concentrations.

A concoction of *Nanma* 3% and Imidacloprid 0.01% was prepared in three combinations as 1:1, 1:3 and 1:9 to be sprayed against sweet potato weevil at weekly interval. This was compared with the efficacy of *Nanma* (3%) and Imidacloprid (0.01%) alone, separately. Infestation at the collar region and tuber damage

by sweet potato weevil and borer was recorded. A significant reduction in the weevil incidence was noted in all the treated plants, both at the collar region and harvested tubers. No weevil infestation was observed at the collar region and tuber when plants were treated with Imidacloprid at 0.01% except mild (5%) sweet potato vine borer infestation. Plants left untreated as control had high (70%), medium (25%) and low (5%) levels of weevil infestation at the collar region. Only 20% tubers were free from weevil infestation, whereas high (70%) and medium (10%) level infestations were noted in other treatments. There was no severe infestation in the *Nanma* and Imidacloprid combinations (1:1 and 1:3), however, 25% plants had mild damage without any tuber damage. The infestation was relatively less (55%) in the plants treated with *Nanma* 3% alone, which recorded only 5% high level infestation.

Flight activity of sweet potato weevil

In order to study the peak activity of sweet potato weevil in the field, a 24 hour continuous observation was made in the field during summer and monsoon. Pheromone traps were set in the germplasm field of sweet potato and at every two hour interval, the weevil trapped were collected and counted and maximum number of male weevils were collected at 9.00 pm followed by 7.00 pm. The number of weevils collected at 2 hour intervals from 5.00 am to 5.00 pm during summer was 37, 19, 0, 1085, 794, 311, 434, 914, 2113, 1972, 283, 116 and 127, and during monsoon, it was 60, 19, 0, 553, 328, 68, 32, 813, 1142, 1212, 223, 69 and 49, respectively. In both cases, activity of the weevils started from 5.00 pm and reached a peak by 9.00 pm. The vertical distribution of the weevil was studied by fixing the pheromone traps on a pole at four vertical heights from the ground level to 1, 2 and 3 m. Maximum numbers were collected from the ground level followed by 1 and 2 m, and no weevil was noticed in the trap kept at 3 m above from the ground.

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

The identification of host plant resistance genes against sweet potato weevil is one of the alternatives in pest management strategy to develop plants resistant to weevil infestation. This experiment was designed with an objective to identify the genes coding for various proteinase inhibitors in sweet potato varieties, viz., Kisan, Sree Vardhini, Sree Arun and Sree Kanaka planted in grow bags in October, related to sweet potato weevil infestation. The intensity of feeding on the leaf, vine and petiole of the sweet potato varieties and different *Ipomoea* sp. (*I. palmata*, *I. triloba*, *I. mauritiana* and *I. obscura*) were studied by exposing them to known number of sweet potato weevils in confined plastic containers (100 ml) covered with muslin cloth. The study revealed that among the different *Ipomoea* sp. sweet potato weevil infestation was significantly less in *Ipomoea mauritiana* leaves and petioles. Specific primers were designed to study the expression of insect resistance genes like cysteine protease inhibitor (451, 138, 139, 129, 125, 126 and 101 bp) proteinase inhibitor (131, 103, 122 and 125 bp) and kunitz trypsin inhibitor (122 bp). DNA was isolated from four sweet potato varieties and *Ipomoea* sp. and were amplified with gene specific primers. For all the plants, both control and weevil infested samples were used for RNA isolation with replicates and cDNA was synthesized for Reverse Transcriptase-PCR (RT-PCR). The Cytochrome c oxidase subunit Vc (COX) reference gene was amplified in all the sweet potato and *Ipomoea* samples with sweet potato weevil infestion as well as those under controlled conditions. The gene expression related to sweet potato weevil infestation was validated with the gene specific primers for sweet potato varieties and related *Ipomoea* sp.

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

Through diversity studies of different trophic groups of nematodes in a cassava soil sample from farmer's field in Pravachambalam, Thiruvananthapram, Kerala during January, 2020, major trophic group of nematodes were distinguished based on the morphology of the anterior region particularly their feeding apparatus and oesophagus. The most prominent group was herbivores (plant feeders) which included *Tylenchus* sp., *Helicotylenchus* sp., *Pratylenchus* sp. and *Hemicycliophora* sp. followed by bacterivores (bacterial feeders, *Rhabditis* sp.), predators (nematode

feeders, *Mylonchus* sp. and *Mylonchulus* sp.), fungivores (fungal feeders, *Aphelenchus* sp.) and omnivores (both fungal and bacterial feeders), which included *Dorylaimus* sp. (Fig. 51).

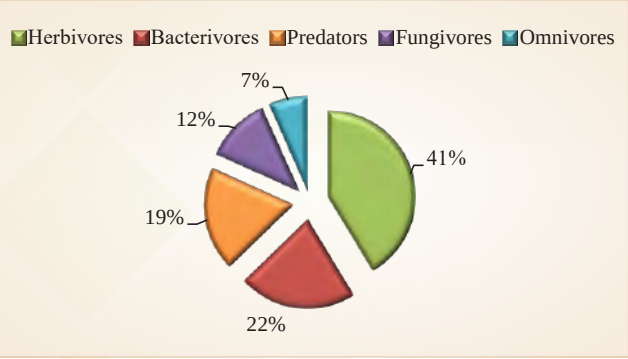


Fig. 51: Composition of major trophic categories of nematodes in cassava ecosystem

Fifteen soil samples were collected from elephant foot yam fields of ICAR-CTCRI during April 2019 to December 2019. Six genera of plant parasitic nematodes were identified viz., *Meloidogyne incognita*, *Pratylenchus coffeae*, *Rotylenchus* sp., *Tylenchorhynchus* sp., *Helicotylenchus* sp. and *Tylenchus* sp. Out of which, *M. Incognita* and *P. coffeae*, were the predominant species with prominence values of 27.3 and 19.2, respectively (Table 4).

Management of nematodes in tuber crops

A field experiment was conducted during April-May 2019 to study the effect of soil solarization on root knot nematode population. A thin transparent polythene sheet of 100 µm thickness was spread over the moistened soil for two months. The population of the root knot nematode, *Meloidogyne incognita* reduced by 50% compared to control.

Table 4. Community analysis of plant parasitic nematodes from elephant foot yam fields of CTCRI, Thiruvananthapuram

Nematode species	Relative density[1]	Absolute density [2]	Relative frequency [3]	Absolute frequency [4]	Prominence value [5]
Meloidogyne incognita	32.6	333.3	26.1	66.7	27.3
Pratylenchus coffeae	25.0	255.6	21.8	55.6	19.2
Rotylenchus sp.	20.7	211.1	21.8	55.6	15.8
Tylenchorhynchus sp.	13.0	133.33	13.0	33.3	7.7
Helicotylenchus sp.	7.6	77.8	13.0	33.3	4.5
Tylenchus sp.	1.1	11.1	4.3	11.1	0.4

1. Relative density = number of individuals of a species in a sample/ total of all individuals in a sample × 100
2. Absolute density = number of individuals of a species in a sample/ units of sample × 100
3. Relative frequency = frequency of a species/sum of frequency of all species × 100
4. Absolute frequency = number of samples containing a species/ number of samples collected × 100
5. Prominence values = absolute density × square root of absolute frequency/ 100

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

Management of fungal diseases of aroids

Epidemiological studies on taro leaf blight (TLB)

Study on the spread of taro leaf blight in a taro leaf during different weather conditions showed complete destruction of leaf within 7-8 days of initiation of symptom during rainy season in the presence of dew (Fig. 52), whereas, in the absence of rain and dew, the infection was restricted and never spread beyond 25% of leaf area (Fig. 53).

Fig. 52. Taro leaf blight spread during rainy season

Fig. 53. Taro leaf blight spread in the absence of rain and dew

Phytophthora colocasiae was isolated from wild *Colocasia* plants and the isolate could successfully infect taro leaf. Similarly, *P. colocasiae* isolate of taro origin also could infect wild *Colocasia* plants, which depicted the major role of wild *Colocasia* in the survival of TLB pathogen.

Identification of most potent isolate of *Trichoderma* to manage collar rot incidence in elephant foot yam

To select the most potent isolate, forty three isolates of *Trichoderma* spp. obtained from tuber crops ecosystem were evaluated for their antagonistic potential (by adopting three *in vitro* screening methods viz., dual culture, production of diffusible metabolites and volatiles); induction of chitinase and β-1, 3-glucanase production and effect of volatile organic compounds (VOCs) on plant growth. In dual culture, 73.3% of these isolates showed more than 50% inhibition, which ranged from 45.67% to 74.13% (Fig. 54). In antibiosis test for production of diffusible inhibitory metabolites, 86.6% of isolates showed 100% inhibition against the test fungus (Fig. 55). The inhibition varied from 41.85% (T21) –100%. The isolates varied in their ability to induce chitinase and β-1, 3-glucanase enzymes. Effect of VOCs produced by the isolates on plant growth was assessed by using mustard seeds. The isolates promoted plant growth in terms of fresh weight, number of leaves, root length, shoot length and number of shoot-lets (Fig. 56). Considering the antagonistic potential, high chitinase and glucanase production and plant growth promotion, isolates viz., T2, T15, T32, T34 (*T. asperellum*) and T40 (*T. erinaceum*) were identified as effective bio-control agents against *Sclerotium rolfsii*, the pathogen responsible for collar rot in elephant foot yam (Fig. 57).

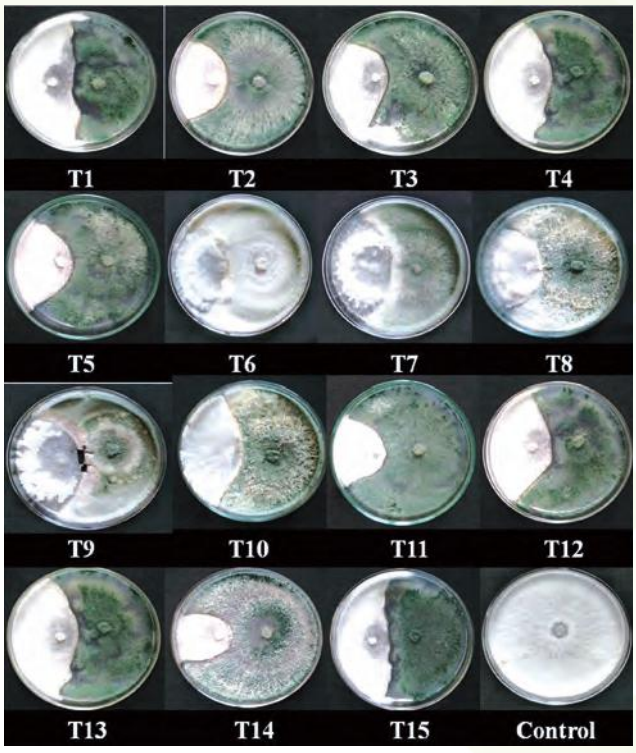


Fig. 54. Mycelial growth inhibition shown by *Trichoderma* isolates (dual culture)

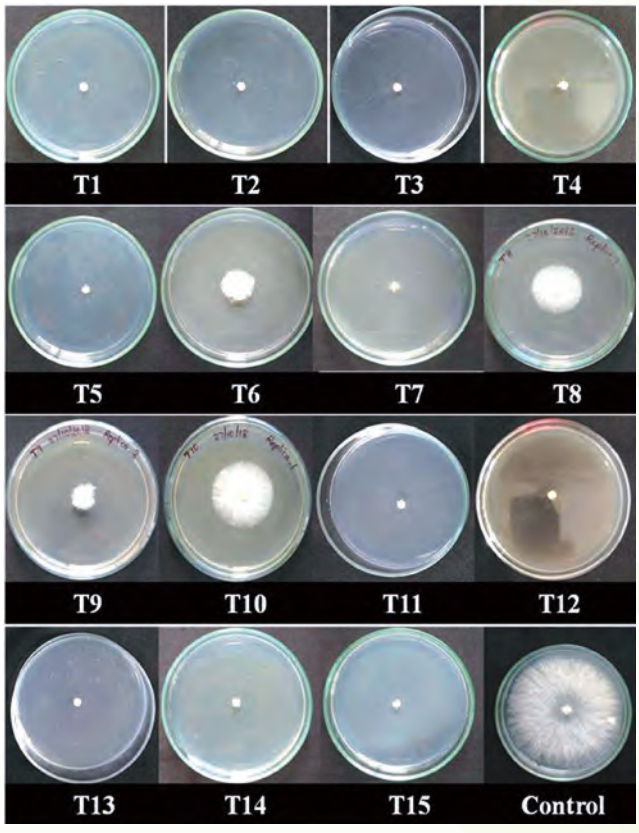


Fig. 55. Mycelial growth inhibition shown by *Trichoderma* isolates (diffusible metabolites)

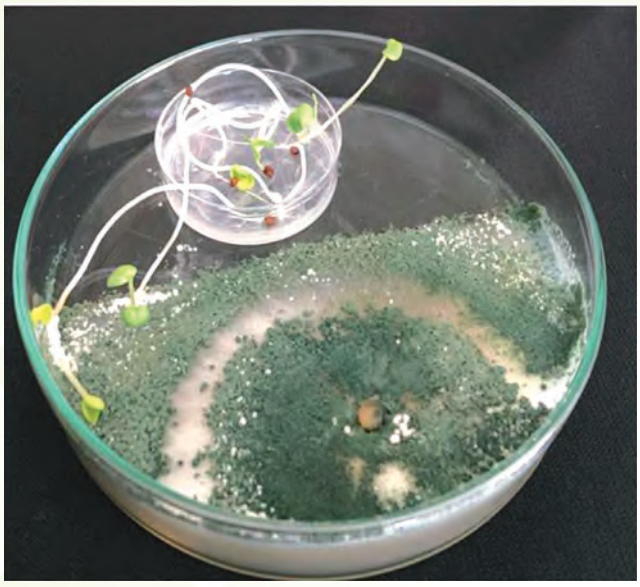


Fig. 56. Effect of VOCs produced by *Trichoderma* on plant growth

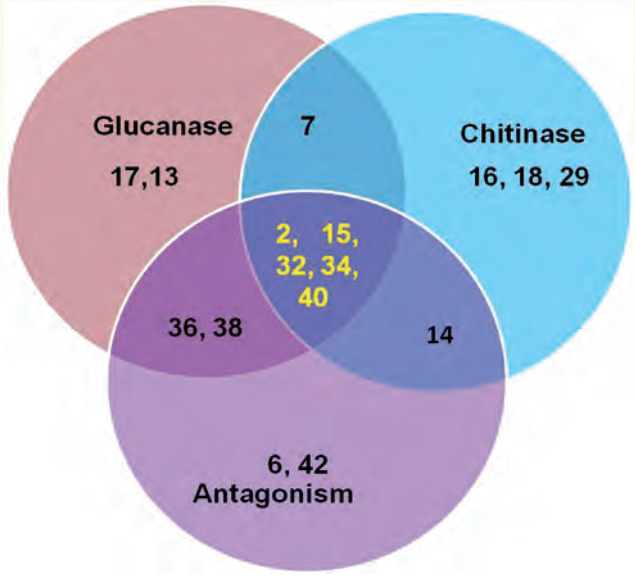


Fig. 57. Selection of *Trichoderma* isolates from the list of 10 top ranked isolates for different properties

Variability in pathogen suppression by microbes associated with tuber crops

The rhizosphere organisms isolated from cassava (3 varieties), sweet potato (5 varieties), elephant foot yam (3 varieties) and yams (5 varieties) planted in crop museum field of ICAR-CTCRI in March 2019 were screened against *S. rolfsii* and eight bacterial isolates showed excellent antifungal property (Fig. 58). Six of these isolates were associated with sweet potato varieties. The isolates were identified as *Bacillus siamensis, B. amyloliquefaciens, B. pumilus, B. halotolerans, B. subtilis* and *B. altitudinis* based on 16s rDNA amplification.

Fig. 58. Mycelial growth inhibition by 8 potent bacterial isolates

Colonization of root cells and plant growth promotion by *Piriformospora indica* in elephant foot yam

P. indica an endophytic mycorrhiza-like fungus successfully colonized elephant foot yam root cells in pots planted in March 2019. The colonization was assessed by Trypan blue staining and further confirmation of colonization was done by amplifying species specific *tef*1 gene (Fig. 59). Growth promotion was noticed in plants consequent to root colonization by *P. indica* and growth parameters like shoot length, root length, biomass, girth, leaf area etc. of host plant showed promotion (Fig. 60 and Fig. 61). It was visible from 12 days of inoculation.

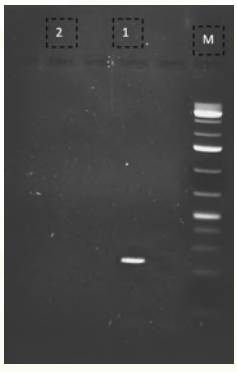


Fig. 59. Confirmation of *P. indica* colonisation in roots using *Pitef*1 primers

Fig. 60 and Fig. 61. Growth promotion in elephant foot yam consequent to *P. indica* colonization

Management of greater yam anthracnose

Field management

Biorationals and fungicidal combination

Different combinations of soil and tuber treatment with *Trichoderma asperellum*; tuber treatment with ICAR-CTCRI developed biopesticide, *Nanma* and spraying of Carbendazim (0.05 and 0.025%) and *Nanma*; tuber treatment and spraying of *Bacillus cereus* (SrS1) isolated from the stem of Chinese potato which showed maximum potential *in vitro* and under pot trial were tested in the field against anthracnose in greater yam, variety Orissa Elite planted in May 2019. Generally, the disease intensity was less during the crop period with a maximum intensity of only 50% whereas, it was 100% in 2018-2019. Tuber treatment along with spraying of *B. cereus* seven times of which, the first three were done at fortnightly intervals and the rest at monthly intervals, showed highest reduction (41%) in anthracnose intensity which was closely followed by the present package and soil and tuber treatment with *Trichoderma asperellum* and seven sprays of Carbendazim (0.05%) (40.6%) and spraying of *B. cereus* (16%). However, among all treatments, spraying 0.025% Carbendazim and *Nanma* (0.7%) seven times of which the first three at fortnightly interval and the rest at monthly intervals after symptom initiation showed highest increase in yield (22%) which was closely followed by tuber treatment with *Nanma* and spraying the above combination (17%) and tuber treatment along with spraying of *B. cereus* seven times of which, the first three at fortnightly interval and the rest at monthly intervals showed 12.5% increase.

In vitro evaluation

Endophytes from medicinal plants

Two potential non pathogenic endophytes isolated from medicinal plants, *Phyllanthus niruri* and *Aloe vera* against *Colletotrichum gloeosporioides* during 2018-2019 were identified as *B. amyloliquefaciens* and *B. licheniformis* (Fig. 62). A pot trial was laid out in greater yam (var Orissa elite) during May 2019 with tuber treatment and spraying of both the endophytes. The anthracnose intensity was not significantly different between treatments. However, spraying *Bacillus licheniformis* showed highest yield (24.22 t ha^{-1}) followed by spraying and tuber treatment with *Bacillus amyloliquefaciens* (14.99 t ha^{-1}) and tuber treatment with *Bacillus licheniformis* (13.63 t ha^{-1}) as compared to control (5.38 t ha^{-1}). Study on secondary metabolite production of these isolates showed that Dimethyl sulfoxonium formylmethylide, a compound identified from ethyl acetate fraction of cell free culture filtrate of *B. licheniformis* by GC-MS, had antifungal activity.

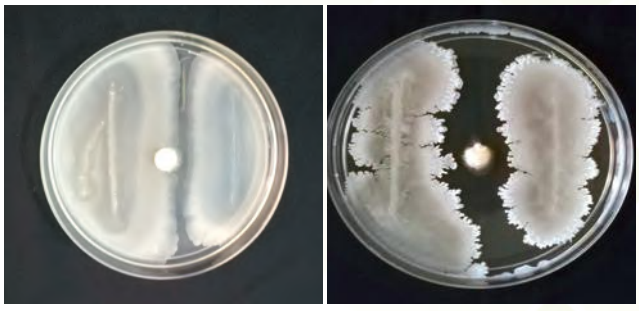


Fig. 62. Effect of *B. amyloliquefaciens* and *B. licheniformis* on *Colletotrichum gloeosporioides* in dual culture

Screening fungicides against *Colletotrichum gloeosporioides*

The fungicides, viz., Propiconazole, Tebuconazole, Thiphanate methyl and combination of Tebuconazole and Trifloxystrobin were screened against *Colletotrichum gloeosporioides* causing greater yam anthracnose *in vitro*. Thiphanate methyl showed 100% inhibition even at 2.5 ppm concentration followed by Propiconazole which showed 89% at 20 ppm concentration after seven days of incubation (Fig. 63).

Fig. 63. Mycelial inhibition of *Colletotrichum gloeosporioides* by Thiophanate methyl *in vitro*
(a: 10; b: 7.5; c: 5.0; d: 2.5; e: 0 ppm)

Epidemiology

The development of anthracnose in greater yam was observed for the fifth year during 2019-2020 to advise the farmers for managing the disease based on weather parameters. Disease severity was observed in the greater yam varieties, viz., Orissa Elite (highly susceptible), Sree Karthika and Sree Keerthi (resistant) at weekly intervals till seventh month of planting i.e., November. The susceptibility score value based on AUDPC were 5.00, 0.68 and 1.72, respectively

Characterisation, diagnosis and management of viruses of tuber crops

Yam mild mosaic virus (YMMV)

Yam mild mosaic virus infection in different ICAR-CTCRI germplasm lines of *Dioscorea alata* was diagnosed using partial coat protein primer YMMV 1S and YMMV 1C. The molecular characterization showed that the sequence got maximum similarity with the isolates from China (NCBI Ac No. KJ125474.1) and Papua New Guinea (AB022424.1). A full coat protein primer with restriction sites were designed and named YMMV TCPF as forward and YMMV TCPR as reverse and was validated. The isolated amplicons were cloned in pUC 19 vector for further investigation.

Dasheen mosaic disease

Field experiments were conducted during March-December for dasheen mosaic disease progress and yield loss in elephant foot yam var Gajendra. The incidence was 4.3% and yield reduction due to DsMV infection was recorded as 25.5%. In order to produce disease free planting material, calli were obtained from meristem culture of elephant foot yam (cvs. *Karunakizhangu* and Gajendra) from corm tips and multiple shoot induction was done.

Tobacco(*Nicotianabenthamiana*)wastransformed with hairpin gene construct of DsMV coat protein gene for evaluating their level of protection against DsMV infection. Transformants were obtained and are being multiplied.

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

Molecular mechanism of *cassava mosaic virus* infection

Using NGS technology, small RNA sequencing was done with healthy and CMD infected cassava plants at Agrigenome, Cochin. Three small RNA libraries were sequenced from the leaves of control uninfected plants (H226C) and SLCMV infected plants (H226 I1 and H226 I2). After removing the low-quality reads, a total of 13660874 raw reads were obtained in the control leaf library. Whereas, in the infected leaf library, replicate 1 and replicate 2 constituted 13488952 and 10169846 total raw reads. The unique small RNAs in H226C was 2,627,476, while in H226 I1 and H226 I2, library consisted of 1,116,532 and 977,318 unique reads, respectively. The unique reads were further annotated into different RNA classes such as siRNA, piRNA, snRNA, snoRNA, tRNA and rRNA (Fig. 64). The clean reads after removal of other non-coding RNAs constituted 4388762 total reads, contributing 1950971 unique small RNAs. Among this, 96.53 per cent of the unique small RNAs had length ranging from 17 to 35bp (Fig. 65). Four novel miRNAs were predicted from the library data. The size of the predicted miRNAs ranged from 18 to 25nt. The precursor characteristics of the novel miRNAs were identified. All the miRNAs predicted possessed a typical hair-pin like precursor and its corresponding star sequences were also detected from the small RNA datasets. mes-miR2118 showed eight-fold increase in expression in the infected leaf. Meanwhile, mes-miR395a and mes-miR156h showed significant downregulation in the infected leaf. The expression of miRNAs analysed from their corresponding read numbers in each library revealed differentially expressed seventy nine miRNAs. Among which, forty three miRNAs were upregulated ($Log_2 \geq 0.5$) and twenty miRNAs were downregulated ($Log_2 \leq 0.5$). The mes-miR9386 and mes-miR2118 showed significant upregulation ($p \leq 0.05$) during infection. The analysis of small RNAs from the infected leaf library revealed 10336 and 8414 unique RNA reads from the H226 I1 and H226 I2, respectively, mapped to the SLCMV bipartite genome. Altogether, 0.19% of the total reads from both the infected leaf library reads combined mapped to SLCMV genome (Fig. 66 and 67).

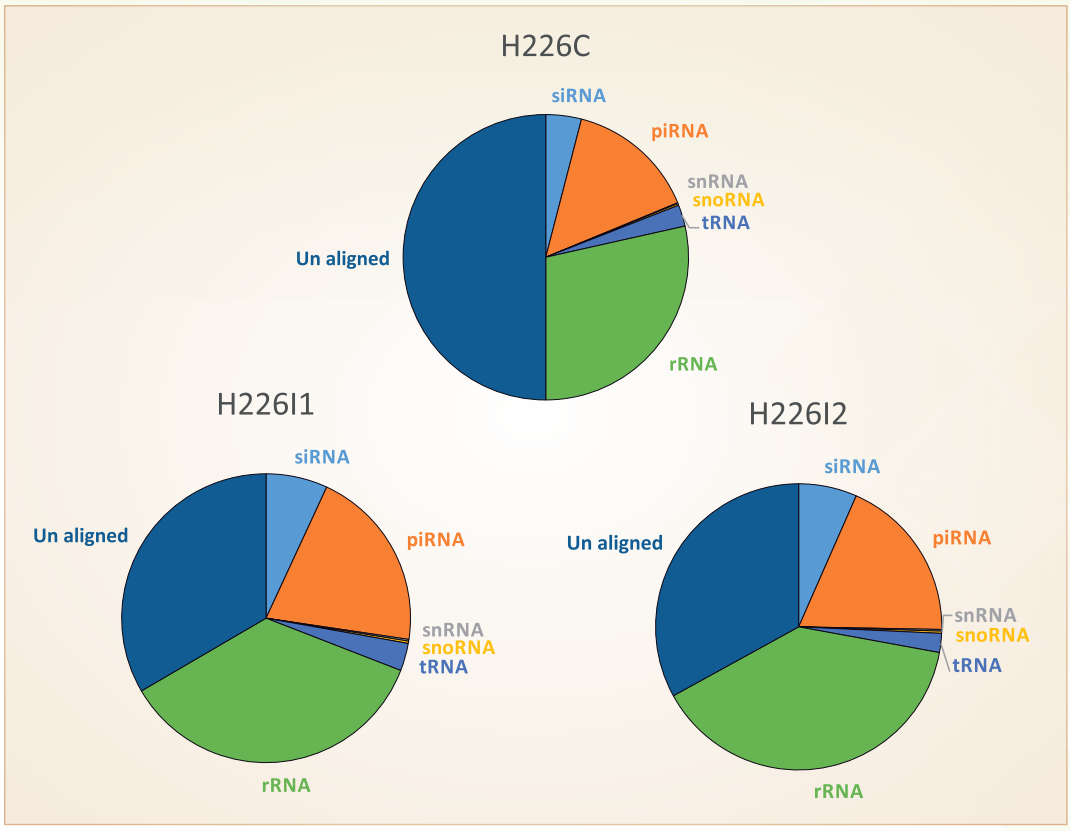


Fig. 64. Functional categorisation of small RNAs

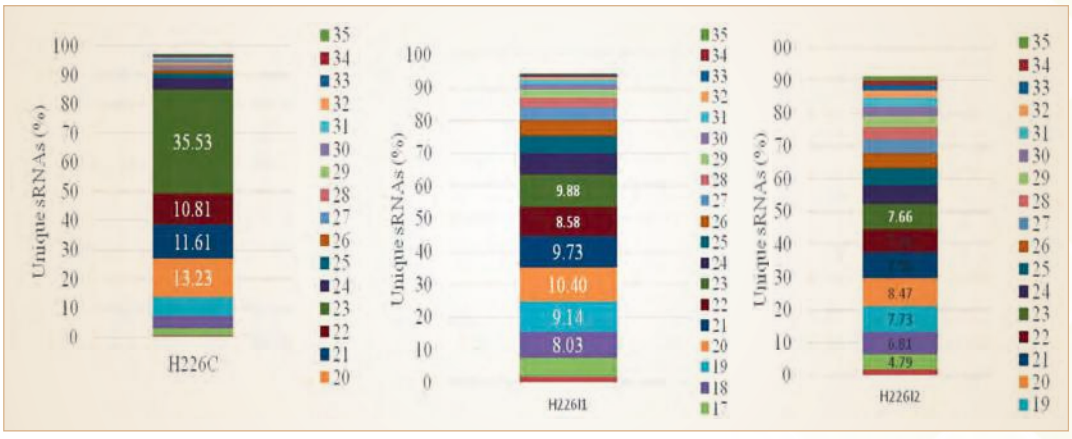


Fig. 65. Length distribution of unique small RNAs

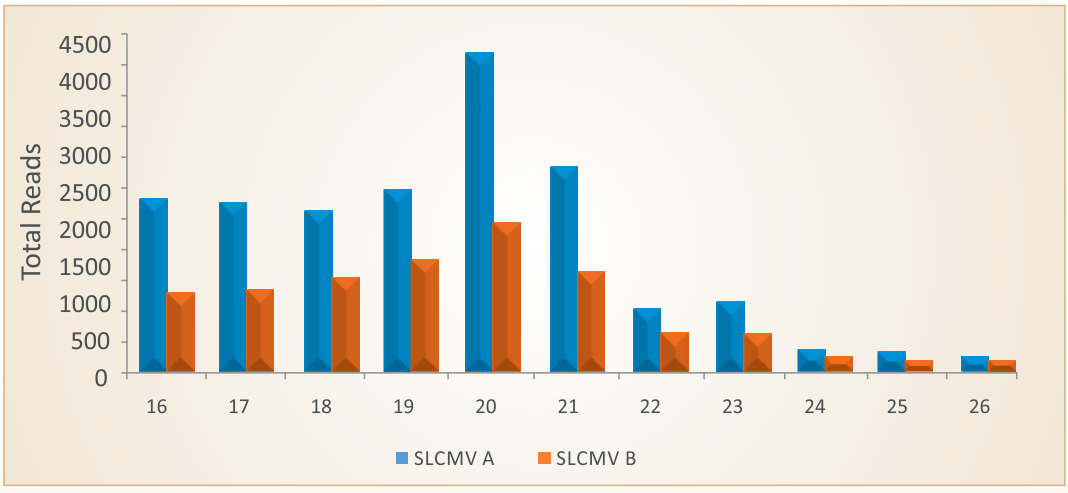


Fig. 66. Length distribution of SLCMV derived small RNAs

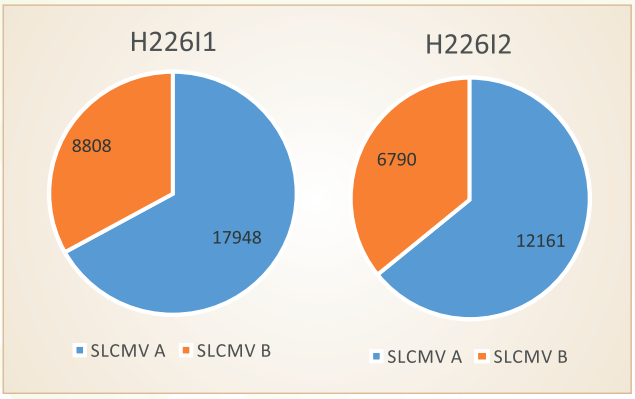


Fig. 67. Small RNA reads mapped to the SLCMV genome

Management of cassava mosaic disease through resistant varieties

Nine cassava mosaic disease resistant genotypes were evaluated in replicated yield trial along with Sree Reksha as check variety. Molecular marker analysis of these genotypes using CMD resistance linked markers viz. SSRY28 and SSRY44 also confirmed the resistance of these genotypes. In the evaluation trial, Sree Reksha had recorded the highest number of tubers plant^{-1} (20.3) followed by 17S-234 (15.7). Among the genotypes, the highest tuber yield plant^{-1} was also produced by 17S-234 (67.2 t ha^{-1}) followed by KBH-18 (65.23 t ha^{-1}). 17S-247 had the highest dry matter (40.8%) followed by 17S-48 (38.4%). Excellent cooking quality along with CMD resistance was recorded in genotypes, viz., 17S-36, 17S-40, 17S-48 and 17S-209.

The pyramiding of different sources of CMD resistance genes was undertaken using cryo-preserved pollen of different sources of resistance through marker assisted breeding. The crosses involving nine elite genotypes viz., Sree Padmanabha, KBH-26/18, CR-43-8, 8W-5, CI-1301, 15S-103, 15S-106, 17S-234 and 17S-143. The percentage seed set ranged from 0 to 75%. The cross CI-1301 x 17S-143 resulted in the highest percentage of fruit set (75%) followed by CI-1301 x 17S-234 when cryo-preserved pollen was used for pollination. In total, 264 seedlings were transplanted to evaluate for CMD resistance.

Nutrient management of pre-released CMD resistant cassava clones

A field trial to standardize the nutrient requirement of six new CMD resistant pre release clones was laid out during September 2018 to July 2019. The clones tested were CR-43-2 (V1), 15S-59 (V2), 15S-409 (V3), 15S-154 (V4), CR-43-7 (V5) and 8S-501-2 (V6) along with the released variety 24-4 (Sree Reksha) (V7). Three nutrient doses viz., 75-50-75 (F1), 100-50-100 (F2) and 125-50-125 (F3) kg N, P_2O5 and K_2O were included as the treatments. Initial soil samples were analysed for nutrient status and the soil was found to be high in organic carbon, available phosphorus and available potassium and medium in available nitrogen. Agronomic parameters were recorded at two month intervals. The crop was harvested during July 2019. There was significant difference in tuber yield among the varieties. Maximum tuber yield was recorded in the clone 8S-501-2 (30.4 t ha^{-1}) followed by 15S-409 (28.7 t ha^{-1}). Among the subplots, F2 and F3 were statistically on par. The interaction effects of the treatments indicated that F1 level of nutrients ie., 75-50-75 kg was sufficient for all the varieties except V6 and V7. Maximum tuber yield in the by 8S-501-2 (42.9 t ha^{-1}) was recorded with a nutrient dose of 100-50-100 whereas, Sree Reksha responded to higher level of nutrients and produced maximum tuber yield (51.1 t ha^{-1}). The second season trial is in progress.

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

NAC gene family members play an important roles in the regulation of the transcriptional reprogramming associated with plant stress responses to virus infection. Twelve virus responsive *NAC* genes i.e. *MeNAC22, MeNAC28, MeNAC38, MeNAC59, MeNAC62, MeNAC63, MeNAC79, MeNAC99, MeNAC113, MeNAC116, MeNAC120* and *MeNAC121* were under regulation of ten miRNAs (*MemiR156, MemiR157, MemiR159, MemiR167, MemiR169, MemiR172, MemiR319, MemiR394, MemiR395* and *MemiR1030*). Details of miRNA targeting *MeNAC* genes is given in Table 5.

Table 5. miRNAs targeting *MeNAC* genes

Gene	miRNA	Inhibition
MeNAC22	*MemiR319*	Cleavage
MeNAC28	*MemiR157*	Translation
	MemiR159	Cleavage
	MemiR172	Translation
MeNAC38	*MemiR394*	Cleavage
	MemiR394	Cleavage
MeNAC59	*MemiR395*	Cleavage
MeNAC62	*MemiR159*	Cleavage
	MemiR1030	Cleavage
	MemiR172	Cleavage

MeNAC63	*MemiR167*	Cleavage
	MemiR172	Cleavage
	MemiR159	Cleavage
MeNAC79	*MemiR167*	Cleavage
MeNAC99	*MemiR394*	Cleavage
MeNAC113	*MemiR156*	Cleavage
	MemiR159	Cleavage
	MemiR319	Cleavage
	MemiR169	Cleavage
MeNAC116	*MemiR172*	Cleavage
MeNAC120	*MemiR395*	Cleavage
MeNAC121	*MemiR395*	Cleavage

Virus - vector relationship and vector management

Behavioural modifications, viz., fecundity, adult longevity and life cycle in *Bemisia tabaci* during interactions between *Cassava mosaic virus* and *B. tabaci* in different cassava genotypes were studied.

Study on fecundity of *B. tabaci* in six different cassava genotypes, viz., CMR-9, CMR-128, CMR-1, CMR-102, H 226 and H 165 showed that, the highest number of eggs laid, in case of virulent ones, was in susceptible cassava genotypes H-165 (80.33) followed by H-226 (68). In the case of non virulent ones, maximum number of eggs was laid in susceptible cassava genotypes H-226 (87.67) followed by H-165 (87). The effect of interaction (virulence and non-virulence x cassava genotypes) on the fecundity of *B. tabaci* were significantly different. Virus infection increased percent egg viability of *B. tabaci*. Whiteflies deposited significantly fewer eggs on virus infected plants as compared to healthy plants (Fig. 68).

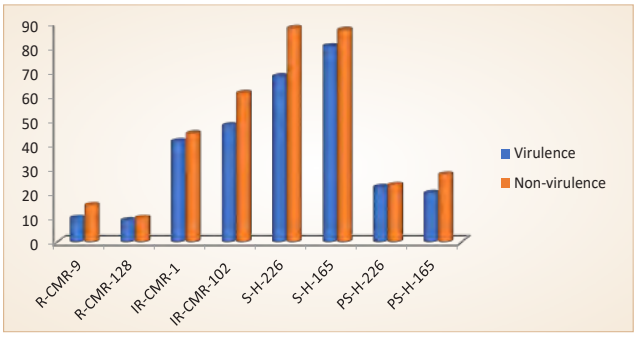


Fig. 68. Influence of cassava genotype on fecundity of *Bemisia tabaci* (NB: R-Resistant, IR-Infected but recovering, S-Susceptible, PS-Purposefully virus infected susceptible. Average of ten insects. Eggs laid for 3 generations (one pair/plant).

In both virulent female and male, the highest longevity was observed in susceptible genotypes H-226 (12.73 and 10.93 days, respectively) followed by H-165 (11.87 and 59.90 days, respectively). In the case of non-virulent female and male, adults lived longer in susceptible genotypes H-165 (16.07 and 12.93 days, respectively) followed by H-226 (15.23 and 12.70 days, respectively). The longevity was significantly different in the three way interaction (virulence and non virulence x sex of the insect x cassava genotypes) (Fig. 69).

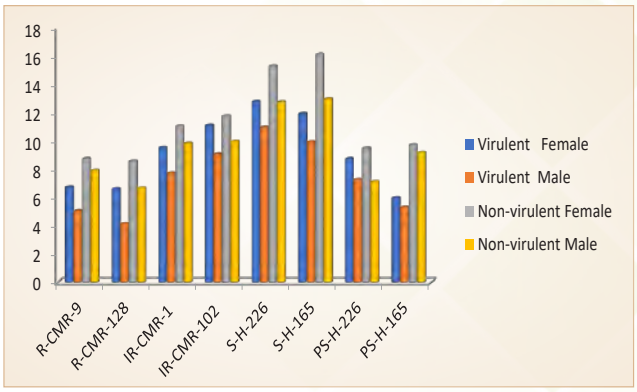


Fig. 69. Influence of cassava genotype on adult longevity of *Bemisia tabaci* (R-Resistant, IR-Infected but recovering, S-Susceptible, PS-Purposefully virus infected susceptible. Average of ten insects (twenty pupae/plant).

In case of virulent female, life cycle was highest in resistant cassava genotype CMR-128 (30.77 days) and it was followed by infected susceptible genotype H-226 (29.77 days). For virulent male, insects lived longest in infected but recovering genotype CMR-1 (27.90 days) and it was followed by resistant cassava genotype CMR-128 (26 days). In the case of both non-virulent female and male, longest life cycle was observed in resistant cassava genotype CMR-128 (27.90 and 23.43 days, respectively) (Fig. 70). The life cycle was significantly different in the three way interaction (virulence and non virulence x sex of the insect x cassava genotypes) .

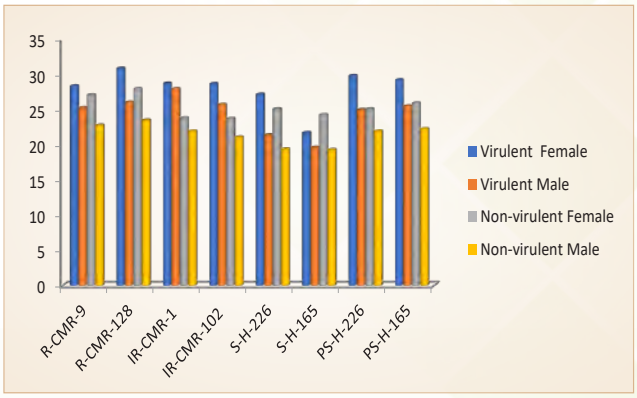


Fig. 70. Influence of cassava genotype on life cycle of *Bemisia tabaci* (R-Resistant, IR-infected but recovering, S-Susceptible, PS-Purposefully virus infected susceptible. Average of one adult pair studied for three generations)

Integrated management of cassava mosaic disease

Nutrient management

For the integrated management of cassava mosaic disease using nutrient management practices, the second year experiment was conducted during October 2018 to July 2019 with nutrients viz., P, K, Ca, Mg, Si, Zn and B along with Devirus, ginger mixture (GM) applied as soil application and foliar spray and compared with the existing package of practices (PoP) and absolute control. The results showed no significant effect of treatments through soil and soil + foliar application on tuber yield over PoP. Zn, Devirus, P, B and Si resulted in an yield to the tune of 48.57, 47.47, 41.60, 39.70 and 39.57 t ha^{-1}, on par with PoP (48.57 t ha^{-1}) while, for the other nutrients viz., K, Ca and Mg, the yield was lower to the tune of 34.10, 33.43 and 32.70 t ha^{-1}, respectively.

As regards to the symptom manifestation determined through disease indexing indicated a sharp decline over period of time with an overall mean percentage of 92.61, 71.87, 61.17, 39.05 and 19.69, respectively at 20, 45, 60, 120 and 180 DAP, respectively. The order of nutrients in manifesting the CMD symptom was Devirus<P<Zn<B<Ginger mixture<Mg<Si <K<Ca with mean intensity as 50.7, 52.1, 52.6, 53.2, 54.3, 55.5, 55.8, 56.8 and 57.2% as compared to 66.0 and 71.4%, respectively for absolute control and PoP (Fig. 71 and 72).

Correlation was worked out between leaf nutrients and soil nutrients with mean intensity at 3, 6 and 9 MAP

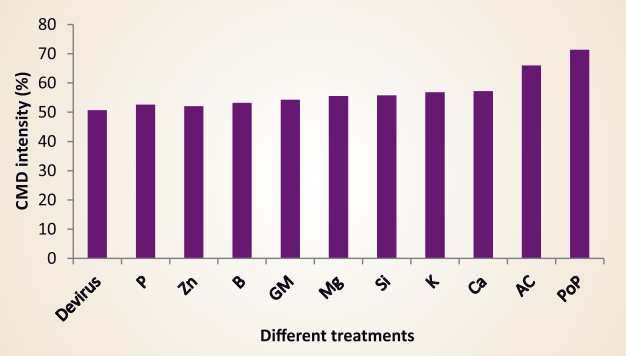


Fig. 71. Intensity of CMD (%) under the influence of different treatments Devirus: Bioviricide; P: Phosporous; Zn: Zinc; B: Boron; GM: Ginger nutrient mix from ICAR-IISR; Mg: Magnesium; Si: Silicon; K: Potassium; Ca: Calcium; AC: Absolute control; PoP: Package of practice

indicated significant positive correlation between leaf N and MDI at 3 MAP (p (0.05)=0.368), significant negative correlation of leaf P (p (0.05)=0.480), leaf Mg (p (0.05)=0.556) and soil K (p (0.05)=0.569) at 6 MAP and positive correlation of soil pH (p (0.05)=0.388). At 9 MAP significant negative correlation was observed for leaf N (p (0.05)=0.491), P (p (0.05)=0.736), Ca (p (0.05)=0.428), Mg (p (0.05)=0.799), Zn (p (0.05)=0.556) and soil P (p (0.05)=0.476) and K p (0.05)=0.640) with MDI.

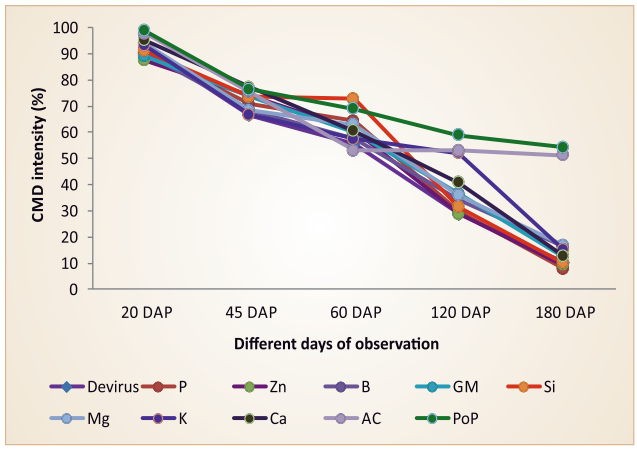


Fig. 72. Decline in intensity of CMD over a period of time under the influence of nutrients Devirus: Bioviricide; P: Phosporous; Zn: Zinc; B: Boron; GM: Ginger nutrient mix from ICAR-IISR; Mg: Magnesium; Si: Silicon; K: Potassium; Ca: Calcium; AC: Absolute control; PoP: Package of practice

Re-infection rate of virus free planting material of cassava

Cassava mosaic virus free planting material of cassava varieties viz., Sree Vijaya (5000 stems), Sree Jaya (4000 stems), Sree Pavithra (2000 stems) and Sree Reksha (500 stems) (Fig. 73) were produced in the fields of ICAR-CTCRI. The primary source was meristem cultured plants. The rate of re-infection of virus was nil up to two months and it was 6 and 7% at 3rd month; 12 and 14% at 4th month; 26 and 28% at 8th month after planting the varieties of Sree Vijaya and Sree Jaya, respectively using virus free stems. Planting of virus infected cassava material showed that the virus symptoms were noticed at the first month itself and the virus incidence was 13 and 18% at 2nd month, whereas, the incidence of 32 and 39% were noticed at 3rd month and 41 and 48% at 4th month and 62 and 74% at 8th month after planting in the varieties of Sree Vijaya and Sree Jaya, respectively.

Development and Refinement of Post-harvest Handling, Storage and Processing Techniques for Minimization of Losses in Tropical Tuber Crops and Production of Value Added Products

Development of value added food products from tuber crops

Development of papad from cassava based composite flour

Cassava (var. Sree Vijaya) based composite flour containing cassava flour, sago flour and maida/ black gram flour was used for making papad. In one experiment, papad was made from the dough of cassava flour (40 to 60%), maida (10 to 30%) and sago flour (20 to 40%) (Fig. 73a) by the solid dough technology by employing Box Behnken response surface design for the process optimization. The various biochemical and frying properties of the papad were evaluated. Moisture content of the papad before frying ranged from 5.04 to 11.63%, starch content from 64.20 to 72.58% and sugar content from 3.93 to 6.10%. The maximum protein content in the papad was 5.95% and minimum was 3.67%. The fibre content ranged between 0.11 and 0.50%. The fat content of the fried papad varied from 7.95 to 21.78% and the diametrical expansion from 6.85 and 73.16%. From the optimized composition obtained by the response surface analysis, the papad made with the composite flour containing 46.8% cassava flour, 18.5% maida and 38.2% sago was found to have a protein content of 4.81%, crude fibre content of 0.31% and fat content of 16.13% in the fried papad. The weight increase after frying was 24.86% and diametrical expansion was 44.05%.

Papad was also made from the dough of cassava flour (50 to 60%), black gram flour (20 to 30%) and sago flour (20 to 30%) (Fig. 73b). Moisture content of the papad before frying ranged from 10.17 to 15.94%, starch content from 44.33 to 55.90% and sugar content from 4.17 and 6.94%. The maximum protein content in the papad was 6.10% and minimum was 4.8%. The fibre content ranged between 0.62 and 2.57%. The fat content of the fried papad was in the range of 16-18% and the diametrical expansion was 17.97-61.95%. The optimized composition obtained by the response surface analysis was 52.63% cassava flour, 23.72% black gram and 23.65% sago flour and this papad had a protein content of 5.2%, crude fibre of 1.11%, diametrical expansion of 33.95% and fat content of 17.3% in the fried papad.

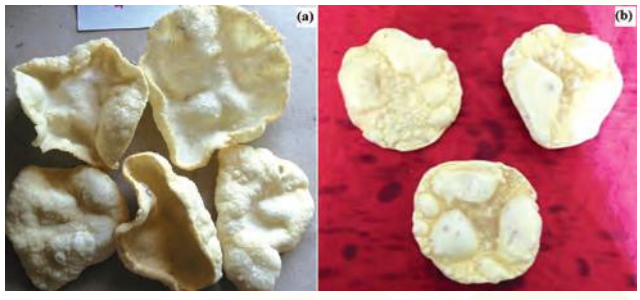


Fig. 73. Cassava papad made from (a) cassava flour, maida and sago flour and (b) cassava flour, black gram flour and sago flour

Rice analogue from sweet potato based composite flour

Rice analogue was prepared from the composite flour containing sweet potato flour (60-70%), refined wheat flour (20-30%), whey protein concentrate (5-10%), starch and guar gum. The physico-chemical, functional and cooking characteristics of the rice analogue were analyzed. The experiments were designed by response surface methods by employing mixture design. The physical properties were as follows: thickness ranged from 1.59 to 2.54 mm, width: 2.23 - 3.41 mm, length: 5 - 6 mm, sphericity: 0.48 - 0.62, surface area: 23.27 - 43.76

mm^2, volume: 7.23 - 10.74 mm^3, eccentricity index: 1.76 - 2.64, flatness index: 6.53 - 11.95, bulk density: 479 - 576 kg/m^3, tapped density: 511 – 631 kg/m^3 and porosity: 53.05 - 62.56. Biochemical analysis of the rice analogue yielded the following results. Moisture content: 5.81 - 8.57%, starch content: 34.82 - 58.89%, sugar content: 3.76 - 8.77%, protein: 8.05 - 12.43%, fat: 0.85 - 1.35% and fiber content: 0.47 - 0.97%. The cooking quality analysis of the rice analogue showed that swelling index varied between 2.27 - 4.11%, cooking loss ranged from 9.28 - 13.87% and cooking time from 6.43 to 9.18 min. The total colour difference of the rice analogue varied from 32.47 to 37.42% and yellowness index from 32.41 to 39.28%. Among the functional properties, solubility index ranged from 4.21 to 9.21%, swelling power from 8.15 - 10.02%, oil absorption index from 1.80 to 2.42% and water activity ranged from 0.489 - 0.631.

The optimized conditions for the rice analogue from sweet potato-maida-whey protein concentrate were as follows: 65.27% sweet potato flour, 29.72% maida and 5.00% whey protein concentrate. The various properties were as follows: thickness 1.9 mm, width: 2.31mm, length: 6 mm, sphericity: 0.54, surface area: 29.02 mm^2, volume: 7.76 mm^3, eccentricity index: 2.57, flatness index: 7.92, bulk density: 507 kg/m^3, tapped density: 525 kg/m^3 and porosity: 54.53. Biochemical analysis of the rice analogue yielded the following results. Moisture content: 6.52%, starch content: 54%, sugar content: 8.2%, protein: 9.6%, fat: 0.97%, fibre content: 0.97%. The cooking quality analysis of the rice analogue showed that swelling index was 2.93%, cooking loss 9.49% and cooking time 7.96 min.

Rice analogue from multi tuber flour

Cassava flour (0 - 65%) was blended with sweet potato (0 - 65 %) and maida flours (20 and 25%) in different ratios along with tapioca starch and whey protein concentrate and rice analogue was made by extrusion. Their proximate composition viz., moisture content, starch, sugar, protein, fibre, ash, fat and cooking quality such as cooking time, cooking loss and swelling index as well as physical properties were analyzed. The moisture content varied from 6.68 to 9.70%, starch 64.49 to 68.56%, sugar content 7.23 to 9.78%, fat content 1.41 to 3.97%, fiber content 0.18 to 0.52%, ash content 1.25 to 1.60% and protein content 8.75 to 10.33%. The analysis on cooking characteristics revealed that the cooking loss ranged from 9.25 to 14.32%, swelling index 2.12 to 3.07% and cooking time 5.46 to 7.21%. The physical properties were determined and it was found that the length of the rice analogue varied from 6.53 to 7.00 mm, width 1.97 to 2.65 mm, thickness 1.76 to 2.05 mm, geometrical diameter 2.86 to 3.26 mm, sphericity 0.42 to 0.49 mm, surface area 25.87 to 34.44 mm^2, grain volume 6.30 to 9.77 mm^3 and bulk density from 470 to 620 kg/m^3. Rice analogue prepared from 80% sweet potato (Fig. 74) and 20% cassava flour was selected as superior by organoleptic analysis, which had the following biochemical properties: starch content 66.50%, sugar content 8.17%, moisture content 9.13%, fat content 3.87%, fibre content 0.37%, ash content 1.46% and protein content 9.45% with energy value 374.90 kcal.

Fig. 74. Rice analogue from (a) sweet potato based composite flour (b) multi tuber flour

Tannia chips

The tannia tubers of a local variety after peeling and washing were sliced into chips (2 mm thick) and subjected to various pre frying treatments by soaking in calcium hydroxide (0.5 and 1%), citric acid (0.25 and 0.5%) and acetic acid (0.25 and 0.5%) solutions for 15, 30 and 45 minutes. The pre-treated slices were soaked in sodium bicarbonate solution for 20 min in order to neutralize the acid and then washed to remove the alkali residue. The slices were then allowed to drain for few minutes to remove the excess water and were subjected to open submersion frying at an oil temperature of 170-180°C for 6-7 min or till it became crispy. Moisture content of the chips ranged from 2.37 to 5.78% for the fried chips made after soaking the slices in calcium hydroxide and acetic acid, respectively. Maximum starch content of 61.98% was obtained for the fried chips made after soaking the slices in calcium hydroxide whereas, minimum of 50.71% for acetic acid treated slices. The maximum sugar content of 3.47% and minimum of 1.75% was obtained for the chips made after soaking the slices in citric acid and acetic acid,

respectively. Protein content ranged from 4.20% for the fried chips made after soaking the slices in citric acid to 2.63% for the chips made after soaking in calcium hydroxide. Maximum fibre content of 5.62% was obtained for the slices soaked in calcium hydroxide whereas, minimum of 1.36% for citric acid. Fat content ranged from 25.08 to 34.07% and ash content varied between 1.84% for acetic acid treated samples and 0.13% for the chips made after soaking in citric acid. The tannia chips (Fig. 75) were evaluated for their sensorial attributes viz., appearance, taste, texture, colour, itching and overall acceptability using a 9-point hedonic scale and overall acceptability of 8.5 was obtained for the samples pre-treated in 0.25% acetic acid solution for 45 min.

Fig. 75. Tannia chips

Pop-ups from cassava - sago - wheat semolina

Cassava-sago-wheat semolina flour-based pop-ups were prepared (Fig. 76) by deep fat frying of the sheets made with the composite flour in the steamed and un-steamed conditions. The composite flours used for pop-up preparation were: 100% semolina (N1), 100% steamed sago powder (N2), 60% steamed sago and 40% semolina (N3), 50% steamed sago and 50% semolina (N4), 40% steamed sago and 60% semolina (N5), 30% steamed sago and 70% semolina (N6), 100% un-steamed sago (N7), 60% sago and 40% semolina (N8), 50% sago and 50% semolina (N9), 40% sago and 60% semolina (N10), 30% sago and 70% semolina (N11). The biochemical properties such as moisture, starch, sugar, fat, fibre, protein and ash contents were determined and sensory analysis was also done. The moisture content ranged from 9.78% (for N7) to 3.22% (N3), ash content from 2.99% (N4) to 1.51% (N6), protein content from 7.0% (for N1) to 0.52% (for N7), sugar content from 2.50% (N6) to 1.02% (N10), starch content from 55.55% (N11) to 46.63% (N3), fat content from 32.09 % (N2) to 12.85% (N1), ash content from 1.08% (N2) to 0.19% (N4), energy content from 508 kcal (N2) to 367 kcal (N1).

Fig. 76. Pop-ups from cassava-sago-wheat semolina

Crackers from cassava- sago- wheat flour

'Crackers' (Fig. 77) were prepared from the composite flours containing 50% cassava flour, 25% sago powder, 25% wheat flour (N1), 40% cassava flour, 30% sago powder, 30% wheat flour (N2), 30% cassava flour, 35% sago powder and 35% wheat flour (N3), 20% cassava flour, 40% sago powder, 40% wheat flour (N4), 50% cassava flour, 35% sago powder, 15% wheat flour (N5), 50% cassava flour, 30% sago powder, 20% wheat flour (N6), 50% cassava flour, 20% sago powder, 30% wheat flour (N7), 50% cassava flour, 10% sago powder, 40% wheat flour (N8), 40% cassava flour, 20% sago powder, 40% wheat flour (N9) and 65% cassava flour, 35% wheat flour (N10). The biochemical properties such as moisture, starch, sugar, fat, fibre, protein and ash contents were analyzed and sensory analysis was also conducted. The moisture content ranged from 2.04% for N1 to 13.78% for N9, ash content from 1.47% for N8 to 2.20% for N5; protein content from 1.76% for N6 to 4.90% for N7; sugar content from 13.52% for N9 and N10 to 15.63% for N4; starch content from 60% for N5 and N8 to 69.23% for N4; fat content from 4.79% for N4 to 11.68% for N7; fibre content from 0.26% for N6 to 0.83% for N10 and energy value from 363 kcal for N5 to 441 kcal for N2.

Fig. 77. Crackers from cassava-sago-wheat flour

Indian flat bread (poori) from cassava-wheat flour

Traditional Indian flat bread (poori) from the composite flour of roasted cassava (10-90%) and wheat flour (10-90%) were prepared and their proximate composition was analyzed. The composite flours used were as follows: 90% cassava and 10% wheat flour (N1), 80% cassava and 20% wheat flour (N2), 70% cassava and 30% wheat flour (N3), 60% cassava and 40% wheat flour (N4), 50% cassava and 50% wheat flour (N5), 40% cassava and 60% wheat flour (N6), 30% cassava and 70% wheat flour (N7), 20% cassava and 80% wheat flour (N8), 10% cassava and 90% wheat flour (N9), 100% cassava (N10) and 100% wheat flour (N11). The protein content of the poori (Fig. 78) ranged from 15.75% for N9 to 4.20% for N1 and the fat content from 22.90% for N2 to 12.79% for N1. The fibre content was in the range of 0.91% for N9 to 0.36% for N1. Starch content varied between 58.06% for N1 and 36.0% for N5 and maximum sugar content from 2.17% for N9 to 1.02% for N1. The maximum energy value (458 kcal) was obtained for N9 whereas minimum (372 kcal) was for N1. Sensory analysis showed that the organoleptic properties of the product prepared from N6 was the best.

Fig. 78. Indian flat bread (poori) from cassava-wheat flour

Refinement of machineries for cultivation and processing of tuber crops

A continuous screw type pressing machine (Fig. 79) was developed for dewatering of cassava mash for the production of high-quality cassava flour. It consisted of a feeder, screw and barrel (with perforated stainless sheet) assembly and outlet with clearance adjusting knob type collar. The whole assembly is fixed on a framework and the machine is run by a heavy-duty motor with power transmission by chain drive whose speed can be controlled by variable frequency drive. The machine was tested for different screw speed and the variation in moisture content, starch, sugar and fibre content of the dewatered samples after three passes were analyzed. When the machine was operated at 10Hz, the moisture content reduced significantly from 71.58% to 63.94%, 61.35% and 52.56%, respectively after 1st, 2nd and 3rd passes. There was a reduction in starch content from 78.26% to 73.77%, 72.58% and 71.56%, respectively and sugar content from 3.76% to 3.37%, 3.28% and 3.19% after 1st, 2nd and 3rd passes. The fibre content, on the other hand, increased from 3.75% to 4.02%, 4.44% and 4.56%, respectively after 1st, 2nd and 3rd passes. Similar observations were made at 20Hz also, i.e., the moisture content reduced from 70.97% to 62.18%, 59.10% and 54.57%; starch content from 78.26% to 70.31%, 67.66% and 64.28% and sugar content from 3.76 to 3.25%, 3.14% and 2.85%, whereas, fibre content increased from 3.75% to 4.27%, 4.34% and 4.30%, respectively after 1st, 2nd and 3rd passes. The properties of the dewatered samples taken at every 2.5 min till 45 min of continuous operation were studied. The moisture content was reduced from 73.4% to 63.5% after 15 min and 57.1% after 30 min. There was not much variation in the moisture content after 37.5 min and it was almost 47.5%. The starch content was reduced from 71.63% to 66.11% after 15 min, to 67.89% after 30 min and 65.21% after 37.5 min. The fibre content increased from 1.94% to 2.33%, 2.90% and 2.88% after 15, 30 and 37.5 min, respectively.

Fig. 79. Continuous screw type pressing machine for dewatering of cassava mash

Particle boards and adhesives from cassava by-products and starch

Development of cassava stem-based particle board using acid modified starch as adhesive

Particle boards were prepared from cassava stem using acid modified starch as adhesive. The process conditions used were - modified starch (5, 10 and 15%), pressure of molding (100, 120 and 140 bar) and glycerol (20, 30 and 40% based on starch dry wt.). Temperature of pressing, time of molding and amount of cassava stalk powder were kept constant as 100˚C, 7 min and 150 g, respectively. The boards were tested for physical, functional and mechanical properties following the Bureau of Indian Standards (BIS) methods. The highest thickness of 6.0 mm was obtained for the board made with 10% starch and 40% glycerol pressed at 140 bar whereas, it was lowest (4.04 mm) for the board made with 5% starch, 20% glycerol and 120 bar pressure. The density ranged from 1247 kg/m^3 for the board made with 10% starch and 20% glycerol pressed at 140 bar to 769 kg/m^3 with 15% starch, 20% glycerol and 120 bar pressure. Moisture content varied from 9.01% for the board made with 15% starch, 30% glycerol and 140 bar pressure to 7.23% for the board made with 5% starch, 30% glycerol and 100 bar pressure. Maximum yellowness index of 57.34 was obtained for the board made with 15% starch and 30% glycerol pressed at 140 bar whereas, it was lowest (44.31) for the board made with 5% starch, 20% glycerol and 120 bar pressure. Under the optimum conditions of starch (9.71%), pressure (140 bar) and glycerol (31.44%), the particle board has the following features: density - 1090 kgm^{-3}, moisture content - 8.28%, total colour difference - 42.68, maximum water absorption - 36.5% and 144.6%, respectively after 2 h and 24 h of soaking and thickness swelling after 2h soaking - 25.68%, modulus of rupture - 7.12 N/mm^2.

Production of cassava stem-based particle board using cashew nutshell liquid as adhesive

Particle boards were prepared from cassava stem using cashew nutshell liquid (CSNL) as adhesive (Fig. 80). The variables used were: CSNL (10, 15 and 20%), pressure of moulding (150, 175 and 200 bar) and temperature of moulding (100, 110 and 120˚C). Time of moulding and amount of cassava stalk powder were kept constant at 7 min and 150 g, respectively. The boards were tested for physical, functional and mechanical properties according to the methods of Bureau of Indian standards (BIS) methods. The density of the boards ranged from 923.77 kg/m^3 (20% CSNL, 100˚C temperature, 175 bar pressure) to 1091.48 kg/m^3 (15% CSNL, 120˚C temperature, 200 bar pressure). The browning index was highest (12.82) for the board made with 15% CSNL at 120˚C temperature and 200 bar pressure, but lowest (8.42) for that made with 20% CSNL at 110˚C temperature and 200 bar pressure. Rupture modulus ranged from 0.76 N/mm^2 (10% CSNL, 110˚C, 150 bar pressure) to 2.78 N/mm^2 (15% CSNL, 120˚C, 200 bar pressure). Water absorption after 2 h of soaking in water varied between 69.7% (15% CSNL, 110˚C, 175 bar pressure) to 233.6% (10% CSNL, 110˚C, 200 bar pressure). However, the boards completely disintegrated after 24 h soaking. The optimum conditions for the production of board were CSNL 10%, pressure 200 bar and temperature 118˚C.

Fig. 80. Cassava stem-based particle boards made using (a) acid modified starch and (b) cashew nutshell liquid as adhesives

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

Wax coating of cassava was developed and tested for extending the shelf-life of cassava roots. Among the four different types of waxes i.e., paraffin, carnauba, microcrystalline and candelilla wax tested for their suitability for surface coating of cassava roots, paraffin wax was found to be most suitable and also cost effective for extending the shelf-life of cassava roots. The wax coating method with suitable pre-treatment was developed and tested for different cassava roots. A batch type surface coating machine for cassava roots was designed and fabrication of the machine is in progress. A total of 16 cassava genotypes viz., Sree Swarna, H-165, Sree Vijaya, Sree Pavithra, Ambakadan, Sree Jaya, Mulluvadi, Quniral, Me 833, Black Thailand, Malayan–4, Malabar Kalpaka, Kalapaka, Burma, CI-848 and H-226 were studied for changes in root quality, PPD expression and biochemical changes when stored in room temperature. The experiment is under progress to identify the biochemical marker using FT-NIR based methods to quantify the PPD intensity.

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

Effect of steaming and roasting treatments on the physicochemical and functional properties of cassava based reconstituted dry starch sago/sago wafers

The effect of different roasting and steaming treatments *viz*., hot air oven roasting at 200°C (7.5, 10, 12.5 min), microwave roasting at 600 W (75, 100, 125 S), open steaming at 100°C (75, 100, 125 S) and pressure steaming at 121°C (30, 45, 60 S) on the properties of reconstituted cassava based dry starch sago was studied. The traditional pan roasting at 170°C for 3 min was considered as control. The physicochemical and functional properties *viz*., bulk density, particle density, porosity, colour, swelling power, solubility, oil absorption index, freeze-thaw stability, viscosity and dynamic rheological behaviour were studied. Highest bulk density, particle density, porosity and lowest colour lightness (L) value were obtained for the microwave roasting treatment as compared to other heat treatments. The lightness 'L' and 'a' and 'b' colour values of sago increased significantly for roasting and steaming treatments when compared to the control sample. Significant decrease in storage modulus (267 Pa) of sago in pressure steaming against 1120 Pa in control was observed. However, roasting led to an increase in swelling power (8.43 - 8.76 g/g), solubility (6.12 - 15.68 %) and oil absorption index (2.76 - 3.20 g/g) compared to steaming treatment. Higher pasting temperature (74.4°C) and other pasting properties were observed for steaming than roasting treatment. Thus, roasting and steaming exhibited a considerable effect of physico-chemical and functional properties of reconstituted cassava based dry starch sago. The freeze-thaw stability was determined for three cycles. Sago samples treated with hot air treatment exhibited a lower syneresis (0.41 - 0.33%), whereas, open steamed sago showed highest syneresis value (3.98 - 1.25 %).

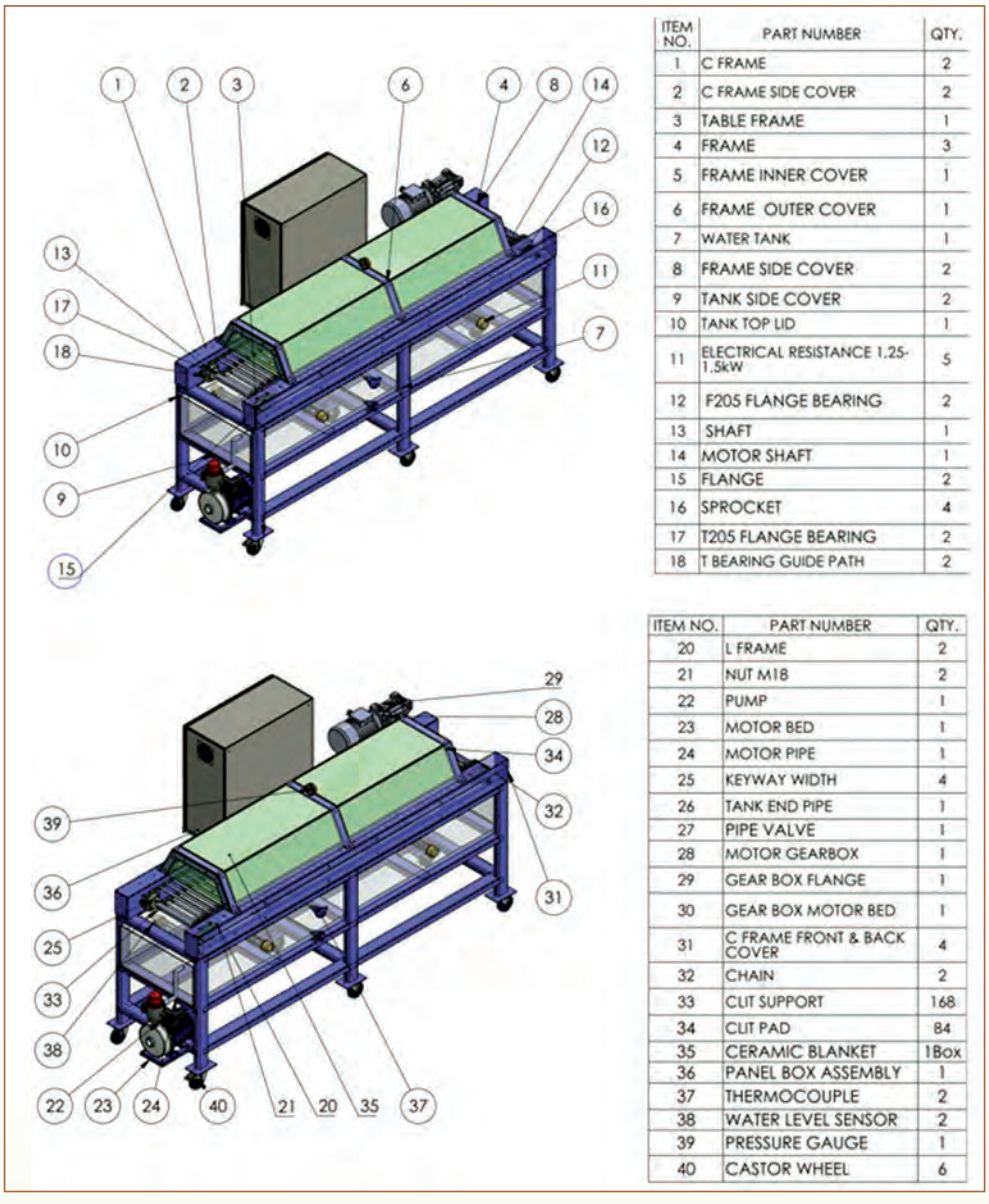
Design and development of a continuous steaming machine for sago wafers/sago papad production

At present, the whole process of making sago wafers from wet cassava starch is done manually, which needs to be taken care in terms of quality and safety. The various unit operations involved in the production of sago wafers in the industries located in Tamil Nadu are, receiving the wet starch, powdering the wet starch, sizing, arranging the globules in small or big aluminium die, steaming, sun drying and packing. At present, a brass vessel of size 450 mm diameter and 460 mm height is used as a boiler for steaming the starch globules. The vessel is filled with water to a depth of 50 mm from the bottom. The aluminium trays containing the dies are placed inside the vessel maintaining a gap of 30 mm and the vessel is closed. Usually male labourers are employed for steaming process. The required steaming time is about 4 to 5 min. About 75 kg of firewood is used to steam 100 kg of starch globules. This method of steaming of sago wafers is not hygienic, laborious and time consuming. Thus, a continuous steaming unit for sago wafers production was designed and fabricated. The fabricated machine consists of chain sprocket conveyor system, steam generation system, temperature and pressure monitoring system and electrical systems (Fig. 81). The capacity of the steaming tank is 0.29 m^3 (or) 290 litre and the overall dimension of the machine is 2.83 m × 0.90 m × 1.10 m.

The comprehensive list of materials and their specification for fabrication of continuous steaming machine is presented in Table 6.

Table 6. Materials used and their specification of the continuous steaming machine

S.No.	Materials used	Specification	Purpose	Quantity
1	Immersion water heater	3 phase, 230/450 V, 3KW	Saturated steam generation	5
2	Motor	3 phase, 230/450 V, 0.5 HP	Operating chain conveyor	1
3	Water pump	Single phase, 230 V, 0.5 HP	Pumping water	1
4	VFD Drive	3 phase, 1 HP	To vary the speed of chain conveyor	1
5	Temperature controller	Operating voltage 230V AC, relay output 230 V AC,5A	To control temperature range	2
6	Thermistor probe	Type PT-100/RTD	Measurement of water and steam temperature	2
7	Water level sensor	Capacitive type	Water level measurement	2
8	Control box	MCB, Contactor, SPDT relay, DIN rail connectors, 230 V ac indication lamp	Effective, easy control for operator	1



ITEM NO.	PART NUMBER	QTY.
1	C FRAME	2
2	C FRAME SIDE COVER	2
3	TABLE FRAME	1
4	FRAME	3
5	FRAME INNER COVER	1
6	FRAME OUTER COVER	1
7	WATER TANK	1
8	FRAME SIDE COVER	2
9	TANK SIDE COVER	2
10	TANK TOP LID	1
11	ELECTRICAL RESISTANCE 1.25-1.5kW	5
12	F205 FLANGE BEARING	2
13	SHAFT	1
14	MOTOR SHAFT	1
15	FLANGE	2
16	SPROCKET	4
17	T205 FLANGE BEARING	2
18	T BEARING GUIDE PATH	2

ITEM NO.	PART NUMBER	QTY.
20	L FRAME	2
21	NUT M18	2
22	PUMP	1
23	MOTOR BED	1
24	MOTOR PIPE	1
25	KEYWAY WIDTH	4
26	TANK END PIPE	1
27	PIPE VALVE	1
28	MOTOR GEARBOX	1
29	GEAR BOX FLANGE	1
30	GEAR BOX MOTOR BED	1
31	C FRAME FRONT & BACK COVER	4
32	CHAIN	2
33	CLIT SUPPORT	168
34	CLIT PAD	84
35	CERAMIC BLANKET	1Box
36	PANEL BOX ASSEMBLY	1
37	THERMOCOUPLE	2
38	WATER LEVEL SENSOR	2
39	PRESSURE GAUGE	1
40	CASTOR WHEEL	6

Fig. 81. Pictorial view of continuous steaming machine with detailed assembly parts

Production of biochar from agricultural biomass and nutrient and biological enrichment

Biochar is considered to be an effective method of carbon sequestration and potentially will help to mitigate climate change. For the second year, two sweet potato varieties, Sree Arun and Sree Kanaka were grown in pots with zero, 2% and 5% biochar to study the performance of sweet potato to applied biochar. Plant growth, leaf area, leaf chlorophyll content, leaf gas exchange, chlorophyll fluorescence kinetics, and tuber yield were determined. The experiment is in progress. Application of biochar on yam bean growth, photosynthetic process and tuber yield is being taken up and the experiment is in progress.

Development of Cassava Starch Based Novel Products and Functional Foods from Other Tuber Crops

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

Thermoplastics starch sheets from cassava starch-saw dust composite

Thermoplastic starch is the focus of interest in the production of single use disposable articles such as plates, cups, containers and loose fills packaging material from biodegradable materials. It can be a substitute for the presently used expanded polystyrene products for their application in disposable products. The experiment was designed using response surface methodology by employing Box-Behnken design and the variables used were: amount of glycerol (30, 40 and 50% of the starch), temperature of the die plate (130, 140 and 150°C) and pressure of the die plate (120, 130 and 140 bar). A hot press was used for making TPS and the time duration of pressing was 5 min and the amounts of starch and sawdust were 100g and 20g, respectively in all cases. The physico-mechanical, hygroscopic and hydration properties of the sheets were analyzed. The density of the sheets ranged from 1074 to 1545 kg/m^3, solubility from 5.85 to 20.24%, expansion index from 66.0% to 86.7%, total colour difference from 61.69 to 68.05 and water activity from 0.517 to 0.571. The sorption at 75% RH was in the range of 10 - 16%, ultimate tensile strength 0.226 - 0.785 N/mm^2 and percent elongation 4.88 - 25.2%. The optimum conditions for the production of thermoplastic starch sheet were as follows: temperature -145.81°C, pressure -135.18 bar and glycerol - 43.91% (Fig. 82a).

Thermoplastics starch sheet with acid modified cassava starch

Box-Behnken design was used to optimize the conditions for the production of thermoplastic starch (TPS) sheets with acid modified cassava starch. The variables used were: amount of glycerol (25, 30 and 35% of the starch), temperature of the die plate (120, 130 and 140°C) and pressure of the die plate (110, 120 and 130 bar). Time of pressing was 5 min and the amount of starch was 100 g in all cases. The density of the sheets ranged from 1057 to 1715 kg/m^3, solubility from 3.08 to 6.77%, expansion index from 22.97 to 48.65%, total colour difference from 44.38 to 56.09 and water activity from 0.629 to 0.715. The water sorption at 75% RH, rupture modulus and percent elongation were 4.6 - 9.26%, 3.75 - 9.87 N/mm^2 and 7.5 - 26.38%, respectively. The optimum conditions for the production of thermoplastic starch sheet were as follows: temperature - 134.22°C, pressure - 121.48 bar and glycerol - 25% (Fig. 82b).

Thermoplastics starch sheets with sorbitol as plasticizer

The experiments were designed using Box-Behnken response surface design and the variables used were: amount of sorbitol (30, 40 and 50% of the starch), temperature of the die plate (120, 130 and 140°C) and pressure of the die plate (120, 130 and 140 bar). Time of pressing was 5 min and the amount of starch was 100 g. The density, solubility, expansion index, total colour difference and water activity were in the range of 885 - 3004 kg/m^3, 26.72 - 50.20%, 30.26 - 84.21%, 50.46 - 61.90 and 0.576 - 0.615, respectively. The water sorption at 75% RH ranged from 11.52 to 17.60%. The rupture modulus was in the range of 4.64 - 177.16 N/mm^2 and percent elongation was 5.36 - 25.17%. The optimum conditions for the production of thermoplastic starch sheet was as follows: amount of sorbitol - 30%, temperature - 130°C and pressure - 130 bar (Fig. 82c).

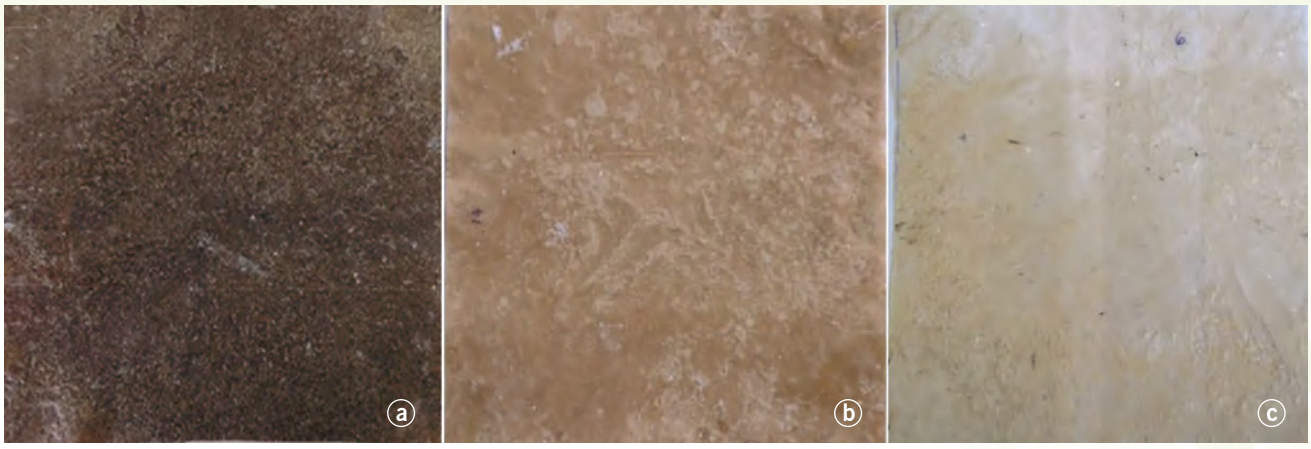


Fig. 82. Thermoplastics starch sheet prepared from (a) cassava starch-saw dust composite, (b) acid modified cassava starch and (c) cassava starch and sorbitol as plasticizer

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

Microwave assisted synthesis of RS4 type cassava resistant starch

Resistant Starch (RS) has been included in the definition of dietary fiber by American Association of Cereal Chemists in 2000 and it displays many physiological benefits such as calorie reduction and colon health and is suggested for use in probiotic compositions to promote the growth of beneficial microorganisms. Microwave assisted green reactions have been proved as efficient methods for the dry phase chemical modifications of starch and are very fast and time saving. Microwave assisted solvent free chemical synthesis of cassava starch by esterification with octenyl succinic anhydride, citric acid and sodium orthophosphate has been standardized for producing cassava resistant starches (RS4) and the physicochemical and digestibility properties were compared with those synthesized by conventional slurry method. The degree of substitution (DS) of OSA starch by slurry method was 0.006 with 20% octenyl succinic anhydride, whereas, the DS of OSA starches prepared by microwave irradiation were 0.047, 0.056 and 0.061, respectively after 3, 4 and 5 min. of irradiation with the same concentration of OSA. Microwave irradiation more effectively brought down the percentage digestibility of starch when compared to those synthesized by conventional method. All the three types of modified starches synthesized by microwave irradiation showed significant reduction in rapidly digestible starch (RDS) content and significantly higher slowly digestible starch (SDS) and resistant starch (RS) contents when compared to those synthesized by conventional slurry reaction. The RS content was significantly higher for the samples synthesized by microwave method in all cases and the highest RS content of 39.2% was obtained for cassava starch citrate modified by microwave irradiation in contrast to 18.1% for the sample synthesized by conventional method.

Effect of thermal processing on the resistant starch content in cassava and sweet potato tubers

The effect of different thermal processing/cooking methods on the resistant starch content in cassava and sweet potato tubers have been studied by *in vitro* technique. The *in vitro* starch digestibility of cooked tubers with porcine pancreatic amylase was in the order sweet potato < cassava. Among the different cooking methods, the *in vitro* starch digestibility was least for steaming, followed by baking and microwave heating while, it was highest for boiling. Cooking methods such as steaming, baking and microwave cooking increases RS content in all tubers than the conventional boiling method. Resistant starch content in the tubers (4.5±1.3% and 5.8±0.9% for raw cassava and sweet potato tubers respectively) and decreased significantly with increase in processing time. Cassava tubers showed highest RS content (4.2%) after microwave aided cooking, followed by baking (3.78%), boiling (3.4%) and steaming (3.1%). The slowly digestible starch (SDS) content was comparatively similar in the tubers cooked by steaming (9.63%) and baking (7.9%). Rapidly digestible starch content was more or less similar in all cooked tubers. The RS content was comparatively higher in the sweet potato tubers cooked by microwave heating (5.4%) and baking (5.3%) followed by other techniques. However, SDS

content was highest in the baked tubers (8.4%) and rapidly digestible starch (89%) was higher for the boiled tubers.

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

Standardization and development of anthocyanin rich cake from purple sweet potato

The formulation for cake enriched with anthocyanins was standardized using purple fleshed sweet potato (var. Bhu Krishna) flour (Fig. 83a). Among the different compositions of the flours tried, the cake prepared with a combination of 70% sweet potato flour and 30% refined wheat flour was found to be the best. The crude protein content in the cake ranged from 6.32 to 6.93%, fat content from 16.24 to 16.50%, and ash content from 3.11 to 3.65%. The anthocyanin content was 39 to 41 mg 100 g^{-1} and the specific volume was 1.51 - 1.63 ml g^{-1}. The overall acceptability of the cake as determined by sensory evaluation ranged from 7.51 to 8.90 on a 1-10 hedonic scale.

Development of β-carotene rich cake from orange-fleshed sweet potato

The formulation for β-carotene rich cake was standardized and prepared with the different combinations of sweet potato and refined wheat flours (Fig. 83b). The flour prepared from the orange fleshed sweet potato variety Bhu Sona was used to enrich the cake with β-carotene. Among the different combinations, the cake prepared with 80% sweet potato flour and 20% refined wheat flour was found to be the best in terms of sensory evaluation and physicochemical properties. The protein content in the cakes ranged from 5.73 to 6.21%, fat content from 16.22 to 16.62%, ash content 3.06 to 3.27% and β-carotene content from 6.3 to 6.7 mg 100g^{-1}. The specific volume was 1.48 to 1.57 ml g^{-1} and the overall acceptability ranged from 7.54 to 8.52 on 1-10 hedonic scale.

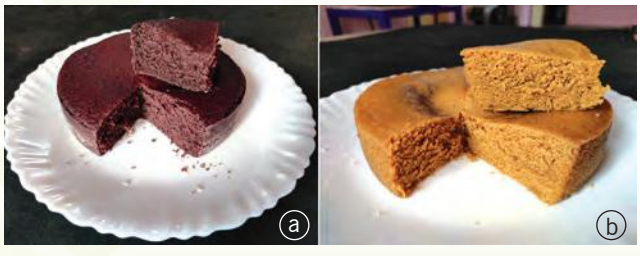


Fig. 83. Sweet potato flour-based cakes.
(a) Anthocyanin rich cake and (b) β-carotene rich cake

Formulation of weaning food mixes from sweet potato

Ready to use weaning food mixes from different combinations of sweet potato (var. Kishan) flour (20 - 30%), arrowroot flour (5 - 15%), chuda powder (20%), malted ragi flour (20%), rice flour (10%), sugar (6%), skim milk powder (8%) and starch (1%) were formulated and prepared (Fig. 84). The nutritional compositions of weaning food mixes were as follows: moisture content 6.4 - 7.2%, crude protein 12.4 - 13.6%, crude fat 5.8 - 6.2%, total ash 3.2 - 3.4%, crude fibre 6.3 - 6.9%, calcium 139 – 147 mg 100 g^{-1} and iron 9 – 11 mg 100 g^{-1}.

Fig. 84. Sweet potato based weaning food mix

Development of ready to use laddu mix from sweet potato

Ready to use laddu mix from different combinations of sweet potato (var. Bhu Krishna) flour (25-75 g), Bengal gram flour (25 – 75 g), sugar (20 g) and cardamom extract (1.5 g) were standardized and prepared (Fig. 85). Among all the combinations, the sample with 50% sweet potato flour and 50% Bengal gram flour was found to be the best.

Fig. 85. Sweet potato flour based laddu mix

EXTENSION AND SOCIAL SCIENCES

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

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

Technological interventions in tuber crops

Forty frontline demonstrations (FLDs) on improved varieties of cassava, sweet potato, taro and Chinese potato; fertilizer best management practices in elephant foot yam and greater yam; integrated management of mealybug in cassava using cassava based bio-formulations were established in an area of 50 cents each in Tamil Nadu, Kerala and Andhra Pradesh with 40 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.

Improved varieties of cassava

Ten frontline demonstrations on improved varieties of cassava viz., Sree Jaya, Sree Vijaya, and Sree Pavithra were established during December 2018 in an area of 50 cents each under irrigated conditions at Thuckalay, Kalkulam taluk of Kanyakumari district of Tamil Nadu (Fig. 86).

Fig. 86. View of demonstration plots on improved varieties of cassava

Table 7. Economic impact of improved varieties of cassava in Kanyakumari dt of Tamil Nadu

Variety	Yield (t ha^{-1})	Gross Income (₹ ha^{-1})	Total Cost of Cultivation (₹ ha^{-1})	Net Income (₹ ha^{-1})	B:C ratio
Improved varieties*	31.80	381200	132150	249050	2.88
Local varieties	28.20	295750	119650	176100	2.47

* - Sree Jaya, Sree Vijaya, Sree Pavithra

Frontline demonstrations on improved varieties of cassava conducted at Kanyakumari district of Tamil Nadu revealed that Sree Pavithra produced the highest yield (34.60 t ha^{-1}) followed by Sree Vijaya (31.50 t ha^{-1}) and Sree Jaya (29.20 t ha^{-1}). The mean productivity of cassava from improved varieties was found to be 31.80 t ha^{-1} which was 14.7% higher than the local varieties *(Lakshmi Vella, Ullicha Vella and Kariyilaporiyan)* yield of 28.20 t ha^{-1} (Table 7). Gross and net income realized from improved varieties of cassava were, ₹3.81 lakhs and ₹2.49 lakhs while, gross and net income obtained from local varieties were, ₹2.96 lakhs and ₹1.76 lakhs, respectively. Benefit Cost ratio was higher for improved varieties (2.88) than the local varieties (2.47) of cassava.

Non availability of quality planting materials of improved varieties, non-availability of skilled labour, price fluctuation, lack of knowledge on value addition, non-availability of quality inputs and incidence of pests and diseases were the major constraints experienced by the cassava growers of Kanyakumari district of Tamil Nadu. Overall, the productivity and profitability of cassava farming with improved varieties increased over the existing local varieties. Establishment of seed villages to ensure timely and continuous supply of quality planting materials of improved varieties, encouraging participatory research and extension, organized marketing system and strengthening the linkages with other stakeholders of tuber crops will ensure sustainability of cassava farming.

Fertilizer best management practices in elephant foot yam

Ten FLDs on Fertilizer Best Management Practices (FBMP) in elephant foot yam var. Gajendra were conducted during April-November 2019 crop season at Atreyapuram & Ravulapalem mandals of East Godavari and at Kovvur & Tallapudi mandals of West Godavari districts of Andhra Pradesh (Fig. 87). Primary and micronutrient-inclusive customized fertilizer formulation developed based on site specific nutrient management (SSNM) technology for elephant foot yam was applied for enhancing the productivity and profitability of elephant foot yam. The foliar liquid micronutrient formulation developed by ICAR-CTCRI was also applied as foliar spray as per recommendations. The yield and economic impact of FBMP is given in Table 8.

Fig. 87. View of demonstration plots on FBMP in elephant foot yam

Table 8. Yield and economic impact of FBMP in elephant foot yam

District	Nutrient management	Yield (t ha^{-1})	Gross Income (₹ ha^{-1})	Total Cost of Cultivation (₹ ha^{-1})	Net Income (₹ ha^{-1})	B:C ratio
East Godavari	FBMP*	42.13	547625	248250	299375	2.21
	Farmers Practices	38.75	503750	255750	248000	1.97
West Godavari	FBMP*	43.25	562250	256250	306000	2.19
	Farmers Practices	40.15	521950	264500	260700	1.99

Table 8 shows that the average yield of elephant foot yam in FBMP treatment was 42.13 t ha^{-1} which was 8.72 % more than the yield obtained from farmers' practices (38.75 t ha^{-1}) in East Godavari district. Similarly, the mean yield of elephant foot yam in FBMP treatment was 43.25 t ha^{-1} which was 7.70 % more than the yield obtained from farmers' practices (40.15 t ha^{-1}) in West Godavari district.

The overall impact of FBMP in elephant foot yam demonstrated in both the districts is given in Fig. 88. There was 8.21 % yield increase in FBMP treatment over farmers' practices. Similar trend was observed in FBMP treatment for gross income (8.21%), net income (8.73 %) and benefit cost ratio (11.11 %) in comparison to farmers' practices. Total cost of cultivation was less for FBMP fields (₹2.52 lakhs ha^{-1}) than the farmers' practices (₹ 2.60 lakhs ha^{-1}) and the difference was 3.03 %. Farmers opined that FBMP treatment resulted in robust vegetative growth of the plants, absence of nutrient deficiencies, higher yield, good shape and size of corm and increase in the weight of corm.

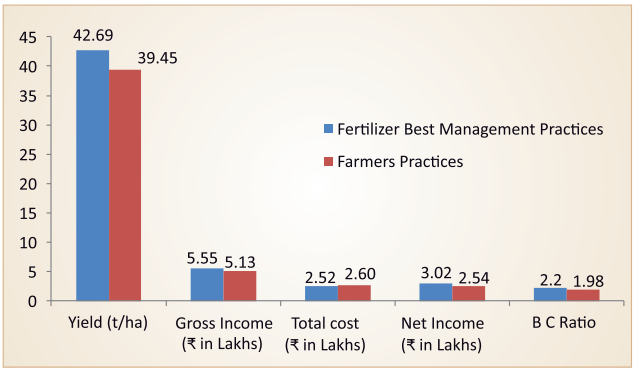


Fig. 88. Overall impact of FBMP in elephant foot yam

Soil health cards were distributed to the farmers (Fig. 89) for managing the soil fertility for sustainable production of elephant foot yam and other crops. The productivity and profitability of elephant foot 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 elephant foot yam farming.

Fig. 89. Distribution of soil health cards to the farmers of East Godavari and West Godavari districts, Andhra Pradesh

Sustainable livelihood analysis of tuber crops farmers

A sample of 50 taro growers and 50 paddy growers were selected using snowball sampling technique from two taluks viz., Ranpur and Khandapada in Nayagarh district of Odisha for assessing the sustainable livelihood of farmers. Data were collected during October–December 2019 using PRA tools, interview schedule and focus group discussions.

Livelihood sustainable index was worked out using the DFID methodology as given below.

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

HCI: Human Capital Index

SCI: Social Capital Index

FCI: Financial Capital Index

NCI: Natural Capital Index

PCI: Physical Capital Index

Capital Index: Actual Score/ Maximum Obtainable Score x 100

Profile characteristics of taro and paddy growers

The taro and paddy growers do not differ significantly in most of their socio-economic characteristics. The average age of taro and paddy growers was almost similar (55 years). There is not much difference in the educational, household size and total land size for both the category of farmers. However, the average area under taro and paddy differs significantly at 1% level. The average yield of taro (43.34 quintal/acre) was higher than the yield of paddy (20.94 quintal/acre). There is not much difference in the cost of production between taro and paddy. But there is significant difference in the yield, cost of cultivation and net profit between taro and paddy. However, the higher yield realization makes taro cultivation more profitable. On an average, the taro growers realized 128% higher net returns than the paddy growers (Table 9).

Livelihood Sustainable Index of taro and paddy growers

Under human capital index, the parameters like education, training, labour, health, experience in farming and knowledge was more for paddy growers when compared to taro growers. The overall human index was 50 for taro growers and 66 for paddy growers. Under physical capital, the house type, drinking water and types of fuel used was more for taro growers than the paddy growers. It was observed that all the households in both the category had electricity. The transport facilities were more for paddy growers when compared to taro growers. The overall physical index was more for taro growers (73.6) as compared to paddy growers (69.5). The social capital index of both the farmers was same (62). The membership in organization was more (80) for taro growers whereas, it was 54 for paddy growers. Under financial capital, the household income and savings were more for taro growers than paddy growers. The overall financial index was 40.8 for taro growers and 37.1 for paddy growers. Under natural capital, the ownership of land was more for paddy growers (98) when compared to taro growers (94). The overall natural capital index was more for the taro growers (69.0) than paddy growers (63.3). With regard to gender involvement, both the crops were important in providing employment opportunities and income generation to women. Majority (> 50%) of women were involved in planting, intercultural operations, harvesting and processing activities.

The livelihood sustainable index of taro and paddy growers was analyzed and the results are presented in Table 10. It is revealed that the rural livelihood sustainable index was marginally more for paddy (60) than taro growers (59). The association or similarities of different capitals between taro and paddy growers is given in Fig. 90. Similarities between capitals of taro and paddy growers are in the decreasing order with respect to physical, natural, social, human and financial capitals.

Table 9. Costs and returns in taro and paddy cultivation

Particulars	Taro (n = 50)	Paddy (n = 50)	Difference	Percentage increase
Yield (quintal acre^{-1})	43.34	20.94	22.4***	107
Cost of cultivation (₹ acre^{-1})	33910	16159	17751***	110
Cost of production (₹ quintal^{-1})	818	916	98	-11
Net Profit (₹ acre^{-1})	49024	21533	27491***	128

Note: *** Significant at 1 per cent level

Table 10. Livelihood index of taro and paddy growers

Capitals	Taro growers (n = 50)	Paddy growers (n = 50)	Ranking
Human Capital	50.0	66.0	IV
Physical Capital	73.6	69.5	I
Social Capital	62.0	62.0	III
Financial Capital	40.8	37.1	V
Natural Capital	69.0	63.3	II
Overall LSI	**59.0**	**60.0**	

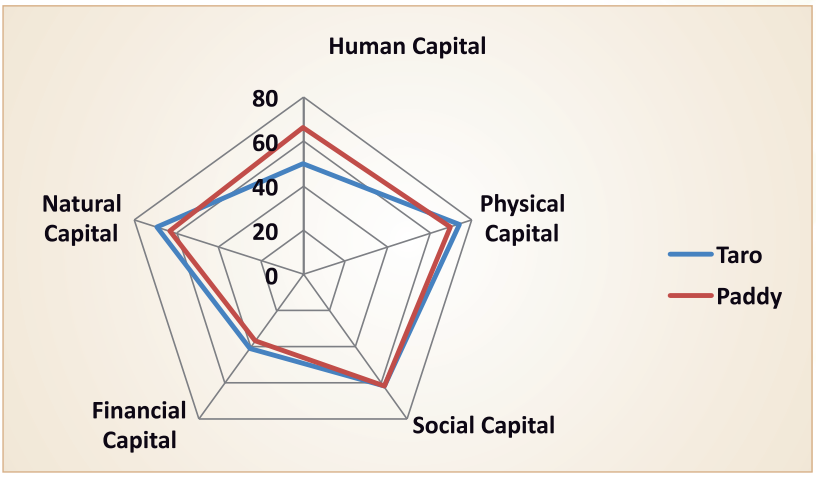


Fig. 90. Livelihood capital asset pentagon for taro and paddy growers

Major sources of livelihood as reported by both the farmers were agriculture, employment in government/private sector and petty business. The vulnerability factors were price fluctuation, climatic variations and increased labour cost. The trends observed were high input cost, climate change and labour shortage. The constraints reported in taro and paddy cultivation as perceived by farmers were ranked based on mean score. Lack of market facilities was ranked first with a mean score of 2.51 out of maximum score of 3. The other constraints reported by the taro farmers were, price fluctuation (2.21), lack of irrigation facilities (2.04), attack of wild animals (1.98) and non availability of labour (1.74). Lack of irrigation facilities (2.35), weather aberrations (2.15) and incidence of pests and diseases (2.0) were perceived as major constraints in paddy cultivation.

Sustainable livelihood analyses were conducted among cassava, sweet potato, elephant foot yam and taro growers in major growing tracts of Kerala, Tamil Nadu, Karnataka, Andhra Pradesh and Odisha during last five years. Based on the findings, the following strategies have been formulated for livelihood improvement of tuber crops farmers (Fig. 91).

Development of ICT applications in tuber crops

Variety Finding Tool (VFT): A mobile app for identifying sweet potato varieties from the images of leaves is being developed. This app uses the Convolutional Neural Network (CNN) image classification model using deep learning algorithm of artificial intelligence for classifying the images. CNN image classification model for sweet potato was developed using the pictures of leaves (Top view) of the varieties Bhu Krishna and Sree Arun. This model was used in VFT: sweet potato mobile app to identify the varieties.

Web interface of eCrop was modified and it was made more user friendly (Fig. 92). Online version of the sweet potato model SPOTCOMS was developed using PHP/MySQL and now it runs online. This will be useful for developing real-time agro advisories in response to user demand.

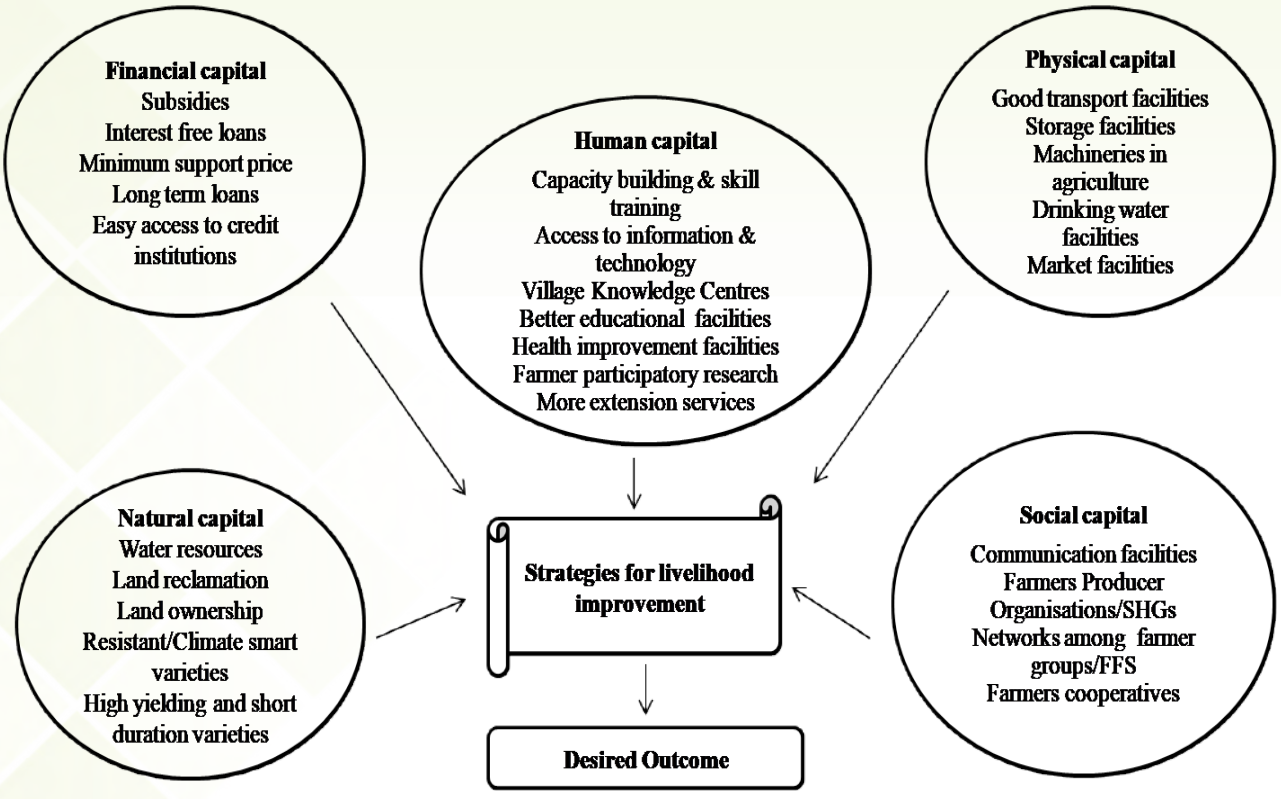


Fig. 91. Strategies for livelihood improvement of tuber crops farmers

eCrop: An IoT solution for precision farming

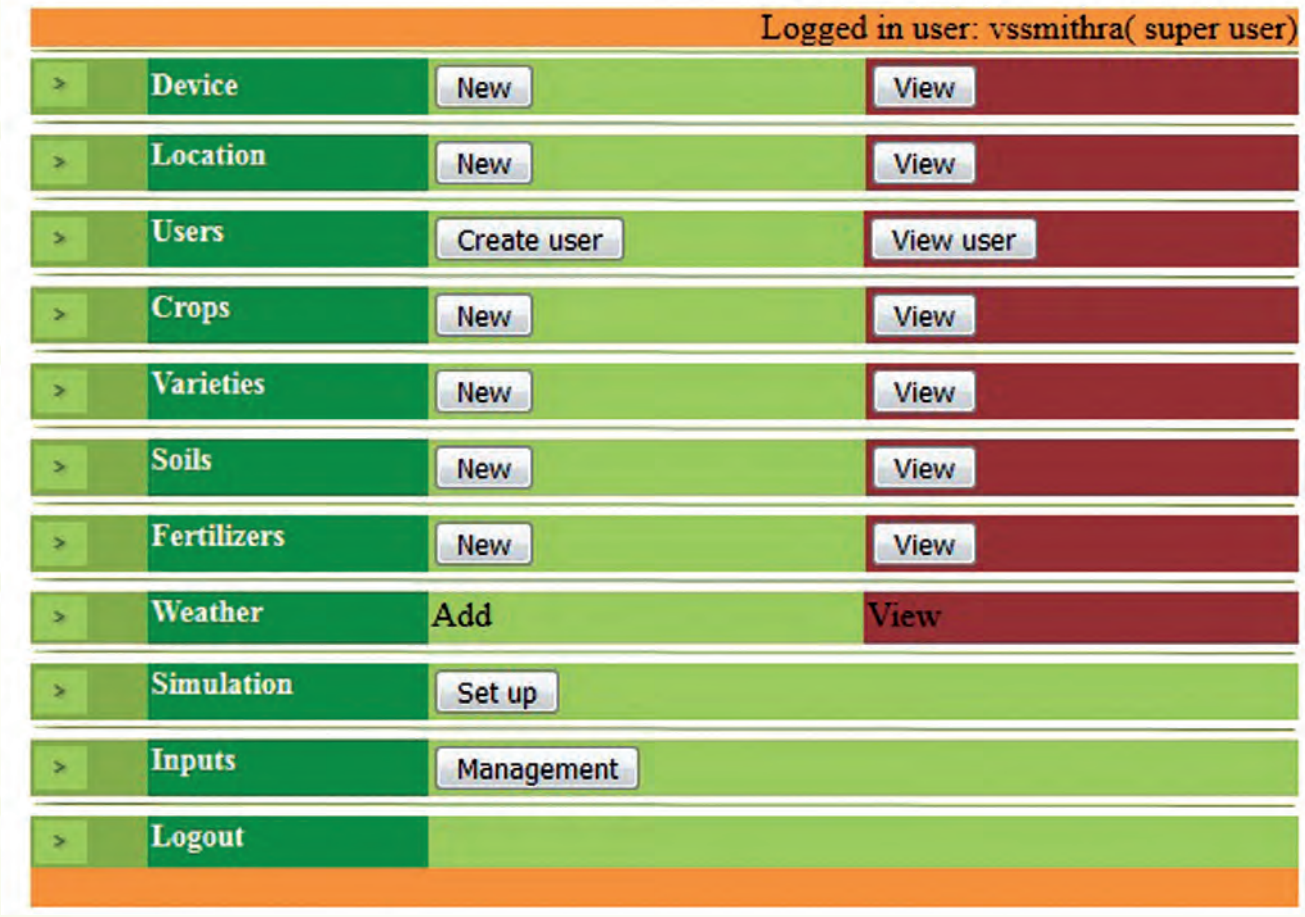


Fig. 92. Web interface of eCrop

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

Intelligent tools for genomic data analysis

Machine learning tools for predicting miRNAs in cassava

Machine learning techniques are increasingly being used to address problems in computational biology and bioinformatics. Micro RNAs (miRNAs) are confirmed to regulate a variety of processes such as development, metabolism and stress responses. Computational approaches and bioinformatics algorithms to identify miRNAs are based on major properties of previously identified miRNAs, such as presence of a hairpin-shaped stem loop like secondary structure, evolutionary conservation and low minimum free energy. Most of these computational tools share is of the same strategy but use different approaches. Homology-based approaches rely on conservation of sequences, secondary structures or miRNA target sites. Machine learning methods are amongst the most popular ways of miRNA identification nowadays. First, the features of primary sequence and secondary structure are extracted from known miRNAs (positive set) and non-miRNA sequences (negative set). Then, the features are used to construct a model which serves to classify candidate sequences as real pre-miRNAs or pseudo pre-miRNAs.

There are several machine learning methods that have been applied in the field of miRNA identification. These include Support Vector Machine (SVM), Hidden Markov Models (HMM), random forest and naive Bayes classifier. The present study used HuntMi, a machine learning-based miRNA identification package for identifying pre-miRNA from the given sequence set of cassava. It exploits ROC-select, a special strategy of thresholding score function output by classifiers, combined with random forest, which help to produce best classification results. The HuntMi tool as well as datasets related to its making is freely available at http://lemur.amu.edu.pl/share/HuntMi/. The tool was used to predict the miRNAs in cassava. The tool has two major programmes, one extract Features. py (extracts features from sequences in FASTA files and stores them in Attribute-Relation File Format (ARFF) and the second one classify.py which generates predictions based on ARFF files. Positive and negative datasets were retrieved from miRNA databases and are used for training the machine learning suite. For collecting positive datasets of *Manihot esculenta*, miRNA hairpin sequences were downloaded from MIRBASE (www.mirbase.org) and were saved in a fasta file. A total of 173 miRNA hairpin sequences of cassava were downloaded from MIRBASE for positive dataset and a total of 697 sequences were extracted from mRNA and genome of cassava for negative set. After extracting the features of datasets using HuntMi, an ARFF feature file was created. This feature file was used to train the model using data mining software Weka with all configured parameters. This model file is further used for the identification of pre-miRNA in cassava transcripts.

As a result, 28 pre-miRNAs were predicted using machine learning package HuntMi. The length of the predicted pre-miRNA varied from 105-357 nt. Identification of mature miRNA prediction widely exploits the evolutionary conserved nature of miRNAs in plants. To identify mature miRNA, pre-miRNA obtained from HuntMi were subjected to homology search blastN against all known mature miRNAs from viridiplantae in miRBase. Hence, a total of 13 potential miRNAs were predicted.

Machine learning tool for prediction of SNP in sweet potato

A machine learning technique SNP-ML was applied as an efficient method to predict SNPs in sweet potato (*Ipomoea batatas* L.), which is a polyploid plant. RNA sequence data of two genotypes of sweet potato viz., Bhu Sona and Bhu Swami were used for the study. SNP identification in polyploids, however, is more challenging due to the need to distinguish homologous SNPs. The preprocessing of the raw sequence data was carried out using an alignment programme, Bowtie 2. SAM tools along with SNP-ML were used for prediction of SNPs. The script was written in C^{++} and python 2.7.1. The C^{++} script was used for processing the data of input, output, and filtering. The binary file runs on linux system, which is a command line interface. Python was used for creating the NN machine-learning model for the prediction of SNPs. SNP-MLer was used for training the new model using the features selected from sequences and SNP-ML was used for prediction of SNP. A total of 771,963 SNPs was extracted using

SNP-ML tool. Using BLAST2GO gene finding module, about 59,653 genes were identified for the predicted SNPs.

Devising stakeholder oriented technology commercialization strategies: A comparative assessment

Development of framework for assessing success of commercialization of tuber crops technologies

A conceptual framework for assessing the success of commercialization of tuber crops technologies (varieties, mineral nutrient mixture, eco-friendly pesticides, novel foods and industrial products) was developed. The technology readiness levels of various technologies as considered at different technology generation organizations are given in Table 11.

Table 11. Technology readiness levels followed in assessing commercial success of tuber crops technologies

Level	Description	Frequency (%)
1	Identification of basic principles and reporting	100
2	Technology concept developed	100
3	Proof of concept characteristics developed	100
4	Validation of concept in a similar environment	100
5	Pilot scale – Prototype demonstration	100
6	Availability for commercialization	36
7	Economic feasibility demonstrated or meeting regulatory requirements	65
8	Ready for full scale commercialization	100

Results given in Table 11 indicated that level 6 and 7, which are concerned with economic feasibility and regulatory requirements of technology were difficult to assess at the Institute level which needs external expertise. Various constraints faced by the technology managers at different technology readiness levels are given in Table 12.

Table 12. Constraints faced by technology managers at various levels of technology readiness

Level	Description	Constraints	Frequency (%)
4	Validation of concept in a similar environment	Food products: High cost of validation for commercial scale	10.00
5	Pilot scale – Prototype demonstration	High cost of pilot plants Lack of local expertise	60.00 20.00
7	Economic feasibility demonstrated or meeting regulatory requirements	Non-availability of system for regulatory clearances	63.33

Assessment of tuber crops entrepreneurial ecosystem in Kerala

The tuber crops entrepreneurial ecosystem involving stakeholders like extension agents, entrepreneurs and scientists 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. The scale was provided to three types of stakeholders entrepreneurs (n=30), scientists (n=30) and extension workers (n=30) to assess their perceptions of each dimension. Among them markets were highly rated by scientists and entrepreneurs (Mean > 4.0) followed by support institutions (Mean > 4.0). Availability of funds for creating new tuber crops based businesses was rated lowest (Mean < 2.5) (Fig. 93)

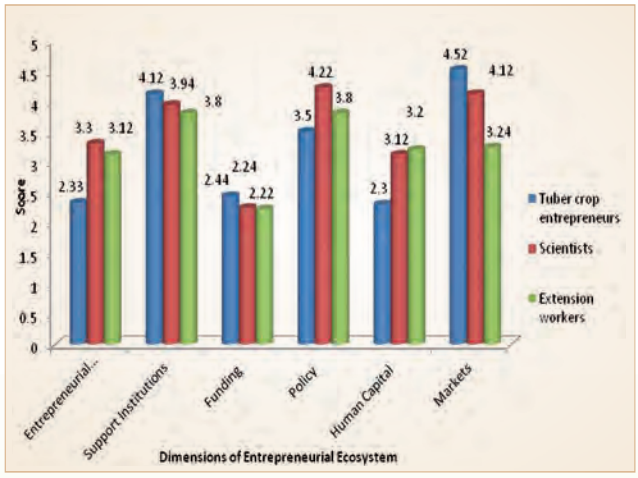


Fig. 93. Perception of stakeholders about tuber crops entrepreneurial ecosystem (n=90)

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

Decadal compound growth rates for cassava, sweet potato and tuber crops based products were estimated. There was significant growth in productivity and production of cassava during the 1961-2017 while, declining trend in area during the same period was observed (FAOSTAT, 2018). In case of sweet potato, both area and production showed declining trend while productivity showed significant growth trend during the same period. Cassava productivity showed significant growth in all the decades except during 2011-17 and non-significant during 1971-80. Sweet potato productivity showed significant growth in all the decades except during 1971-80.

There is no continuous export of tropical tuber crops in different forms during all these years. Among different forms, cassava and substitutes (1971-2018); sago starch (1995-2018); sweet potato tubers (1996-2018) and flour meal of sago (1987-2018) individually had significant growth in exports from India both in quantity and value of exports. Cassava starch had significant decline in quantity of exports while significant growth in cassava starch imports both in terms of the quantity (32.5%) and value (43.9%) was observed during 2003-2018 in India. Very high starch import growth was recorded during 2011-18 (55% in terms of quantity and value). Thailand and Vietnam are the countries from which cassava starch is being imported by India.

Revealed Symmetric Comparative Advantage (RSCA) 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 has comparative 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, export of sweet potato and roots and tubers nes; in the case of BRICS region, export of cassava dried products and in the case of IOR-ARC, export of sweet potato, flour roots and roots and tubers nes.

Tariff rates collected for tuber crops for foreign trade from different players/Institutions revealed that Government of India imposed import duty on cassava starch imports during 2006 to 2008 to protect the domestic starch industry. In 2018, the prevailing customs duty on cassava starch imports was at 68%.

EXTERNALLY AIDED PROJECTS

1. **Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro** (PPV & FRA, New Delhi; PI: Dr. Archana Mukherjee (till October 2019), Dr. Kalidas Pati (from November 2019); Co-PIs: Drs. J. Sreekumar and J. Tarafdar (BCKV, Kalyani)

DUS testing guidelines of both elephant foot yam and taro were standardized. The reference varieties of elephant foot yam (18) and taro (21) were maintained in the field gene bank. DUS testing guidelines of elephant foot yam included 41 characteristics and that of taro included 51 characteristics. DUS testing of farmers varieties of two taro received from PPV&FRA were planted in the field for testing.

2. **Establishment of varietal gene bank and development of standards of DUS testing in yam bean (*Pachyrhizus erosus*) and greater yam (*Dioscorea alata*)** (PPV & FRA, New Delhi; PI: Dr. Archana Mukherjee (till October 2019), Dr. M.N. Sheela (Lead Centre) and Dr. Kalidas Pati (Collaborating Centre); Co-PIs: Drs. Vivek Hegde, M. Nedunchezhiyan, P.P. Singh (RAU, Dholi) and Ashish Narayan (Dr. RPCAU, Dholi)

The project was initiated with the objective to develop distinct, stable and uniform morphological characters for differentiating various varieties/ clones and to establish a 'varietal gene bank' and computerized database in greater yam and yam bean. DUS guidelines of greater yam and yam bean were developed. For 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 (colour of standard and wing petal), pod length, tuber shape (Fig. 94) and seed shape were selected as grouping traits. Apart from these, a varietal gene bank in both the crops was established.

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

Fig. 94. Tuber shape in yam bean: Fusiform (a), Round (b) and Irregular (c)

The gene bank of reference varieties of cassava (55) and sweet potato (52) are being conserved in the field. DUS testing guidelines of both cassava and sweet potato were standardised. DUS testing guidelines of cassava included 30 characteristics, of which six traits, viz., pubescence on apical leaves, predominant shape of central leaf lobe, petiole colour and colour of mature stem: exterior, tuber rind colour and tuber flesh colour were selected as grouping traits. DUS testing guidelines for sweet potato included 25 characteristics, including six grouping traits viz., plant growth habit, vine pigmentation, mature leaf shape, tuber shape, predominant skin colour of tuber and tuber flesh colour. All the reference varieties were harvested and replanted both at the Headquarters as well as at the Regional Centre, ICAR-CTCRI. Farmers were sensitized to do registration of cassava and sweet potato varieties.

A Regional Workshop on 'Enriching Custodian Farmers with PPV&FR Act to Safeguard Valued Plant Genetic Resources Towards Green Prosperity' was organized during 10-11 October 2019. Two hundred and seventy five farmers from Karnataka and Kerala attended the workshop and exhibition. Facilitated a progressive farmer, Sri R. Raveendran, Ulloor for receiving Plant Genome Saviour Award 2019 (Fig. 95). Documents were prepared and forms submitted for the registration of four varieties of cassava and five varieties of sweet potato under extant variety category.

Fig. 95. Shri. R. Raveendran receiving the Genome Saviour Award 2019 from Shri Narendra Singh Tomar, Hon'ble Minister for Agriculture and Farmers Welfare

4. 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 had supplied a total of approximately 20,000 seeds obtained from controlled crosses to ICAR-CTCRI through NBPGR. Due to constraint of space, germination was carried out in a phased manner. Seeds were germinated using acid scarification method. The germinated seeds were then transferred to small polybags filled with potting mixture and irrigated daily. The seedlings produced tuber after 5 months. The tubers were screened for flesh colour and dry matter. The seedling with orange fleshed tubers and high dry matter based on visual observation were selected and the clones were maintained in bigger polybags for final evaluation trial. During the year, a total of 3500 seeds were germinated and out of this, 3000 hybrid seedlings established. Of these, 200 hybrids were selected based on flesh colour (orange) and dry matter (Fig. 96). These hybrid clones were planted in big polybags for getting sufficient vines for advanced trials. The selected clones were replanted as duplicates and pruned and maintained in an open fenced field with regular irrigation and insecticide application.

Fig. 96. Few promising orange fleshed hybrid clones of sweet potato

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

(Department of Biotechnology, Government of India, Ministry of Science and Technology; PI: Dr. Vivek Hegde; Co-PI: Dr. P. Sethuraman Sivakumar)

Taro varieties including leaf blight disease resistance, tolerant and susceptible varieties were selected for *in vitro* regeneration. Tuber sprouts from Muktakeshi (resistant to TLB), Sree Kiran, Bhu Kripa, Thamarakannan (tolerant to TLB) and Sree Rashmi (susceptible to TLB) were used to initiate the *in vitro* culture. The efficacies of the four different surface sterilizing agents were studied to establish aseptic *in vitro* taro cultures. Among the surface sterilizing agents studied, 2.0% silver nitrate ($AgNO_3$) treated for 15 minutes was found to be superior. Buds from *in vitro* grown plants were used for regeneration studies (Fig. 97). For regeneration of taro, different concentrations of BAP and TDZ along with NAA as well as 2,4-D along with TDZ and BAP were used for regeneration studies. Direct regeneration was observed in the medium supplemented with BAP alone and along with other growth regulators (Fig. 98) and medium with 2,4-D along with TDZ and BAP were produced indirect regeneration (Fig. 100). Among the different concentrations and combinations of growth regulators used for regeneration, 4.0 mg l^{-1} BAP along with 1.0 mg l^{-1} NAA recorded the highest number of shoots (3.50 explant^{-1}) in the variety Muktakeshi (Fig. 99). Similar trend was observed in other taro varieties under study. The well elongated shoots generated and obtained from shoot regeneration medium was transferred to MS basal medium for root induction. Taro plant with well-developed shoot and roots were obtained in MS basal medium (Fig. 100). The amount of wax in resistant and susceptible varieties of taro for TLB was estimated using the colorimetric method. For wax estimation, leaf samples were collected from eight different taro varieties in order to determine whether the quantity of wax plays a role in leaf blight resistance. Epicuticular wax was extracted from Muktakeshi, RNCA-1 (resistant to TLB), Sree Kiran, Bhu Kripa, Bhu Sree, Sree Pallavi, Thamarakannan (tolerant to

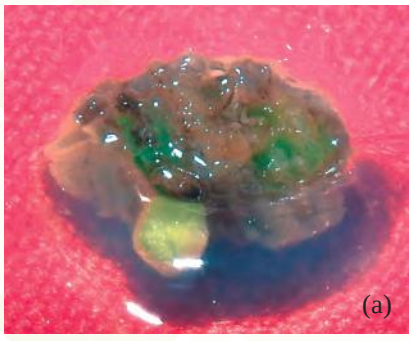


Fig. 97. *In vitro* culture initiation in taro (a) cultured taro explant, (b) regenerating explants

Fig. 98. Direct regeneration of taro explants with multiple shoots

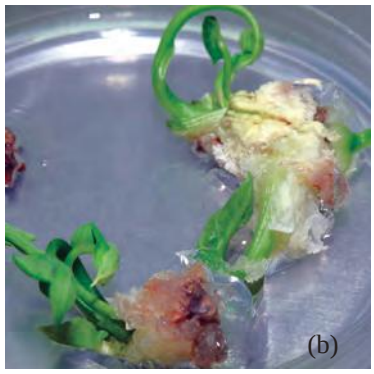


Fig. 99. Indirect regeneration (callus mediated) in taro (a) callus, (b) organogenesis from callus (c) taro plantlets produced through callus mediated regeneration

TLB) and Sree Rashmi (susceptible to TLB). The epicuticular wax varied between 0.00525 and 0.00586 mg cm^{-2}. The minimum (0.00525 mb cm^{-2}) and maximum (0.00586 mg cm^{-2}) epicuticular wax were recorded in the variety Bhu Sree and Muktakeshi, respectively.

Fig. 100. *In vitro* produced taro plant with well developed shoots and roots

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

This project was initiated in January 2019 with an objective to identify and isolate putative mutant clones of cassava with disease resistance, high yield and better post-harvest properties. The stem cuttings of 10 cm length in Sree Jaya and H-226 cassava varieties were treated with gamma irradiation. The LD_{50} dose of gamma irradiation of stem cuttings was found as 16.0 Gy for the cultivar Sree Jaya and 21.0 Gy for the cultivar H-226.

High sprouting of 73.01% was observed in H-226 when the stem cuttings were treated with 15 Gy gamma irradiation. In Sree Jaya also, high sprouting percentage (64.4%) was recorded at 15 Gy gamma irradiation.

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 on 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), green basal colour (8) and greenish purple basal colour (10). Thirty five mutants had green colour shoot like the 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 had an average leaf length and width of 22.4 and 6.2 cm, respectively.

7. *In vitro* quality planting material production of tuber crops to meet the demand of Odisha (RKVY, Dept. 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 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. Kisan

Healthy plants of sweet potato var. Bhu Krishna, Bhu Sona and Kisan were selected and young vines were collected for regeneration using standard protocol. Maximum number of shoots regenerated from the nodal segments of sweet potato var. Bhu Krishna on MS basal medium supplemented with 2.0 mg l^{-1} mT. *In vitro* regenerated shoots were rooted on half MS medium supplemented with 0.5 mg l^{-1} IBA (Fig. 101 a-g).

While in Bhu Sona, shoots were initiated from all explants within one week of inoculation and the response of explants for regeneration of shoot initiation and proliferation differed in the various concentrations and combinations tested. Maximum number of shoots was obtained from nodal segments on MS basal medium supplemented with 3.0 mg l^{-1} mT. Rooting of *in vitro* regenerated shoots is in progress.

Similarly, in sweet potato var. Kisan, shoots were initiated from all explants within one week of inoculation and response of explants for

Fig. 101. (a) Tuber of sweet potato var. Bhu Krishna, (b) Sweet potato field, (c) Nodal segments of sweet potato, (d) Shoot bud initiation from the nodal segment on MS medium supplemented with 2.0 mg l^{-1} BA after one week of inoculation, (e, f) Multiple shoot proliferation and elongation from the nodal segment of sweet potato on MS + 2.0 mg l^{-1} mT, (g) Rooting of *in vitro* regenerated shoot on half MS+0.5 mg l^{-1} IBA

regeneration of shoot initiation and proliferation differed in the various concentrations and combinations tested. Maximum number of shoots was obtained from nodal segments on MS basal medium supplemented with 2.0 mg l^{-1} BA and 0.5 mg l^{-1} KIN. *In vitro* regenerated shoots were rooted on half MS medium supplemented with 0.5 mg l^{-1} IBA.

Development of *in vitro* plant regeneration protocol of taro var. Muktakeshi

Healthy taro var. Muktakeshi corms were collected from the field and were washed under running tap water to remove the sand and soil adhered to it. The tuber was cut into small pieces *i.e.* each piece having at least one bud. Tuber segments were washed in liquid detergent followed by fungicide (Carbendazim). Then, the explants were surface sterilized by using $HgCl_2$ and washed with autoclaved distilled water. Surface sterilized tuber segments were inoculated on Murashige and Skoog (MS) basal medium supplemented with different concentrations and combinations of N^6- Benzyl adenine (BA) (0.5 - 5.0 mg l^{-1}), Kinetin (KIN) (0.5 - 5.0 mg l^{-1}). Shoots were initiated from all explants after one week of inoculation and the response of explants for regeneration of shoot initiation and proliferation differed in the various concentrations and combinations tested. Maximum numbers of shoots along with roots were regenerated from tuber segments on MS basal medium supplemented with 3.0 mg l^{-1} BA (Fig. 102 a-g).

8. All India-Network Programme on Organic Farming (AI-NPOF) (ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut as Lead Centre; PI: Dr. G. Suja; Co-PIs: Drs. G. Byju, S. Sunitha, S.S. Veena, A.N. Jyothi 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 and geo-referenced on-farm characterization of organic growers.

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

Four cropping systems, cassava-vegetable cowpea, cassava-groundnut, taro-black gram and taro-green gram, were evaluated under six management options, 100% organic, 75% organic, 100% inorganic, state recommendation (PoP), 50% organic +50% inorganic, 75% organic + 25% inorganic in large plots (18 m x 5.4 m) in strip plot design (unreplicated) with border fences of subabul between plots, border rows of lemon grass, karonda

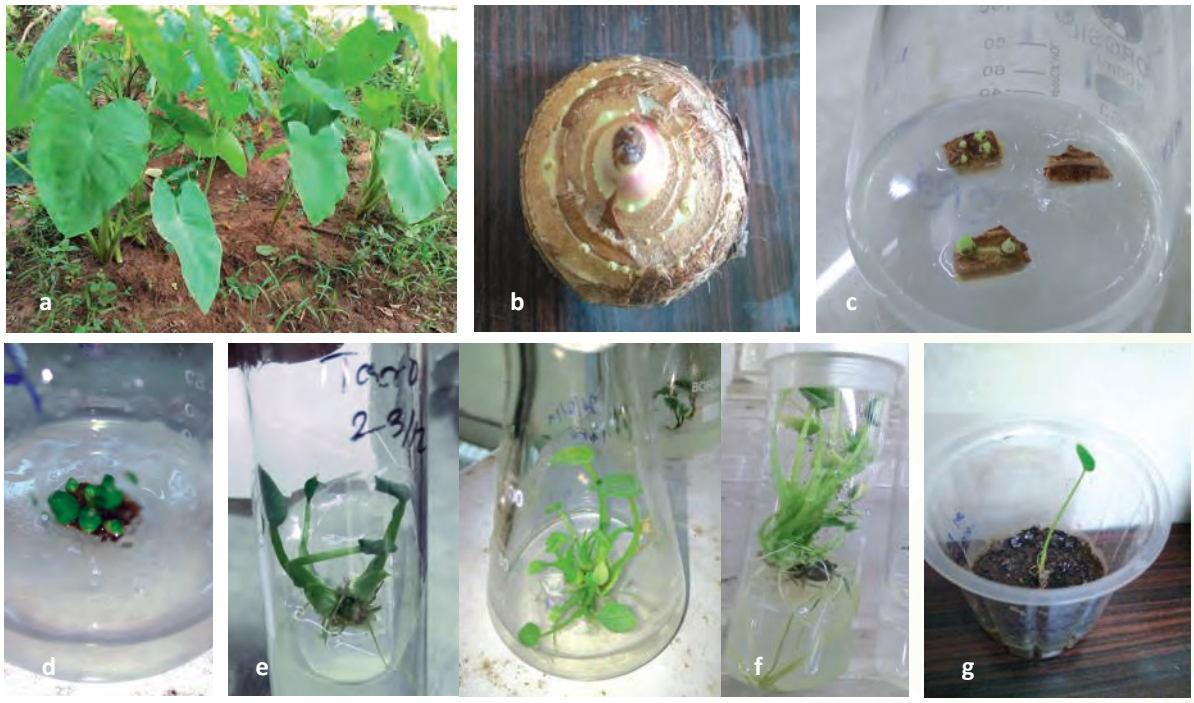


Fig. 102. (a) Taro var. Muktakeshi in the field, (b) Mother corm of taro, (c, d) Shoot bud initiation from the tuber segment on MS + 3.0 mg l^{-1} BA medium, (e, f) Simultaneous multiple shoot proliferation and elongation with rooting on the same medium (g) Acclimatization of *in vitro* regenerated plantlets

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 third consecutive season.

Of the four systems, cassava-groundnut was the most remunerative. In cassava-groundnut, 100% inorganic was the most profitable followed by 100% organic. However, with premium price, 100% organic was the most profitable. In cassava-vegetable cowpea system, with and without premium price, state PoP followed by 50% organic + 50% inorganic was profitable. In taro-green gram, without premium price, 50% organic + 50% inorganic was the most profitable, followed by 100% organic. In taro-black gram, without premium price, 50% organic + 50% inorganic was the most profitable, followed by 100% inorganic. When premium price was accounted in both the above systems, 100% organic outperformed and gave the highest returns.

In cassava-vegetable cowpea and cassava-groundnut systems, 50% organic + 50% inorganic and 100% inorganic resulted in the highest equivalent energy, tuber equivalent yield and production efficiency. In taro-green gram and taro-black gram systems, 100% organic generated the highest equivalent energy, tuber equivalent yield and production efficiency.

Evaluation of response of different varieties of cassava to organic farming

The third year result indicated that of the 12 varieties tested, Sree Reksha (CR-24-4) produced significantly higher yield. Second highest yield was obtained from Sree Vijaya.

Highest profit (₹ 179,839 ha^{-1}) and B:C ratio (2.07) was obtained from Sree Reksha followed by Sree Vijaya (₹ 45,161 ha^{-1} profit and 1.27 B:C ratio) under organic mode. Based on combined analysis of three years, varieties varied significantly under organic management. Sree Reksha yielded the highest (36.57 t ha^{-1}) on par with Sree Pavithra (25.30 t ha^{-1}). Sree Pavithra was on par with Sree Athulya (24.03 t ha^{-1}).

Geo-referenced on-farm characterization of organic growers

Geo-referenced survey of 30 farmers practicing organic farming in Malappuram District of Kerala was conducted. The survey was carried out in Mankada Block, Malappuram and Kazhakkoottam and Kilimanoor Blocks, Thiruvananthapuram (Fig. 103). Eighty per cent of the farmers belonged to

the small and marginal group with a land holding size < 2 ha. Average land holding size was 0.86 ha. Most of the farming situation surveyed was rainfed (60%) whereas, 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 50% of the surveyed farmers owned cow, 13.33% had goat, 46.66% had poultry (hen and duck) as an integral part of organic farming. Animal wastes were converted to excellent manures using biogas (in 6.67% cases) and vermicompost units (10% 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 (66.67%), vermicompost (43.33%), biogas slurry (6.7%), neem cake (66.67%), groundnut cake (33.33%), bio-formulations like *Panchagavya* (33.33%), *Jeevamrutham* (16.67%), and green manuring (16.67%). 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 through application of neem oil-garlic emulsion (46.67%), neem oil (16.67%), fish amino acid (46.67%), egg amino acid (26.67%), *Kanthari* emulsion (40%), neem soap (33.33%), *Beauveria* (60%), *Trichoderma* (66.67%), *Pseudomonas* (73.33%) and pheromone trap (40%). In addition, cultural methods, intercropping, trap crops on field bunds and some indigenous practices were also resorted to.

Development of Integrated Organic Farming System (IOFS) models

Without dairy and fishery components in the IOFS, net returns of ₹ 23,005 could be obtained from cassava based cropping system (Maize-cassava + vegetable cowpea + fodder grass) from an area of 65 cents (Fig. 104).

Fig. 103. Glimpses of geo-referenced survey of organic growers

Fig. 104. IOFS crop 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. Planting materials (cassava setts), concentrate organic manures (neem cake), biofertilizers (*Azospirillum*, P solubilizer and K solubilizer) and green manure cowpea seeds were supplied (Fig. 105). The NPOF technologies, cassava-groundnut and cassava-vegetable cowpea under 100% and 75% organic, respectively are under validation.

9. 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 proposed objective *i.e.*, on farm validation trials of the customized fertilizers (CF's) developed for cassava and elephant foot yam in farmers fields through KVKs was successfully achieved by conducting field trials in KVKs of Alappuzha, and Idukki districts (Fig. 106). The grade of the CF formulation for cassava under intercropping in coconut given to KVK Alappuzha was N:P:K:Mg:Zn:B @ 8:11:21:3.5:1:0.3 at an application rate of 500 kg ha^{-1}. There was significant difference in yield and quality under CF's over existing PoP.

At KVK, Idukki, the CF formulations developed for EFY with grade as N:P:K:Mg:Zn:B @ 7:12 :24:3.5:1.25:0.4 at an application rate of 625 kg ha^{-1} and for cassava with two grades as N:P:K: Mg:Zn:B @8:11:21:3.5:1:0.3 and 8:11:21:3.5:1:0.3 @ 500 kg ha^{-1} tested in selected farmers' fields indicated the superiority of the CF's with respect to tuber yield and quality parameters over existing PoP under intercropping in coconut gardens. BC ratio yet to be worked out in both locations.

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

The project 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. Six experiments in two AEU's viz., AEU 3 (Onattukara sandy plain) and AEU 9 (south central laterites) were conducted in five farmers fields (Fig. 107) and one on-station at ICAR-CTCRI. The experiment consisted of nine treatments replicated thrice and the variety used was 'Sree Pavithra'. The treatments were fixed based on the lime requirement in the case of application of lime and dolomite. The crop was planted during July-August 2018 and harvested during April-May 2019 in all these locations.

Observations were recorded at tri-monthly intervals on plant growth characters viz., plant height, stem girth, number of fallen and retained leaves. The initial soil nutrient status on pH, EC, organic carbon, available N, P, K, Ca, Mg and S was determined in each of the locations. The post harvest soil samples were also analysed to see the increase in pH and

Fig. 105. Glimpses of SCSP scheme under AI-NPOF: Organic cassava cultivation

Fig. 106. Demonstration trials on cassava and elephant foot yam at ICA- KVK, Idukki

especially K, Ca, Mg and S since the polysulphate is a natural mined product rich in these nutrients (K_2O: 13.5%, CaO:16.5%, MgO:5.5%, S:18.5%). In addition, the effect of the treatments on cassava tuber quality parameters viz., starch and cyanogenic glucosides were also determined.

The tuber yield data of the four locations in AEU 9 including at ICAR-CTCRI indicated significant effect of treatments in three locations with polysulphate @ 1.5-2 t ha^{-1} along with either full lime or dolomite or half lime or dolomite along with PoP. The pooled data over the locations of AEU 9 indicated an yield increase of 10.4% under polysulphate along with either lime or dolomite over PoP with tuber yield to the tune of 50.29 t ha^{-1} under half dolomite and polysulphate @ 1.5-2 t ha^{-1} which was on par with full lime and polysulphate (47.87 t ha^{-1}). Though there was no significant effect of treatments on cyanogenic glucosides, application of polysulphates along with lime and dolomite resulted in reducing the bitterness of cassava tubers. In the case of starch content, application of polysulphate did not result in any significant increase over PoP in all the locations.

In the case of improvement in soil chemical properties due to polysulphate application, it was found that, there was an increase of 10.9, 128, 40, 90, 149%, respectively for pH and nutrients viz., K, Ca, Mg and S, respectively especially when applied along with lime or dolomite full or half, as per lime requirement. The increase/decrease with respect to the above chemical parameters over initial nutrient status after one year of application of polysulphate alone or polysulphate along with lime and dolomite as well as lime and dolomite without polysulphate are presented in Fig. 108.

11. Higher productivity and profitability from coconut gardens through soil health management in tuber crops (Coconut Development Board, Government of India;

AEU 3-Field view and tuber yield

AEU 9 - Field view and tuber yield in different locations

Fig. 107. Field view of trials conducted in various farmers fields

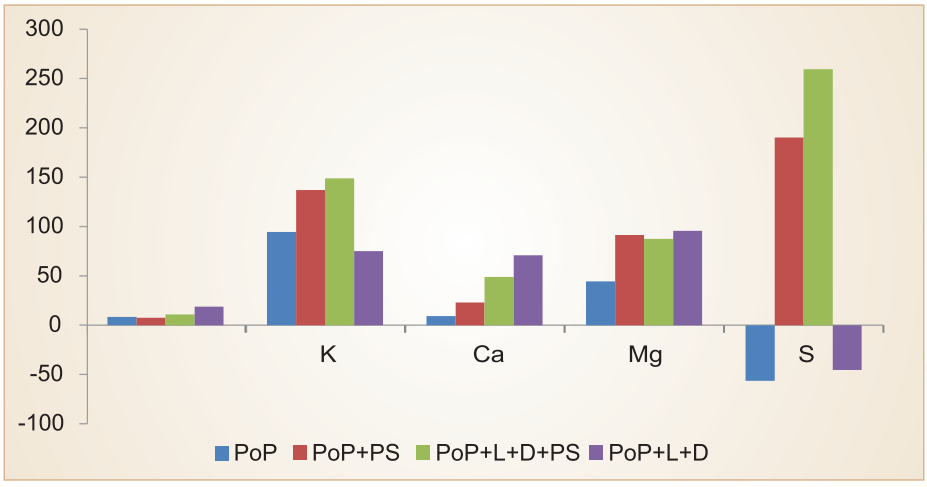


Fig. 108. Percentage increase in pH, K, Ca, Mg & S over initial due to polysulphate application

PIs: Dr. G. Byju and Dr. G. Suja; Co-PIs: Drs. Archana Mukherjee and D. Jaganathan)

A total of twenty on-farm trials were conducted in Thiruvananthapuram and Kollam districts of Kerala. Farmers were supplied with quality planting materials of improved varieties/selections of tuber crops for planting in coconut gardens and organic manures and chemical fertilizers were applied as per the recommendations. Demonstrations on soil health management were conducted in cassava (6 nos.) and greater yam (4 nos.) in Thiruvananthapuram District and greater yam (4 nos.) and elephant foot yam (6 nos.) in Kollam District. Biometric data were recorded, soil samples were collected and analyzed.

In Thiruvananthapuram District, on-farm validation of customized fertilizers (CF), developed based on SSNM technology was demonstrated in two coconut farms with greater yam as intercrop and another three farms with cassava as intercrop. Likewise, the organic farming technology was validated in two coconut farms with greater yam as intercrop and another three farms with cassava as intercrop. SSNM technology resulted in higher cassava tuber yield (31.50 t ha^{-1}) over the other two treatments viz., farmer's practice (20.92 t ha^{-1}) and package of practices (PoP) (26.47 t ha^{-1}). However, the tuber yield of greater yam was higher in package of practices (4.74 t ha^{-1}), followed by SSNM treatment (3.99 t ha^{-1}) and farmer's practice (3.39 t ha^{-1}). Overall, in cassava, SSNM resulted in higher yield over farmer's practice (by 50.57%) and PoP (by 19%). In greater yam, SSNM performed better than farmers practice by yielding 17.35% higher.

The cassava tuber yield obtained from organic farming technology (24.08 t ha^{-1}) was higher than the other two treatments viz., farmer's practice (17.36 t ha^{-1}) and package of practices (16.10 t ha^{-1}). Similarly, the tuber yield of greater yam was higher in organic farming technology (3.65 t ha^{-1}) followed by farmer's practice (3.60 t ha^{-1}) and package of practices (3.35 t ha^{-1}). Overall, in cassava, organic farming yielded higher over farmer's practice (by 38.70%) and PoP (by 49.66%). In greater yam, organic farming yielded slightly higher over farmer's practice (by 1.38%) and PoP (8.95%).

On-farm demonstrations established in Kollam District (Fig. 109) are being monitored for growth and yield parameters, which will be continued for the next one or two years for estimating the system productivity and profitability. Apart from the above 20 trials, two demonstration trials one each on customized fertilizers and organic farming in greater yam were also being carried out at Open Prison and Correctional Home, Nettukaltheri, Thiruvananthapuram, under the CDB project.

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

A study was conducted to identify the climate smartness of cassava, based on the future projections in one of the major cassava growing areas in India. The future projections are derived using the Long Ashton Research Station-Weather Generator (LARS-WG), which incorporated


Organic farming technology


SSNM technology

Fig. 109. View of demonstrations on soil health managment in Kollam District

climate projections of global climate models (GCMs). The projections of EC-EARTH, HadGEM2-ES, MIROC5, and MPI-ESM-MR models for the RCP4.5 were tested in the crop model, World Food Studies (WOFOST) to assess the impact on growth and yield characteristics of cassava. Two varieties (H-266 and Sree Vijaya) were used to calibrate the model. The crop model predictions based on the outputs from the GCMs indicated that the crop yield will increase from 8.6 to 12% and 3.6 to 5.5% during 2030 for H-226 and Sree Vijaya, respectively (Fig. 110). During 2050, the yield increase ranged from 3.3 to 6.7% for H-226 and -4.3 to 1.9% for Sree Vijaya, respectively. However, beyond a particular threshold in climatic variables, heat stresses in the crop reduce its yield. As an outcome of this study, the variety H-226 can be considered as climate-smart variety in the context of climate change and food security.

This study also analyzed the variability in the crop water and irrigation requirements of two major tuber crops in Kerala, India in the context of water scarcity and food security. The FAO-CROPWAT model was used to estimate the optimal water requirements of cassava and sweet potato, known as the future food and fuel crops over the 23 agro-ecological units (AEUs) of Kerala, India (Fig. 111). The results detected variability in the actual crop water as well as the irrigation water requirements of cassava and sweet potato over the 23 AEUs. The gross irrigation requirement ranged from 158 to 816 mm and 145 to 469 mm in the case of cassava and sweet potato, respectively. These results indicate the crop water and irrigation water requirements

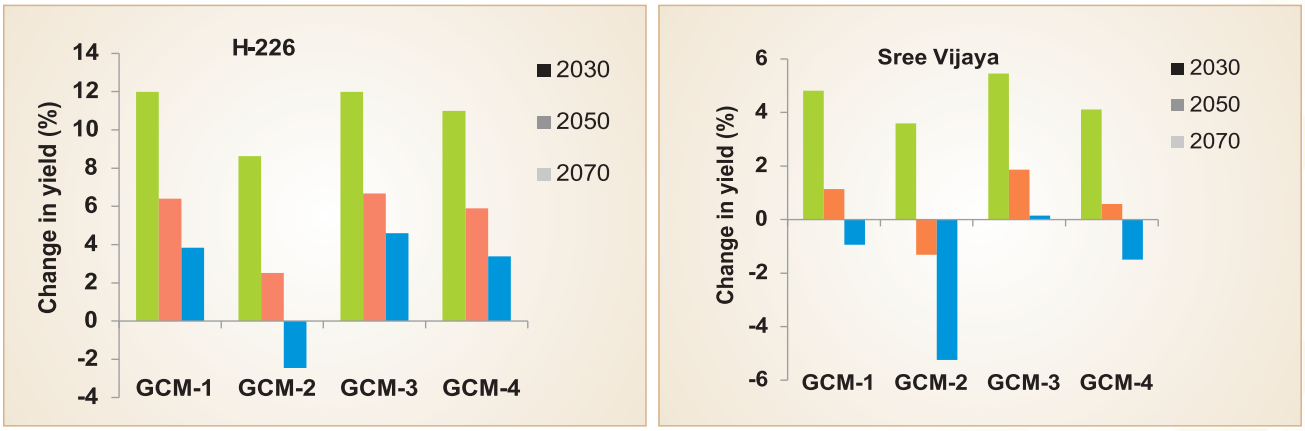


Fig. 110. Percentage changes in crop yield predictions based on the projections

change from one location to another depending on the meteorological parameters eventhough it is for the same crop and the same soil. This highlights that climate change can have a significant influence on the crop water requirement for a particular crop for a particular region.

Apart from that, the current study also calibrated the FAO-AquaCrop model for cassava and sweet potato over the major growing areas of India. AquaCrop provides potential crop yield along with the irrigation water requirement based on the crop and study location.

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 (RKVY-RAFTAAR, Government of Kerala; PI: Dr. V. Ravi, Dr. Archana Mukherjee, Dr. G. Byju and Dr. J. Sreekumar; Co-PIs: Drs. M.N. Sheela, C.A. Jayaprakas, Sheela Immanuel, G. Suja, K. Susan John, V. Ramesh, R. Muthuraj, Saravanan Raju, Sanket J. More and D. Jaganathan)

This project envisages developing infrastructure in the Institute for quality planting material production of improved varieties and establishing seed villages in tribal settlements in three Districts of Kerala. During 2019-20, the following root and tuber crops were cultivated in 10 acres. Cassava - 3.5 acres; yam- Sree Karthika, Sree Keerthi, Sree Shilpa, Sree Nidhi, Sree Dhanya, Odisha elite -1.5 acre; sweet potato - var. Bhu Krishna, Bhu Sona, Kanhangad, Sree

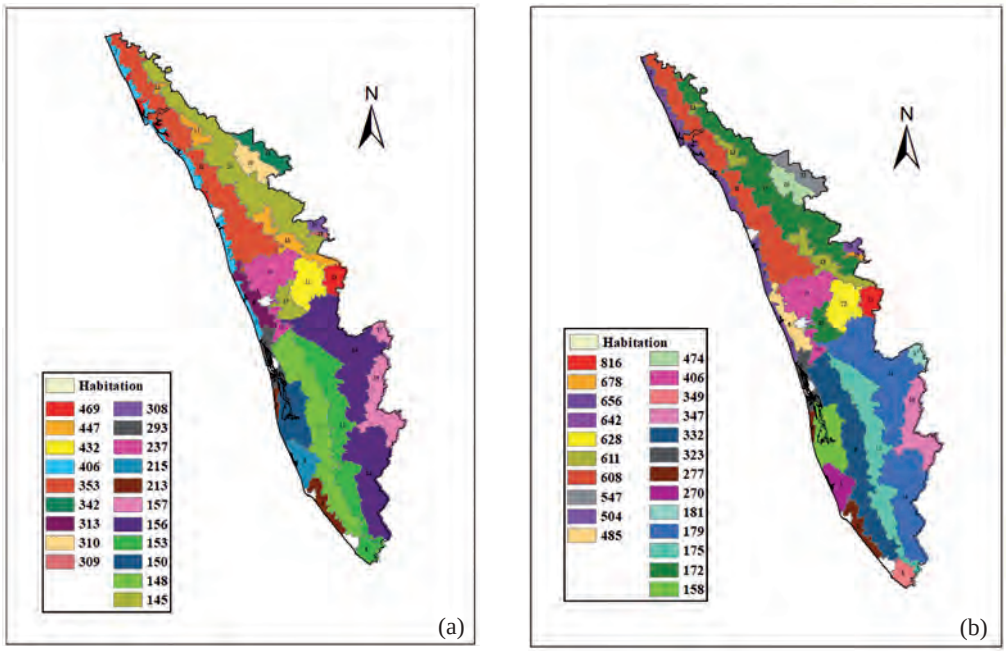


Fig. 111. Gross irrigation requirements (mm) of cassava (a) and sweet potato (b) over the AEUs, Kerala

Kanaka, Sree Arun -1 acre and elephant foot yam - Gajendra - 4 acres were multiplied. Total quantity of 1,05,000 sweet potato vine cuttings were supplied to 44 ST contact farmers in Kuttichal, Amboori, Tholicode, Vithura and Kotoor Panchayats in Thiruvananthapuram District (Fig. 112).

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

During the year 2019, front line demonstration of tuber crops technologies were taken in eight districts (Dhenkanal, Nayagarh, Keonjhar, Bargarh, Koraput, Kandhamaal, Navrangpur and Mayurbhanj) of Odisha. A total of 364 demonstrations were laid out covering 33.8 ha (sweet potato - 8.2 ha; cassava - 6.1 ha; yam - 5.9 ha; yam bean - 6.4 ha; elephant foot yam - 4.6 ha and *Colocasia* - 2.6 ha) (Fig. 113). Further, 10 lakhs sweet potato vine cuttings were given to the Directorate of Horticulture, Odisha to multiply and distribute to the farmers under their sweet potato area expansion project.

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 (RKVY; 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 2019, sweet potato + red gram intercropping system was demonstrated in 1.0 ha covering 12 farmers in Pappadahandi block of Nabarangpur district. The crop was regularly monitored by field visits. The red gram sown as intercrop in sweet potato field had not sprouted in many places due to high rain during sowing.

Kuttichal

Amboori

Kotoor

Vithura

Fig. 112. Distribution of sweet potato planting materials to ST farmers at different locations

Greater yam + maize demonstration

Sweet potato harvest

Fig. 113. Glimpse of activities carried out under the RKVY project

Sweet potato crop was harvested during November 2019, four months after planting. In farmers fields, sweet potato tuber yield was in the range of 1035-1210 kg per 0.1 ha with the average yield of 11310 kg ha^{-1} (Fig. 114). The gross and net income from sweet potato cultivation were ₹ 2,26,200 ha^{-1} and ₹ 1,41,500 ha^{-1}, respectively. Yam bean cultivation was demonstrated in 1.0 ha covering nine farmers in Pappadahandi block of Nabarangpur District. The crop was monitored regularly by field visits. In farmers fields, yam bean tuber yield was in the range of 1125-1425 kg per 0.1 ha with the average yield of 12427 kg ha^{-1} (Fig. 114). The gross and net income from sweet potato cultivation were ₹ 3,22,810 ha^{-1} and ₹ 2,91,510 ha^{-1}, respectively. Greater yam + maize intercropping system was demonstrated in 1.0 ha in Pappadahandi, Dabugaon and Nandahandi blocks of Nabarangpur District covering eight farmers. Maize population was very less due to late sowing and failed to establish in many places due to continuous rain after sowing. The greater yam crop had good growth and the crop is yet to be harvested.

Fig. 114. Sweet potato and yam bean tubers after harvest

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

During the year 2019, 20 tribal households were adopted from Budukakhol, Bandhakhamana and Kharijhola villages of Chakapada (Block), Kandhamal (District) and 15 tribal households were adopted from Andragada, Jubagaon, Ateli and Chandragiri villages of Mohana (Block), Gajapati (District) for demonstrating tuber crops based farming system (0.2 ha model). In this 0.2 ha model the area of various crop components were as follows: rice/ragi/maize - 0.08 ha; greater yam + maize intercropping - 0.03 ha; sweet potato - 0.04 ha; yam bean - 0.04 ha and cassava - 0.01 ha. All the above crop components were sown/ planted during *kharif* season. Vegetables were grown in *rabi* season in 0.01 ha. Backyard poultry 20 Vanaraja birds (45 days old) were also given to each farmer/demonstration. Planting materials of sweet potato - 1,50,000 vine cuttings; greater yam tubers - 2000 kg; elephant foot yam - 2000 kg; taro - 200 kg; cassava - 2000 stems; yam bean seeds - 20 kg; maize seeds - 20 kg; rice - 10 kg; red gram - 10 kg, vegetable seed kits - 60 nos. and back yard poultry birds (Vanaraj) - 800 nos. were

Cassava in tribal farmer's field

Sweet potato in tribal farmer's field

Fig. 115. View of farmer's field

distributed to the tribal farmers. Vegetable kits contain Amaranthus, bhendi, chilli, onion, cowpea, French bean, *Dolichos* and bottle gourd seeds were also provided. Farmers also contributed maize/ rice seeds. Regular monitoring was carried out to address the problems faced by the tribal farmers. For capacity building of the tribal farmers on tuber crops cultivation, four on-farm trainings were organized.

In tribal farmers field, the average yield of sweet potato was 14 t ha^{-1}, yam bean 18 t ha^{-1}, taro 17.5 t ha^{-1}, elephant foot yam 32 t ha^{-1}, maize 3525 kg ha^{-1} and ragi 1125 kg ha^{-1} (Fig. 115). Each tribal household produced sufficient tubers, rice, ragi, maize, etc. for household consumption (food and nutritional security) and surplus for selling (farm income).

17. 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: Dr. M.L. Jeeva, Mr. R. Arutselvan and Dr. R. Muthuraj)

The polyclonal antibody obtained from two New Zealand white rabbits against *Dasheen mosaic virus* recombinant protein (DsMV-IgG) was assessed for its performance through ELISA and DIBA. The sensitivity and specificity of the polyclonal antibody (DsMV-IgG) were determined through DAC-ELISA and DIBA (Fig. 116) and the results showed that optimum titre value of the polyclonal antibody is 1:10000 dilutions and specificity was also good. Dipsticks for DsMV detection were prepared using this antibody and tested using the leaf samples (infected with DsMV as well as healthy samples) were homogenized with PBS-T-PVP and briefly centrifuged to collect the supernatant. The dipsticks were placed in an upright position in a tube containing the sap (supernatant) for 5 min or more. The result was analyzed based on the colour development at Test and Control lines (Fig. 117).

A one step LAMP assay was developed for detection of *sweet potato feathery mottle virus* (SPFMV). A set of six primers were designed, based on the coat protein gene sequence of the SPFMV virus. The assay was optimized to amplify SPFMV DNA under isothermal condition at 63^0C for 60 min. LAMP amplification products were detected by visual examination using calcein nucleic acid stain (Fig. 118) and had a ladder-like appearance on a 2% agarose gel (Fig. 119). The detection limit of the LAMP assay was found to be 100 times more sensitive than the conventional PCR method. The assay was evaluated using diseased samples and the results indicated the reliability and simplicity of the assay as a quick field diagnostic tool for SPFMV.

18. On Farm trial of cassava biopesticides against borer pests of banana in Kerala

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

The biopesticides *Nanma* and *Menma* were evaluated in collaboration with five KVKs in Thiruvananthapuram, Ernakulam, Thrissur, Wayanad and Kasaragod as well as one NGO, Centre for Innovation in Science and Social Action (CISSA), Thiruvananthapuram, Kerala. On the whole, 19,780 banana plants were treated with *Nanma* and *Menma* at the farmers' fields in coordination with the five KVKs. There was significant reduction (over 95%) in pseudostem weevil infestation over control. All the untreated fields recorded heavy infection (>90%). Under this project, 26 training programmes were organised with KVKs and CISSA across the state, and many awareness programmes were also conducted at village level in selected districts. Feedback on the use of *Nanma* and *Menma* collected from the farmers showed that these biopesticides were very effective in the management of banana pseudostem weevil and rhizome weevil. Banana fields treated with *Nanma* and *Menma* were demonstrated as model exhibition plots in all the selected five KVKs. Arrangements were made for the supply of bio-pesticides through Bio-pharmacy of the selected KVKs. Extension workers and Agricultural officers were trained on the use of *Nanma* and *Menma* biopesticides. Video films in six languages, including Russian language, on the use of biopesticides were produced.

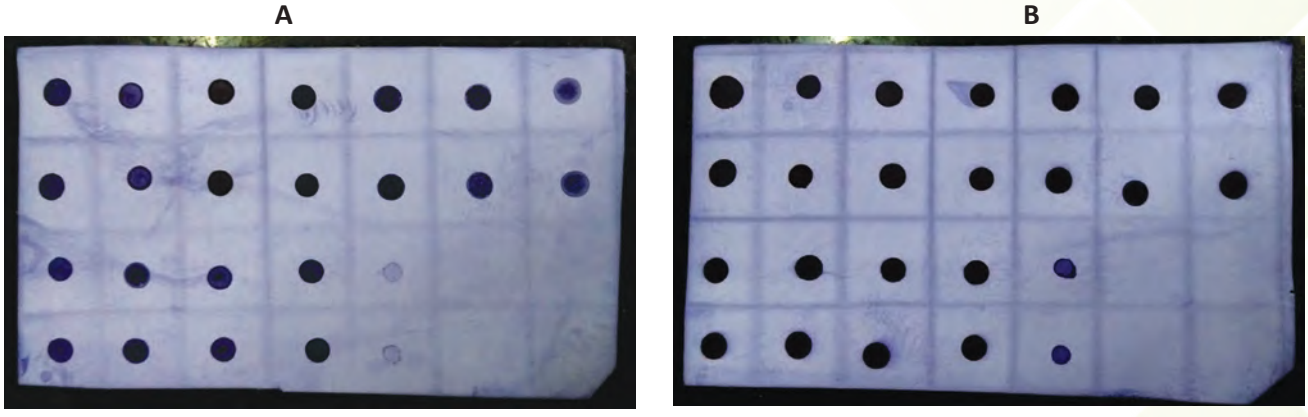


Fig. 116. Standardization of DsMV-IgG using DIBA. A - DIBA using DsMV IgG (DsMZ), B-DIBA using DsMV IgG (In-house raised), Lanes 1 to 10 (Duplicates) - Field samples, Lane 11 (Duplicates) - Positive control, Lane 12 (Duplicates) - Negative control

Fig. 117. Validation of DsMV-IgG coated strip (dipstick) developed in ICAR-CTCRI Transgenic Lab. Lane 1 - Strip dipped in DsMV positive control sample leaf sap, Lane 2 - Strip dipped in buffer control sample leaf sap, Lane 3 - Strip dipped in DsMV negative control sample leaf sap, A-Control line, B-Test line

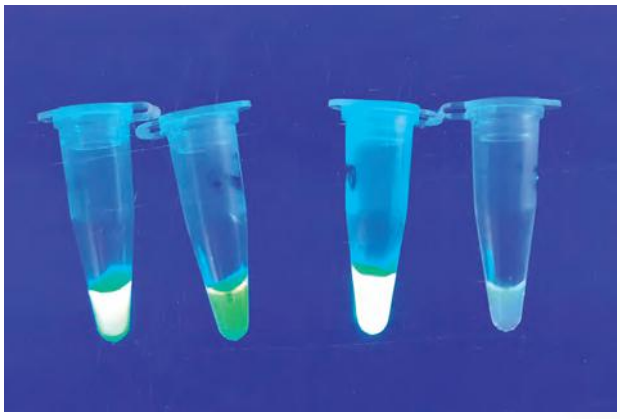


Fig. 118. Visualization of LAMP products using calcein nucleic acid dye

Fig. 119. Gel electrophoresis using 2% agarose gel for LAMP PCR. Lanes 1 to 4 - SPFMV PCR positive samples collected from ICAR-CTCRI field, Lane 5 - Negative control, M - 1 kb plus DNA ladder

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

Effect of pH and digestive enzymes on stability of sweet potato anthocyanins

The effect of pH and digestive enzymes on the degradation and stability of anthocyanins in purple sweet potato tubers of variety Bhu Krishna was studied by *in vitro* methods. The gastric simulated digestion was performed in the presence of pepsin that is normally found in high amounts in the gastric juice. The pH of the solution was set at 3.0 to mimic the conditions of the stomach during digestion. Simulated gastric digestion did not interfere with the overall stability of the anthocyanin extract as revealed by the amount of anthocyanins detected before and after gastric reactions. During the intestinal digestion (pH 7.5), a degradation of anthocyanins was observed. A decrease of about 72% was observed after the intestinal digestion of anthocyanins for 2 h in the case of purple sweet potato anthocyanins. After the simulation of small intestine digestion, a significant decrease in anthocyanins concentration was observed, due to a general decrease of all the individual anthocyanins, more marked for peonidin glycosides. Sweet potato tuber anthocyanins were highly stable in acidic pH and its stability decreased with increase in pH. These anthocyanins have higher absorbance values and colour stability at pH 2.0 and the stability decreased with increase in pH. Simulated gastric digestion did not interfere with the overall stability of the anthocyanins.

Docking studies for the anticancer activity of sweet potato anthocyanins

Molecular docking study was conducted for the anticancer activity of sweet potato tuber Bhu Krishna and leaf anthocyanins from accession S-1467 using three cancer target proteins, 4FA2 (breast cancer), 4FLH (colon cancer) and V226F (cervical cancer) (Fig. 120). The major anthocyanin present in both tuber and leaf, peo-3-O-(6″-caffeoyl-6‴-p-hydroxybenzoylsoph)-5-O-glc exhibited good binding energy with breast cancer and cervical cancer proteins. The results are in agreement with those of *in vitro* cell line studies, which revealed that both tuber and leaf anthocyanins were highly effective against breast cancer cells due to the presence of high content of the compound peo-3-O-(6″-caffeoyl-6‴-p-hydroxybenzoylsoph)-5-O-glc. *In vitro* studies of leaf anthocyanins showed better activity against colon cancer cells than tuber anthocyanins due to the presence of higher content of compounds Cy-3-O-(6″,6‴-dicaffeoylsoph)-5-O-glc and Peo-3-O-(6″-caffeoylsoph)-5-O-glc in leaves than that of tuber.

20. Techno Incubation Centre (Small Farmers Agribusiness Consortium, Government of Kerala; PI: Dr. M.S. Sajeev; Co-PI: Dr. T. Krishnakumar)

Thirty five training programmes were organized at the Techno Incubation Centre of ICAR-CTCRI on value added products from tuber crops, which were attended by 940 people including farmers and young entrepreneurs from different districts of Kerala. Among them, about 546 were female and 344 male participants. The incubation centre was used by 48 entrepreneurs for the production of snack foods such as *pakkavada*, crisps, nutrichips, *murukku*, sweet fry and pasta. Two MoU were signed on the technology of fried snack products by M/S Tapas Naturals, Ernakulam and M/S Mithram Food Products, Muzhoor Farmers Club, Palai, Kottayam and one MoU on protein enriched pasta with Smt. Athira T. B., Ernakulam and a revenue of ₹ 59,000/- was generated. Two processing units, Dora Foods, 3/336, Aravangat Building, Kuruvattoor, Kozhikode and M/S Mithram Food Products, Muzhoor Farmers Club, Palai, Kottayam started functioning during 2019.

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

The technology commercialisation and entrepreneurship development activities of the Institute are executed by the Intellectual Property Management Unit and Professional Services Cell (IPTMU & PSC) in collaboration with Divisions/ Section and Techno-Incubation Centre (TIC). The following activities were conducted during 2019.

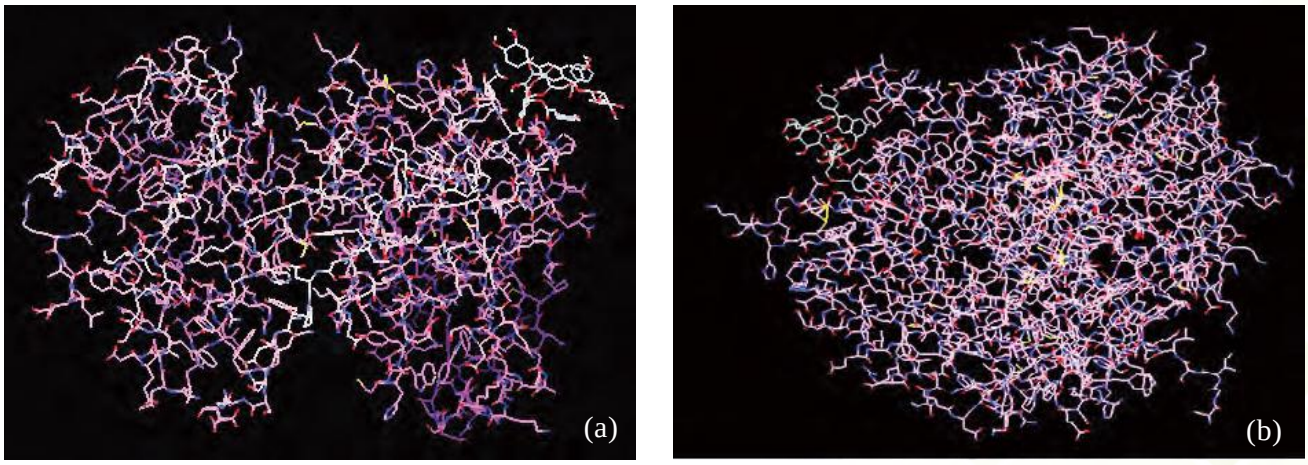


Fig. 120. Image showing the binding sites of sweet potato anthocyanins with (a) 4FA2 and (b) V226F cancer target proteins

Technology Commercialization

Value added fried products and fried chips from cassava and sweet potato on a technology licensing and consultancy mode was given to three firms/ individuals – 1) Mithram Food Products, Moozhoor Farmers Club, Moozhoor P.O. Kottayam – 686503: and 2) Tapas Naturals, 1st Floor, Mystic Heights Kaniyampuzha Road, Vytilla, Kochi- 682302 as well as Pasta to 1) Smt. Athira, T.B., Parayath Puthan Pura, Iramalloor, PO, Kothamangalam, Ernakulam-686691, Kerala and license fee of ₹ one lakh was collected.

Entrepreneurship development activities

One ICAR-CTCRI-KAU collaborative 'Entrepreneurship Orientation Programme' was organised for final year B.Sc.(Ag.) students from College of Agriculture, KAU, Vellayani. A 'Technology Conclave and Industry Meet' was organized in the event of ICAR-CTCRI Foundation Day.

22. Chlorophyll fluorescence kinetics and monitoring of photochemical efficiency in cassava (*Manihot esculenta* Crantz) genotypes for energy efficient cassava

(KSCSTE, Govt. of Kerala; Woman Scientist: Dr. Raji S. Nair; Scientist Mentor: Dr. Saravanan Raju)

The objective of the study was to identify the high light efficient cassava genotype that has fast Non-photochemical Quenching (NPQ) relaxation time on varying sunlight. Preliminary study was carried out on existing cassava plot with genotypes Black Thailand, Mulluvadi, Quintal kappa, Kalpaka, H-165 and Sree Pavithra. All the plants were grown under natural field conditions. Plants were maintained at well watered condition. All gas exchange and fluorescence measurements were taken on fully grown youngest leaves using LI-6400 XT Portable Photosynthesis system (Li-COR Inc, NE, USA). Varying external Photosynthetically Active Radiation (PAR) was provided using additional light source available attached to the system. For the measurement of chlorophyll fluorescence, the leaves were dark adapted for 30 minutes and the maximum fluorescence (Fm), variable fluorescence (Fv) and the minimal fluorescence (Fo) were measured. Steady state fluorescence (Fs), maximum fluorescence (Fm') and Variable Fluorescence (Fv') were measured under varying external PAR of 1000, 1500 and 2000 µ mol $m^{-2}s^{-1}$. It was observed that NPQ and qN (non photo chemical quenching) increased and PhiPS2 (quantum efficiency of PSII), qP (photochemical quenching) and Fv'/Fm' decreased with increasing PAR. At 1000 µmol $m^{-2}s^{-1}$, highest PhiPS2 was observed for Sree Swarna variety at 1000 µmol $m^{-2}s^{-1}$. Non photochemical quenching (NPQ and qN) was seen to increase with increase in PAR values in all the genotypes. Among the cassava genotypes studied, Black Thailand showed minimum variation in NPQ values when the PAR was increased from 1000 µmol $m^{-2}s^{-1}$ to 2000 µmol $m^{-2}s^{-1}$. Higher qN and NPQ value at PAR of 2000 µmol $m^{-2}s^{-1}$ was observed in Quintal kappa.

TECHNOLOGIES ASSESSED, TRANSFERRED, CONSULTANCY AND PATENT SERVICES

Technologies transferred

The Intellectual Property and Technology Management Unit & Professional Services Cell (IPTMU&PSC) under the guidance of the Intellectual Property and Technology Management Committee (IPTMC) has carried out the following technology transfer and contract activities during 2019.

Technology commercialisation

Value added fried products and fried chips from cassava and sweet potato on a technology licensing and consultancy mode were given to three firms/ individuals viz., Mithram Food Products, Moozhoor Farmers Club, Moozhoor Po. Kottayam and Tapas Naturals, 1st Floor, Mystic Heights, Kaniyampuzha Road, Vytilla, Kochi as well as Pasta to Smt. Athira, T.B., Parayath Puthan Pura, Iramalloor, PO, Kothamangalam, Ernakulam on a technology licensing and consultancy mode and a license fee of Rupees one lakh was collected. Two processing units viz., M/s. Dora Foods, 3/336, Aravangat Building, Kuruvattoor, Kozhikode and M/s. Mithram Food Products, Muzhoor Farmers Club, Palai, Kottayam were started during 2019.

The revenue generated through various activities at the Institutional level in all modes is indicated in Table 13.

Table 13. Revenue generated through technology commercialisation and other professional service functions

Sl. No.	Activity	Revenue generated (₹)
1	Technology licensing	100000*
2	Sale of technological products	232600
3	Professional training	156256
4	Consultancy	118000
5	Students fees	3030684
	Total	3637540

*Excluding GST

Technologies/varieties developed

Varieties and potential genotypes

- One CMD resistant cassava line, 9S-125 (TCa13-7) was recommended for submission of proposal for central release in the states of Kerala, Manipur and Chhattisgarh based on AICRP trials conducted during 2013-2019. It is a hybrid, having 8-9 months duration with high yield (35 t ha^{-1}), dry matter (40.06%), starch (25.9%) and good culinary quality having an organoleptic score of 6.47.
- A new greater yam variety, Sree Hima, was recommended for release by AICRP (TC) for Kerala State
- Two short duration CMD resistant varieties (D-36 and D-48) were identified
- Identified six high yielding greater yam and seven white yam accessions which recorded > 5 kg $plant^{-1}$
- Identified one white yam variety SD-15 suitable for growing under non trailing conditions
- Genetic map for cassava mosaic disease (CMD) resistance with eleven meta QTLs and seventy three candidate genes associated with CMD were predicted
- Seven differentially expressed genes involved in the carotenoid biosynthesis pathway were identified in sweet potato
- Identified five sweet potato genotypes suitable

for processing based on evaluation for important processing traits

- Identified 15 flowering lines in elephant foot yam
- DUS guidelines of greater yam and yam bean were developed

Production technologies

- Production technology for dwarf white yam + pulse system
- Production technology for rice-short-duration cassava + black gram system
- Production technology for elephant foot yam + pulse system
- Production technology for taro + pulse system
- Four cropping systems models viz., cassava-vegetable cowpea, cassava-groundnut, taro-black gram and taro-green gram were developed
- NPK use efficient genotypes viz., Sree Pavithra, 7 III E3-5, CI-905 and CI-906 for high yield under low levels of NPK (25%) were identified
- Drip irrigation along with porous ground cover mulching or soil application of super absorbent polymers like Pusa hydrogel to reduce the water requirement of elephant foot yam to 50% without adversely affecting the corm yield
- Continuous irrigation upto 24 weeks from planting at IW/CPE ratio of 0.75 for producing optimum cormel yield as well as total yield in upland taro
- Developed drip fertigation technology for greater yam + maize intercropping system
- Developed SSNM strategies for sustainable production of elephant foot yam + black gram cropping system in Alfisols of eastern India
- Sree Reksha was identified as drought-tolerant variety based on the assessment of morpho-physiological parameters of cassava subjected to normal and water stress growing conditions
- Developed SSNM strategies for *Colocasia* production in marshy/low lands of eastern India
- Crop model for future projections of cassava were derived using the Long Ashton Research Station-weather generator (LARS-WG), which incorporated climate projections of global climate models (GCMs)
- AquaCrop model was tested for cassava and sweet potato over the major growing areas of India
- Tested and estimated the meteorological sensitivity of WOFOST in predicting the yield of cassava in India
- Climate smart agricultural practices for cassava with reduced c emission and increased carbon efficiency
- Soil test based application of NPK, Mg, Zn and B
- Green manuring *in situ* with cowpea, coirpith compost, vermicompost as alternate organic sources to farmyard manure
- Need based soil application of secondary nutrient Mg and micronutrients, Zn and B based on soil test

Protection technologies

- A new strain of entomopathogenic nematode, *Steinernema siamkayai* (CTCRI EPN 01) was identified from a soil sample from the cassava field in Ucchakada, Thiruvananthapuram
- Ascertained an endophyte *Bacillus cereus* from arrowroot for the management of anthracnose in greater yam
- Combination of Carbendazim 0.025% and *Nanma* (0.7%) for the management of anthracnose in greater yam
- Spraying of fungicide combination of Mefenoxam 4% + Mancozeb 64% for the management of taro leaf blight
- Role of miRNA in cassava mosaic disease was established
- Optimized techniques to study the life cycle responses of *Bemisia tabaci* in cassava plants
- LAMP based diagnosis of S*weet potato feathery mottle virus* (SPFMV)

Technologies for value added food products

- Papad from cassava based composite flour
- Rice analogue from sweet potato based composite flour
- Crackers from cassava- sago- wheat flour

- Development of weaning food mixes from sweet potato flour, millet flour, pulse flour and cereal flour
- Development of anthocyanin and β-carotene rich cake from sweet potato flour and refined wheat flour
- Development of ready to use laddu mix from sweet potato and Bengal gram composite flour
- Continuous screw press type machine for dewatering of cassava mash for the production of high quality cassava flour
- Prototype for continuous steaming machine for sago papad and sago wafer production

Technologies for industrial products

- Thermoplastics starch sheets with cassava starch-saw dust and acid modified cassava starch composites
- Microwave assisted synthetic method for the production of RS4 type cassava and sweet potato starches

Models/Packages/ICT tools developed

- Machine learning method for plant microRNA identification
- Machine learning method for SNP prediction in plants

EDUCATION, TRAINING AND CAPACITY BUILDING

Education

ICAR-CTCRI is recognized as an approved Research Centre by the University of Kerala, Kannur University, Manonmaniam Sundaranar University, Utkal University, Orissa University of Agriculture & Technology, Bhubaneswar, Odisha and Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, Madhya Pradesh for undertaking Ph.D. programme on tuber crops. During the period, the Institute has offered exposure training to students, imparted technical guidance for Ph.D. programme and project work of M.Sc./B.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. project work	163
B.Sc./B.Tech. internship	51
M.Sc. project work	45
M.Sc. Integrated Biotechnology	5
Ph.D.	20
PDF	3

Training programmes

A total of 1276 farmers, 292 students and 60 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 Priority Setting, Monitoring and Evaluation of Agricultural Research Projects	19 January 2019	122 PG and Ph.D. students from College of Agriculture, Vellayani	ICAR-CTCRI and College of Agriculture, Kerala Agricultural University, Vellayani
Training on Soil Analysis	4-8 February, 8-12 April & 17-21 June 2019	60 officers of 14 districts of Kerala from the Department of Agriculture, Soil Survey and Soil Conservation, Government of Kerala	Division of Crop Production, ICAR-CTCRI, Thiruvananthapuram
Stakeholders interface in connection with Prime Minister's Kisan Samman Nidhi Yojana (PM KISAN) cum Live Web Telecast	24 February 2019	200 farmers and other stakeholders	ICAR-CTCRI, Thiruvananthapuram
Training on Improved Technologies of Tuber Crops	26-28 February 2019	25 progressive farmers of Dapoli, Maharashtra	
Training on Improved Technologies of Tuber Crops	28 February - 02 March 2019	105 progressive farmers of Salem, Tamil Nadu	
Training on Improved Technologies of Tuber Crops	20 - 23 March 2019	15 progressive farmers of Champaran, Bihar	

Particulars of training	Date	Number of beneficiaries and category	Sponsoring Institute/State
Training on Improved Technologies of Tuber Crops	03 May 2019	35 progressive farmers of Pathanamthitta District, Kerala	ICAR-CTCRI, Thiruvananthapuram
Training on Improved Technologies of Tuber Crops	27 May 2019	40 progressive farmers of Palakkad District, Kerala	
Training on Improved Technologies of Tuber Crops	03 June 2019	34 progressive farmers of Palakkad District, Kerala	
Training on Improved Technologies of Tuber Crops	22 June 2019	44 progressive farmers of Thiruvananthapuram District, Kerala	
Stakeholders Interface Meeting in connection with 56th Foundation Day Celebrations of ICAR-CTCRI, Thiruvananthapuram	27 July 2019	86 farmers from Kerala	
Training on Improved Technologies of Tuber Crops for Enhancing Productivity and Farm Income	27-29 August 2019	30 SC farmers of Tirunelveli District, Tamil Nadu	
Entrepreneurship Development Programme	4-7 September 2019	110 B.Sc. (Ag.) students of College of Agriculture, Vellayani, Thiruvananthapuram	
Feed The Future India Triangular Training (FTF-ITT) programme on Integrated Technology for Production, Processing and Value Addition in Tuber Crops	16-30 September 2019	29 delegates from African and Asian Countries	
Training on Improved Technologies of Tuber Crops	3-4 October 2019	6 Department Officials of Trichy District, Tamil Nadu	
Training on Value Addition in Tuber Crops	05 October 2019	32 SC farmers of Alleppy District, Kerala	
Training on Value Addition in Tuber Crops	18 October 2019	35 SC farmers of Thiruvananthapuram District, Kerala	
Stakeholders Interface Meeting was organized in connection with Regional Workshop on Enriching Custodian Farmers with PPV&FR Act to Safeguard Valued Plant Genetic Resources Towards Green Prosperity	10-11 October 2019	200 farmers and other stakeholders	PPV & FR Authority, New Delhi and ICAR-CTCRI, Thiruvananthapuram
Financial Management for Agristartups	25 October 2019	60 students	ICAR-CTCRI, Thiruvananthapuram
Training on Innovative Extension Approaches for Horticultural Crops with Special Reference to Tuber Crops	19-22 November 2019	25 officers from different parts of the country	MANAGE, Hyderabad and ICAR-CTCRI, Thiruvananthapuram
Training on Improved Technologies of Tuber Crops	11-13 & 18-19 December 2019	25 farmers of Namakkal District and 24 farmers from Tirunelveli District, Tamil Nadu	ICAR-CTCRI, Thiruvananthapuram
Training on Improved Technologies of Tuber Crops	24, 26 and 27 December 2019	15 B.Sc. (Ag.) students of Banaras Hindu University, Varanasi, Uttar Pradesh	ICAR-CTCRI, Thiruvananthapuram

Inaugural session of training on Priority Setting, Monitoring and Evaluation of Agricultural Research Projects

Participants of the training on Soil Analysis

Farmers from Tirunelveli

Agricultural Department officials of Trichy District

Students attending the training on Financial Management for Agristartups

Training for farmers from Tamil Nadu

Trainings organized by Techno-Incubation Centre, ICAR-CTCRI

Thirty five on-campus training programme were organized at the Techno-incubation centre of ICAR-CTCRI, which were attended by about 890 participants (546 females and 344 males).

Glimpses of training programmes at Techno Incubation Centre at Headquarters

Trainings at RC, ICAR-CTCRI Bhubaneswar

Particulars of training	Date	Sponsoring Institute/State
Tuber Crops Day at Chandragiri village, Mohna Block, Gajapati (Aspirational District) Odisha	9 January 2019	RC, ICAR-CTCRI, Bhubaneswar, Odisha
Brain Storming Workshop on Tuber Crops Area Expansion: Scope and Prospects in Odisha	28 January 2019	
Training programme on Processing and Value Addition of Tuber Crops	7-9 March 2019	NABARD under CAT programme
Training programme on Tuber Crops Technology for Livelihood and Nutritional Security in Watershed Areas of Koraput District, Odisha	26 - 28 March 2019	RC, ICAR-CTCRI, Bhubaneswar, Odisha
Training on Improved Technologies of Tuber Crops for farmers of Mayurbhanj District, Odisha	26 June 2019	
Training on Improved Technologies of Tuber Crops for farmers of Keonjhar District, Odisha	28 June 2019	
Training on Improved Technologies of Tuber Crops for farmers of Dhenkanal District, Odisha	29 June 2019	
Training cum Exposure Visit for 5 B.Sc. (Ag.) students of Gyan Vihar University, Jaipur, Rajasthan	24 July 2019	
Training on Processing and Value Addition of Cassava and Other Tuber Crops for industrial personnel of Pedilite Industries Limited, Ahmadabad	19-21 September 2019	
Training on Tuber Crops and Allied Agricultural Technologies for Livelihood and Nutritional Security for farmers of Odisha	24-28 September 2019	
Training programme on Tuber Crops and Allied Agricultural Technologies for Livelihood and Nutritional Security	15-19 October 2019	ATMA Bargardh District, Odisha
Stakeholders Interface Meet on Performance Evaluation to Maximize Farmer's Income, Better Livelihood with Tuber Crops and Allied Technological Intervention	19 October 2019	RC, ICAR-CTCRI, Bhubaneswar, Odisha
Farmers training programme on Production and Value Addition of Tuber Crops	28-30 October 2019	ATMA, Odapada block, Dhenkanal District, Odisha
Training programme on Tuber Crops Technologies for 85 B.Sc. (Ag.) students of Centurion University of Technology and Management, Bhubaneswar, Odisha	01 November 2019	RC, ICAR-CTCRI, Bhubaneswar, Odisha

Training programme on Tuber Crops Technologies for 74 B.Sc. (Hort.) students from Centurion University of Technology and Management, Gajapati, Odisha	05 November 2019	
Training on Tuber Crops and Allied Agricultural Technologies for Livelihood and Nutritional Security for farmers of Sonepur District, Odisha	18-22 December 2019	
Farmers training programme on Tuber Crops and Allied Agricultural Technologies for Livelihood and Nutritional Security	23-24 December 2019	ATMA, Kamkhyanagar block, Dhenkanal District, Odisha
Farmers training programme on Value Addition of Tuber Crops	26-28 December 2019	ATMA, Gondia block, Dhenkanal District, Odisha

On farm training and distribution of planting materials at Mayurbhanj District of Odisha

Off campus training programmes

Particulars of training	Date	Number of beneficiaries and category	Venue
Field day cum entrepreneur meet on Chinese Potato	11 January 2019	100 farmers and other stakeholders	Alvan Thulukapatti, Alankulam, Tirunelveli District, Tamil Nadu
Stakeholders interface programme on Improved Technologies of Elephant Foot Yam	13 February 2019	60 farmers and other stakeholders	Savaram village in West Godavari District of Andhra Pradesh
Training module on Business Plan Development and Bankable Projects jointly organized by ICAR-CTCRI and College of Agriculture, Kerala Agricultural University, Vellayani in connection with Agriclinic and Agribusiness Center scheme (AC & ABC) training	25 February 2019 to 3 March 2019	25 participants	College of Agriculture, Vellayani, Thiruvananthapuram
Stakeholders interface programme on Improved Technologies of Tuber Crops	30 April 2019	85 farmers	Atreyapuram, East Godavari, Andhra Pradesh
Stakeholders interface programme on Improved Technologies of Tuber Crops	30 April 2019	90 farmers	Ravulapalem, East Godavari, Andhra Pradesh
Field Day cum Launching Workshop of SCSP Project	20 September 2019	60 farmers	Pellakal Pudhukkudi, Ambasamudram, Tirunelveli, Tamil Nadu

In house training for Technical personnel and Skilled Supporting Staff of ICAR-CTCRI

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

Training on 'Enhancing personal efficiency in job performance' for 23 Skilled Supporting Staff was organized during 4-6 February 2019 at ICAR-CTCRI, Thiruvananthapuram. The classes were handled by the Scientists and other staff of the institute. Exposure was given to them in all research and extension activities undertaken by the Institute.

Participants of the in-house training for Technical personnel

Participants of the in-house training for Skilled Supporting Staff

Professional Attachment Training of newly recruited ARS Scientist

Dr. Pampi Paul, Scientist (Agricultural Extension), ICAR Research Complex for NEH Region, Umiam, Meghalaya has undergone her professional attachment training during 12 November 2018 to 11 February 2019 at ICAR-CTCRI under the guidance of Dr. P. Sethuraman Sivakumar, Principal Scientist and Dr. D. Jaganathan, Scientist.

Resource person in training programmes

More than 250 classes on production, protection, processing and value addition aspects were handled by Scientists of various divisions under different programmes within and outside the Institute beneficial to department officials, subject matter specialists, students and farmers all over the country. The specific topics covered were improved varieties, tissue culture, agro-techniques with special focus on organic management, INM, IPM, vermi-composting, bio-pesticides and bio-control strategies, post-harvest management and value addition.

Exposure visit cum training programme

One day exposure visit cum training on 'Improved technologies of tuber crops' was organized for the benefit of 1050 farmers, 2031 students and 210 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. State wise number of farmers visited the institute on exposure visit is given in Fig. a. A total of 545 farmers from Kerala, 400 from Tamil Nadu and 105 from other states visited the

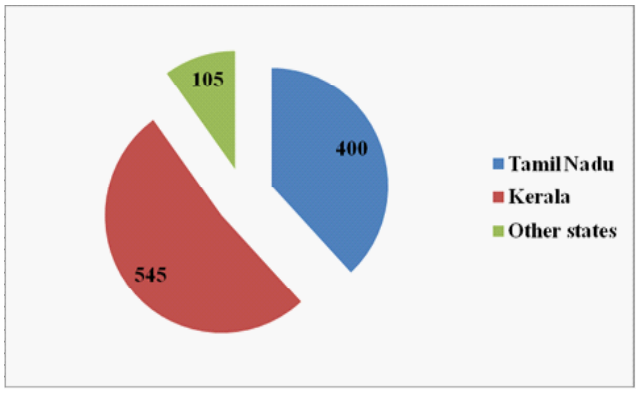


Fig. a. State-wise exposure visits of the farmers to ICAR-CTCRI

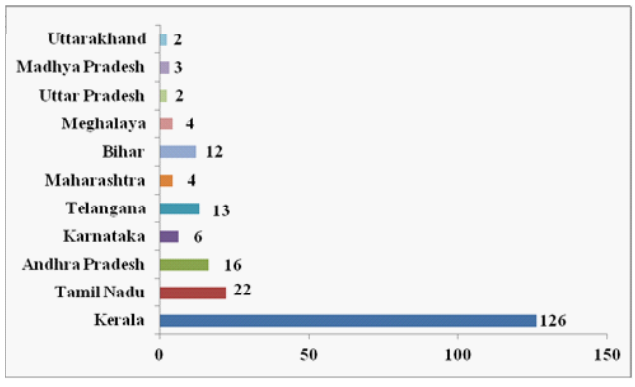


Fig. b. State-wise exposure visits of the officials to ICAR-CTCRI

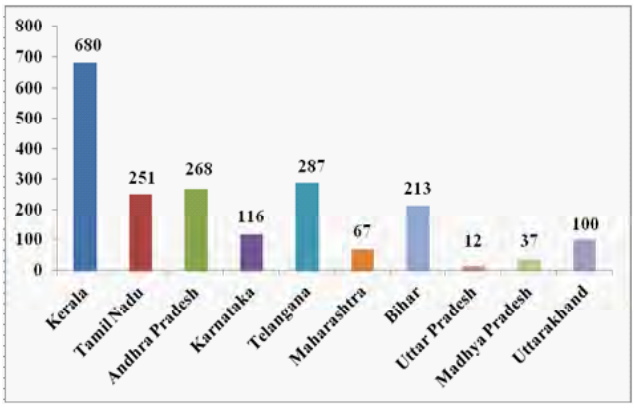


Fig. c. State-wise exposure visits of the students to ICAR-CTCRI

Institute. Similarly, 210 officials and 2031 students from different parts of the country visited ICAR-CTCRI on exposure visits (Fig a to c).

Farmers from Tirunelveli, Tamil Nadu

Farmers from Krishnagiri, Tamil Nadu

Students from Andhra Pradesh

Students from Bihar

Students from Kerala

Students from Tamil Nadu

RC, ICAR-CTCRI, Bhubaneswar

One day exposure visit cum training on 'Tuber crops technologies' was organized for 2997 persons comprising of farmers, students and officials visited at ICAR-Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar, Odisha. State-wise numbers of the persons who visited the Institute for exposure visits are Odisha (2544) followed by Jharkhand (170), Andhra Pradesh (137), Chhattisgarh (50), Delhi (47), Gujarat (24), West Bengal (20) and Madhya Pradesh (5).

Exposure visit of farmers at RC, ICAR-CTCRI

Exposure visit of students at RC, ICAR-CTCRI

Trainings attended by ICAR-CTCRI Staff

a. Scientific staff

Sl. No.	Name	Particulars of the training	Period
1	Dr. V.B.S. Chauhan	Modern Statistical Techniques in Genetics at ICAR-IASRI, New Delhi	1-21 February 2019
2	Dr. T. Srinivas	Training Cum Workshop on Improving eGovernance in Agriculture at MANAGE, Hyderabad	4-8 February 2019
3	Dr. D. Jaganathan Dr. T. Krishnakumar	Training on Analysis of Experimental Data using R at ICAR-NAARM, Hyderabad	21-26 February 2019
4	Dr. Vivek Hegde	Advances in Plant Biotechnology and Molecular Biology, Module II at ICAR-Research Complex for NEH Region Manipur Centre, Lamphelpat, Imphal, Manipur	5-11 March 2019
5	Dr. M.L. Jeeva Dr. T. Makesh Kumar Dr. C. Mohan Dr. D. Jaganathan Dr. H. Kesava Kumar Dr. T. Krishnakumar Dr. S. Karthikeyan	Hindi correspondence course 'Praveen' at AGs office, Thiruvananthapuram	25-26 April 2019
6	Dr. J. Suresh Kumar	Statistical Advances in Designing Agricultural Experiments and Data Analysis under the aegis of CAFT at ICAR-IASRI, New Delhi	19 July - 8 August 2019
7	Dr. Sanket J. More	Analysis of Experimental Data at ICAR-NAARM, Hyderabad	22-27 August 2019
8	Dr. Kalidas Pati Dr. V.B.S. Chauhan	Radiation Technology Application in Agriculture at CHES, ICAR-IIHR, Bhubaneswar	4 September 2019
9	Dr. N. Krishna Radhika Dr. K.M. Senthilkumar	Omics Meet Plant Biochemistry: Applications in Nutritional Enhancement with one Health Perspective at Division of Biochemistry, ICAR-IARI, New Delhi	7-27 September 2019
10	Dr. K. Sunil Kumar	Model Training Course on Organic Farming for Safe and Sustainable Food Production with Special Focus on Tropical Tuber Crops at ICAR-CTCRI, Thiruvananthapuram	1-8 November 2019

11	Dr. P. Murugesan	Biodiversity Conservation at Wildlife Institute of India, Dehradun	4-8 November 2019
12	Dr. N. Krishna Radhika	Gene Editing for Enhancing Plant Productivity and Stress Tolerance at ICAR-IIRR, Hyderabad	10-12 November 2019
13	Dr. K. Sunil Kumar Dr. Sanket J. More Dr. J. Suresh Kumar	Innovative Extension Approaches for Horticultural Crops with Special Reference to Tuber Crops at ICAR-CTCRI, Thiruvananthapuram	19-22 November 2019
14	Dr. R. Saravanan Raju	Training on Multivariate Data Analysis Using R at ICAR-NAARM, Hyderabad	22-27 November 2019
15	Dr. N. Krishna Radhika	DNA Sequencing and Analysis at University of Kerala, Thiruvananthapuram	2-7 December 2019
16	Dr. T. Krishnakumar	ICAR sponsored short course on Entrepreneurship Development Through Agro/Food Processing Centres at ICAR-Central Institute of Agricultural Engineering (CIAE), Regional Centre, Coimbatore	12-21 December 2019

b. Technical staff

Sl. No.	Name	Particulars of the training	Period
1	Shri. R. Bharathan, Chief Technical Officer Shri. V.S. Sreekumar, Senior Technical Officer Smt. N. Sujatha Kumari, Chief Technical Officer Dr. L.S. Rajeswari, Assistant Chief Technical Officer Shri. A. Madhu, Assistant Chief Technical Officer Shri. I. Puviyarasan, Assistant Chief Technical Officer Shri. M. Kuriakose, Assistant Chief Technical Officer Shri. C.S. Salimon, Assistant Chief Technical Officer Shri. V.R. Sasankan, Senior Technical Officer Shri. B. RenjithKishor, Senior Technical Officer Shri. V. Ganesh, Technical Officer Shri. S. Natarajan, Technical Officer Shri. A.S. Manikuttan Nair, Technical Officer Shri. G. Suresh, Senior Technical Assistant Dr. S. Shanavas, Senior Technical Assistant Shri. B.S. Prakash Krishnan, Senior Technical Assistant Shri. G. Shajikumar, Senior Technical Assistant Shri. Luke Armstrong, Technical Assistant Dr. S. Karthikeyan, Technical Assistant Smt. K. Pallavi Nair, Technical Assistant Shri. K. Sunil, Technical Assistant Shri. T. Raghavan, Senior Technician Shri. B. Satheesan, Senior Technician Shri. D.T. Rejin, Senior Technician Shri. T.M. Shinil, Senior Technician Shri. C. Krishnamoorthy, Technician Shri. K.Velayudan, Technician Shri. T. Manikantan Nair, Technician	Refresher Training on Improved Technologies of Tuber Crops for technical personnel of ICAR-CTCRI	08-10 January 2019

2	Shri. V. Ganesh, Technical Officer	Motivation, Positive Thinking, Communication Skills and Personality Development for Technical Officers of ICAR Institution at ICAR-National Academy of Agricultural Research Management, Hyderabad	13-19 March 2019
3	Shri. V.R. Sasankan, Senior Technical Officer Shri. B. Satheesan, Senior Technician Shri. D.T. Rejin, Senior Technician	Innovative Extension Approaches for Horticultural Crops with Special Reference to Tuber Crops, ICAR-CTCRI, Thiruvananthapuram	19-22 November 2019

c. Administrative staff

Sl. No.	Name	Particulars of the training	Period
1	Shri. Abhishek Rana, SAO Shri. P. Krishnakumaran, FAO Shri. T.V. Kurup, AAO	Sensitization/Training Programme for E-Office at ICAR-Indian Agricultural Statistics Research Institute, New Delhi	23-24 January 2019

d. Skilled Supporting Staff

Sl. No.	Name of the Skilled Support Staff	Particulars of the training	Period
1	Shri. S. Radhakrishnan Nair Shri. D. Arun Raj Shri. S. Abhishek Shri. P. Aswin Raj Shri. A. Chandran Shri. T. Lawrence Shri. K. Sivadas Smt. S. Ushakumari Smt. J. Thenmozhi Shri. S. Sudhish Shri. Stiphin George Shri. Sreenath Vijay Shri. K. Sarathchandra Kumar Shri. L. Samynathan Ms. Rohini K. Nair Smt. Rini Alocious Smt. V.S. Remya Shri. G. Madhu Ms. C.P. Gayathri Smt. R. Nijamol Ms. S. Anjitha Smt. C.T. Chellamma Shri. K. Chandran	Training on Enhancing Personal Efficiency in Job Performance for Skilled Support Staff of ICAR-CTCRI	4-6 February 2019

AWARDS AND RECOGNITIONS

Awards

- Dr. P. Murugesan was conferred as Fellow of the Indian Society of Seed Technology during the valedictory function of 'National Seminar on Strengthening of Seed Systems in the North-Eastern and Unreached Regions–Problems, Prospects and Policies' on 5 February 2019 at Imphal, Manipur.

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

- Dr. H. Kesava Kumar and Dr. E.R. Harish were conferred as Life Fellow of 'The Entomological Society of India' instituted by the Entomological Society of India, New Delhi on 31 December 2019.
- Dr. V.V. Bansode was awarded the Young Scientist Award-2019 in the Discipline of Food Technology in the 2nd International Conference on Recent Advances in Agricultural, Environmental and Applied Sciences for Global Development' during 27-29 September 2019 organized by Agro Environmental Development Society and Dr. Y.S. Parmer University of Agriculture and Forestry, Nauni, H.P.
- Dr. K. Susan John won the Dr. R.L. Narasimha Swamy Memorial Award for the Best Research Paper on 'Nutrient partitioning in root wilt disease affected *vis a vis* healthy coconut palms grown in an Entisol of humid tropics' (Authors: Jeena Mathew, A. Abdul Haris, Chinju M. Raj, V. Krishna Kumar, Ravi Bhat, K. Muralidharan and K. Susan John)in the PLACROSYM XXIII, held during 06-08 March 2019 at Central Coffee Research Institute, Chikkamagaluru, Karnataka.
- Dr. B.G. Sangeetha was awarded the Best Oral Paper Award for the paper entitled: Validation of proteinase inhibitor genes expression in sweet potato plants related to *Cylas formicarius* (Fabricius) infestation (Authors: B.G. Sangeetha, C.A. Jayaprakas, T. Makeshkumar, Shirly Raichal Anil, Ajina Ajeem, S. Adithya, Hizaana Noushad and Kalidas Pati)in the International conference PROVECTUS PLANTAE'19 on Exploring the Scope of Plant Genetic Resources held during 22-24 May 2019 at the Department of Botany, University of Kerala, Thiruvananthapuram, Kerala.
- Dr. Sirisha Tadigiri was awarded the Best Oral Presentation Award for the research paper entitled 'Biosensors: Engineered *Caenorhabditis elegans* as the sensing machinery' in the 'International Conference on Global Research Initiatives for Sustainable Agriculture & Allied Sciences' during 13-16 October 2019 at ICAR-NAARM, Hyderabad, Telangana.
- Dr. D. Jaganathan bagged the best oral presentation award for the research paper entitiled 'Livelihood assessment for technological interventions in elephant foot

yam and banana cultivation in Andhra Pradesh' (Authors: D. Jaganathan, Sheela Immanuel, A.V.V. Koundinya and P.S. Sivakumar) in the 'International Conference on Extension for Strengthening Agricultural Research and Development (eSARD 2019)' organized by Extension Education Society, TNAU, Coimbatore during 14-16 December 2019 at Mysuru, Karnataka.

- Dr. P. Murugesan was awarded the Best Poster Award for the research paper entitled 'Integration of digital image analysis for seed quality evaluation in sweet potato' (Authors: P. Murugesan, Archana Mukherjee, M.N. Sheela, V. Ravi, C. Visalakshi Chandra, H. Kesava Kumar, T. Krishnakumar, J. Sreekumar, Sheela Immanuel, P.S. Sivakumar and V.S. Santhosh Mithra) in the 'National Seminar on Strengthening of Seed Systems in the North-Eastern and Unreached Regions–Problems, Prospects and Policies' on 05 February 2019 at ICAR-Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal.
- Dr. N. Krishna Radhika was awarded the Best Poster Award for the research paper entitled 'Biotechnological explorations of unexplored tuber crops germplasm for a nourishing diet' (Authors: N. Krishna Radhika, A. Mukherjee, M.N. Sheela, K.I. Asha, Shirly Raichal Anil, A. Asha Devi, K.M. Senthilkumar and V.V. Asha) in the International Conference on New horizons in Biotechnology held during 20-24 November 2019 at CSIR-National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram.
- Dr. Vivek Hegde was awarded the Best Poster Award for the presentation on 'Long term pollen storage studies in cassava and greater yam' (Authors: Vivek Hegde, A.V.V. Koundinya, M.N. Sheela, C. Visalakshi Chandra, K.M. Senthilkumar and P.V. Abhilash) in the 8th Indian Horticulture Congress held during 17-21 January 2019 at Indira Gandhi Krishi Viswavidyalaya, Raipur, Chhattisgarh.
- ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, bagged the first prize in the category of 'Best Exhibition Stall Award' in the National Horticultural Fair held during 23-25 January 2019 at ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru.
- ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, bagged the first prize in the category of 'Best Exhibition Stall Award' in Krishidham Expo held during 15-17 February 2019 at ICAR-Central Potato Research Institute, Regional Station, Modipuram, Meerut, Uttar Pradesh.

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

- ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram bagged the first prize in the category of 'Best Exhibition Stall Award' in Kanakolsavam 2019 during 5-15 April 2019 at Kanakakunnu palace, Thiruvananthapuram.
- ICAR-CTCRI basketball team consisting of Dr. J. Sreekumar, Dr. K.M. Senthil Kumar, Dr. Sanket J. More, Shri. P.C. Noble, Shri. V.R. Sasankan, Dr. A. Shanawas, Shri. C. Chandru and Shri. A. Chandran bagged the first position in the basketball tournament in ICAR South Zone Sports meet conducted at ICAR-Central Institute of Fisheries Technology, Kochi during 4-7 November 2019.

Award of Ph.D.

- Athira G.K. was awarded Ph.D. in Chemistry from the University of Kerala, for the thesis entitled 'Development and studies on starch based polymer matrices as delivery systems for curcumin and some selected drugs' under the guidance of Dr. A.N. Jyothi.
- Mithra, M.G. was awarded Ph.D. in Biotechnology from the University of Kerala, for the thesis entitled 'Sustainable 2G ethanol

production technology for selected root and vegetable processing wastes' under the guidance of Dr. M.L. Jeeva and co-guidance of Dr. G. Padmaja.

- Remya, R. was awarded Ph.D. in Chemistry from the University of Kerala, for the thesis entitled 'Comparative study on the synthesis of resistant starches of diverse botanical origin by different modification techniques and investigations on their structural and functional properties' under the guidance of Dr. A.N. Jyothi.

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

- Ms. Lekshmi J.K. was awarded M.Sc. (Ag.) in Entomology from Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur, Madhya Pradesh. The thesis work was done on the topic 'Utilisation of gamma irradiation technique for the management of *Cylas formicarius* (Fab.) (sweet potato weevil) in stored sweet potato' at ICAR-CTCRI under the guidance of Dr. C.A. Jayaprakas.
- Ms. Jyothi Lekshmi O.B. was awarded B.Sc.-M.Sc. (Integrated) Biotechnology from Kerala Agricultural University. The thesis work was done on the topic 'Differential response of resistant gene analogues (rgas) against *Phytophthora colocasiae* causing leaf blight in taro (*Colocasia esculenta)*' at ICAR-CTCRI under the guidance of Dr. M.L. Jeeva.
- Mrs. Linet K. Joseph was awarded B.Sc.-M. Sc. (Integrated) Biotechnology from Kerala Agricultural University. The thesis work was done on the topic 'Comparative analysis of antimicrobial activities of 43 *Trichoderma* isolates against *Sclerotium rolfsii,* the pathogen causing collar rot disease in elephant foot yam' at ICAR-CTCRI under the guidance of Dr. S.S. Veena.
- Mr. Sabarinath V.B. was awarded B.Sc.-MSc. (Integrated) Biotechnology from Kerala Agricultural University. The thesis work was done on the topic 'Genetic diversity analysis of sweet potato (*Ipomoea batatas* (L.) Lam.) germplasm using morphological and ISSR markers' at ICAR-CTCRI under the guidance of Dr. Shirly Raichal Anil.
- Ms. Ann Maria Varghese was awarded M.Sc. in Biotechnology from University of Kerala. The thesis work was done on the topic, 'Molecular characterization of cassava (*Manihot esculenta* Crantz) germplasm using SSR and ISSR markers' at ICAR-CTCRI under the guidance of Dr. K.I. Asha.
- Ms. Arathi Shaji was awarded M.Sc. in Biotechnology from University of Kerala. The thesis work was done on the topic, 'Development of an efficient micropropagation protocol for biofortified varieties of sweet potato (*Ipomoea batatas* L.)' at ICAR-CTCRI under the guidance of Dr. Vivek Hegde.
- Ms. Devi Subash was awarded M.Sc. Biotechnology from University of Kerala. The thesis work was done on the topic 'Genetic fidelity analysis of *in vitro* raised cassava (*Manihot esculenta* Crantz) varieties by using molecular markers' at ICAR-CTCRI under the guidance of Dr. N. Krishna Radhika.
- Ms. Febin Mumthaz A. was awarded M.Sc. in Biotechnology from Mahatma Gandhi University. The thesis work was done on the topic 'Molecular identification of cysteine proteinase inhibitor gene in sweet potato plants associated with sweet potato weevil infestation' under the guidance of Dr. B.G. Sangeetha.
- Mr. Jishnu K.B. was awarded M.Sc. Biotechnology from University of Kerala. The thesis work was done on the topic 'Assessment of genetic diversity in Indian taro (*Colocasia esculenta* (L.) Schott) using ISSR markers' under the guidance of Dr. A. Asha Devi.
- Mrs. Lekshmi K.S. was awarded M.Sc. in Microbiology from Mahatma Gandhi University. The thesis work was done on the topic 'Exploitation of actinomycetes of tuber crops of rhizosphere origin for plant disease suppression' at ICAR-CTCRI under the guidance of Dr. S.S. Veena.
- Ms. Liji Anna Johnson was awarded M.Sc. Biotechnology from University of Kerala. The thesis work was done on the topic 'Morphological and molecular characterization of sweet potato (*Ipomoea batatas* (L.) Lam.) germplasm' at ICAR-CTCRI under the guidance of Dr. Shirly Raichal Anil.

- Mrs. Shinsi S. was awarded M.Sc. in Microbiology from Calicut University. The thesis work was done on the topic 'Isolation of endophytes from leaf blight susceptible and tolerant varieties of taro and their role in incidence' at ICAR-CTCRI under the guidance of Dr. S.S. Veena.
- Ms. Sreejitha E.V. was awarded M.Sc. in Microbiology from Calicut University. The thesis work was done on the topic 'Molecular identification of endosymbiotic bacteria associated with *Aphis gossypii* (Glover) infesting tuber crops' under the guidance of Dr. B.G. Sangeetha.
- Ms. Teena A.T. was awarded M.Sc. Biotechnology from University of Kerala. The thesis work was done on the topic 'Tissue specific expression of *MeNAC* genes in leaves and tuber tissues of cassava (*Manihot esculanta* Crantz)' at ICAR-CTCRI under the guidance of Dr. K.M. Senthilkumar.
- Mrs. Veena P. Lal was awarded M.Sc. in Microbiology from Mahatma Gandhi University. The thesis work was done on the topic 'Antifungal properties of *Calocybe indica* (milky mushroom) and *Agaricus bisporus* (button mushroom)' at ICAR-CTCRI under the guidance of Dr. S.S. Veena.

Recognitions

Dr. Archana Mukherjee

- President, Indian Society for Root Crops.
- Reviewer, *Agricultural Research*.

Division of Crop Improvement

Dr. M.N. Sheela

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

Dr. K.I. Asha

- Recognised as Ph.D. guide in Botany by the University of Kerala.

Dr. P. Murugesan

- Chairman, Technical session on Palmyrah Biology and Environment in the 2nd World Conference on Palmyrah Economy during 3-5 May 2019 at Coimbatore, Tamil Nadu.
- Convener, National Conference on Climate Smart Agriculture for Livelihood Security jointly organized by MASU and TNAU – Anbil Dharmalingam Agriculture College and Research Institute during 13-14 September 2019.
- Delivered invited lecture on 'Wild American oil palm germplasm and prospects of production of premium palm oil' in the National Conference on Climate Smart Agriculture for Livelihood Security: Challenges and Opportunities from 13-14 September 2019 at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu Agricultural University.
- Expert member, Technical Paper Evaluation Committee for the 32nd Kerala Science Congress with a theme entitled 'Science & Technology for Climate Change Resilience and Adaptation during December 2019.
- External Examiner, PG programme of Tamil Nadu Agricultural University, Coimbatore and acted as external examiner for 4 students.
- Set questions and evaluated Comprehensive Qualifying Examination 2019 conducted for M.Sc. students of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore.

Dr. A. Asha Devi

- External expert, Pre-submission seminar of Ms. Midhu C.K. Research Scholar in Botany, JNTBGRI, Palode, Thiruvananthapuram at University of Kerala on 16 April 2019.
- Resource person, delivered a lecture on Molecular data analysis in the National Workshop on 'Tools and Techniques in Advanced Plant Science Research', Department of Botany, University of Kerala,

Thiruvananthapuram from 05-12 December 2019.

- Expert member, Technical Paper Evaluation Committee for the 32nd Kerala Science Congress with a theme entitled 'Science & Technology for Climate Change Resilience and Adaptation' during December 2019.
- Chaired the oral paper presentation session on Phytochemistry and Formulation of Products in Provectus Plantae'19 International Conference on Exploring the Scope of Plant Genetic Resources held at Department of Botany, University of Kerala, Kariavattom during 22-24 May 2019.
- Reviewer, *Journal of Environmental Biology.*

Dr. Shirly Raichal Anil

- Executive Committee Member, Indian Society for Root Crops.
- Chaired the oral paper presentation session on Cytogenetics, Plant Systematics and Conservation of Diversity in Provectus Plantae'19 International Conference on Exploring the Scope of Plant Genetic Resources held at Department of Botany, University of Kerala, Kariavattom during 22-24 May 2019.
- External examiner, pre submission viva of Smt. A.P. Nisha, Ph.D. scholar, Department of Botany, University of Kerala on 28 October 2019.
- External expert, pre submission Seminar of Mr. Anto Mathew, Research Scholar in Botany, JNTBGRI, Palode on 15 November 2019.
- External examiner, M.Sc. (Genetics and Plant Breeding) (first Semester) Department of Botany, University of Kerala held on 2-3 December 2019.
- Reviewer, *International Journal of Food Science.*

Dr. Kalidas Pati

- External expert for selection of JRF for the project vegetable grafting, MIDH, Govt. of Odisha at CHES-ICAR-Indian Institute of Horticultural Research, Bhubaneswar, Odisha on 10 May 2019.
- Member, assessment committee for promotion of technical personnel of ICAR-Central Institute for Women in Agriculture in the discipline of Horticulture on 05 July 2019.
- Resource person for Farmers Scientist Interaction on the eve of Jal Shakti Abhiyan at Derabis, Kendrapara on 03 September 2019.
- Resource person, delivered a lecture on Scientific cultivation techniques in sweet potato in Prospects of Odisha on 24 November 2019 at IMAGE, Bhubaneswar under CIP sponsored programme.
- Resource person, delivered a lecture on Varietal improvement and agronomic practices of sweet potato on 03 December 2019 at IMAGE, Bhubaneswar under CIP sponsored programme.
- Resource person for Doubling Farmers Income (DFI) of 5 districts of Odisha (Mayurbhanj, Baleswar, Bhadrak, Jajpur and Kendrapara) in consultation with programme coordinator of KVKs and other ICAR institutes in Odisha.

Dr. N. Krishna Radhika

- Editor, *Journal of Root Crops*.
- External examiner, M.Sc. (Ag.) thesis, College of Horticulture, Vellanikkara, Thrissur.

Dr. K.M. Senthil Kumar

- Delivered a lead lecture on 'Genome analysis, identification and characterization of agronomically important genes in cassava (*Manihot esculanta* Crantz)' in the 1st National Conference on Neglected and Underutilized Crop Species for Food, Nutrition, Energy and Environment (NUCS-FNEE-2019) held at NIPGR, New Delhi on 2 August 2019.
- Research work was selected as a cover image in the *Functional Plant Biology Journal* **46**(5) 2019 (NAAS rating: 8.08).
- Web-Editor, *Journal of Root Crops.*
- Reviewer, *3 Biotech.*

Dr. C. Visalakshi Chandra

- Joint Secretary, Indian Society for Root Crops.
- Member, selection committee for the recruitment of SRF and Technical person at ICAR-Indian Institute of Oil Palm Research, Palode, Thiruvananthapuram on 05 November 2019.
- Awarded the certificate of appreciation for best research work and publications made during 2015-19 by the Research Advisory Committee of ICAR-Central Tuber Crops Research Institute.

Dr. V.B.S. Chauhan

- Expert, setting question paper for final term examination of M.Sc. (Hort.), Central Agricultural University, Imphal, Manipur, May 2019.
- External member, selection committee for Project Fellow under S&T Project, CHES, ICAR-Indian Institute of Horticultural Research, Bhubaneswar, Odisha on 18 October 2019.

Dr. A.V.V. Koundinya

- Editor, Background Document of Quinquennial Review Team Meeting 2014-2019.
- Resource person, delivered a talk on Improved varieties of tuber crops in the seminar on 'Improved Technologies of Horticulture Crops with Special Reference to Tuber Crops' on 01 August 2019 at Ryali village, Athreyapuram, East Godavari, Andhra Pradesh.

Division of Crop Production

Dr. V. Ravi

- Chief Editor, *Journal of Root Crops*

Dr. G. Suja

- Member, Advisory Committee, Ph.D. student programme at Dept. of Agronomy, College of Horticulture, Vellanikkara, Thrissur,
- External examiner, 1 Ph.D. and 4 M.Sc. Agronomy students at Dept. of Agronomy, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala Agricultural University.
- External Examiner, qualifying viva voce of 1 M.Sc. student, Dept of Agronomy, College of Agriculture, Vellayani.
- Reviewer, 4 research papers in *Agronomy for Sustainable Development* and *Journal of Tropical Agriculture*.
- Mentor, 2 certified farm advisors allotted by ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut.

Dr. K. Susan John

- Member, Management Committee, Bharatiya Vidhya Bhavan School, Manvila, Thiruvananthapuram.
- External examiner, M.Sc. (Ag.) Soil Science and Agricultural Chemistry thesis evaluation from Kerala Agricultural University and Tamil Nadu Agricultural University.
- Panelist, Scientist-Farmer Interactive meeting at ICAR-Indian Institute of Spices Research on 11 October 2019
- Reviewer, research paper in the Journal *Agricultural Research.*

Dr. V. Ramesh

- IMC member, ICAR-Sugarcane Breeding Institute, Coimbatore
- Treasurer, Indian Society for Root Crops
- External examiner, 3 M.Sc. (Ag.) Soil Science and Agricultural Chemistry thesis evaluation from Kerala Agricultural University and Tamil Nadu Agricultural University.
- Member, State Agricultural Award Committee, Govt. of Kerala.

Dr. Sanket J. More

- Editor, Journal of Root Crops

Division of Crop Protection

Dr. C.A. Jayaprakas

- Lead talk in the 'International Conference on Plant Protection in Horticulture-Advances and Challenges' (ICPPH-2019) organized by The Association for Advancement of Pest Management in Horticultural Ecosystems (AAPMHE).
- Expert member to screen project under the Technology Development Programme (TDP), Department of Science and Technology, Govt. of India, New Delhi.
- Conducted the Ph.D. open defence at the Department of Zoology, Guru Nanak Dev University, Amritsar, Punjab.

Dr. M.L. Jeeva

- Invited expert, ATMA, Kollam in Multidisciplinary team visit for analyzing the unsolved problem in cassava presented in the monthly technology advice (MTA).
- External expert, SRF assessment of JRF students at CSIR-National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram.
- External examiner, evaluation of thesis of 5 M.Sc. (Plant pathology), and one each in B.Sc.-M.Sc. Integrated Biotechnology and Plant Biotechnology students.

- Passed Hindi Praveen examination during May 2019.

Dr. S.S. Veena

- External examiner, evaluation of thesis and conduct of final viva-voce examination of B.Sc.-M.Sc. (Integrated) Biotechnology student of Kerala Agricultural University.
- External examiner, evaluation of thesis of 3 M.Sc. (Plant Pathology) students of Kerala Agricultural University.
- Reviewer, *Journal of Environmental Biology, Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, Indian Journal of Agricultural Sciences, Journal of Tropical Agriculture* and *Current Science.*
- Research Supervisor, Biotechnology, Faculty of Applied Sciences and Technology, Kerala University.

Dr. T. Makeshkumar

- External examiner, Ph.D. Plant Biotechnology thesis viva at KAU, Vellayani, Thiruvananthapuram.
- External examiner, evaluation of thesis from University of Agricultural Sciences, Dharwad (Ph.D. in Plant Pathology), ICAR-Indian Agricultural Research Institute, New Delhi (M.Sc. in Plant Genetic Resources), Kerala Agricultural University, Thiruvananthapuram (Ph.D. in Plant Biotechnology and M.Sc.(Ag) in Plant Pathology).
- DBT Nominee of ICAR-Indian Institute of Spices Research Institute Biosafety Committee.
- Member, Institute Management committee, ICAR-Central Plantation Crops Research Institute and ICAR-Indian Institute of Spices Research.
- External expert, JRF selection committee, ICAR-Indian Institute of Spices Research, Kozhikode.
- External member, Kerala Agricultural University, Institute Biosafety Committee.
- Passed the Hindi Praveen examination during May 2019.

Dr. Harish E.R.

- Judge, 27th National Children's Science Congress Regional Level competition held at Kendriya Vidyalaya, Akkulam, Thiruvananthapuram, Kerala during 30 September to 01 October 2019.
- Member, State level agricultural award committee-2019 of Kerala and visited all the districts of Kerala from 26 July to 10 August 2019.

Dr. H. Kesava Kumar

- Editor, *Journal of Root Crops*
- Reviewer, *Entomon*, published by Association for Advancement of Entomology and reviewed a research article entitled 'Biochemical changes of *Holotrichia repetita* (Coleoptera: Melolonthidae) and *Galleria mellonella* (Lepidoptera: Pyralidae) due to the Biopesticide *Steinernema- Xenorhabdus* symbiont'.
- External examiner, evaluation of M.Sc. (Nematology) thesis of Ms. K. Suganthi from Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu during July 2019.
- External examiner, evaluation of M.Sc. (Plant Pathology) thesis of Shri. Amaresh Hadimani from KRC College of Horticulture, Arabhavi, Belgaum, Karnataka during August 2019.
- Passed the Hindi Praveen examination during May 2019.

Dr. B.G. Sangeetha

- Judge, 27th National Children's Science Congress Regional Level competition held at Kendriya Vidyalaya, Akkulam, Thiruvananthapuram, Kerala during 30 September to 01 October 2019.

Division of Crop Utilization

Dr. M.S. Sajeev

- Expert, M.Tech. and Ph.D. thesis evaluation of Tamil Nadu Agricultural University, Coimbatore; Indian Institute of Technology, Kharagpur; Kerala Agricultural University, Tavanur Campus and Assam Agricultural University, Jorhat..
- Expert, Career Advancement Scheme interview at ICAR-Central Institute of Fisheries Technology, Kochi on 26 August 2019.
- Advisory Committee Member, M.Sc. Food Processing at Kerala Agricultural University, Vellayani, Thiruvananthapuram.
- Member of Board of Studies, B.Tech. Food Engineering, Kelappaji College of Agricultural

Engineering and Technology, Tavanur, Malappuram, Kerala.

- Expert, handled classes on 'Value addition and entrepreneurship development in tuber crops', at Palai Social Service Welfare Society, Palai, Kottayam on 10 July 2019 and 28 November 2019; Koipuram Block Panchayath Hall, Pullad, Pathanamthitta on 21 November 2019; Krishi Vigyan Kendra, ICAR-Central Plantation Crops Research Institute, Kasaragod on 12 December 2019 and Farmers Training Centre, Panthalam on 19 December 2019.

Dr. A.N. Jyothi

- Member, Technical Committee of State Pesticide Testing Laboratory, Department of Agriculture, Govt. of Kerala and attended 4 committee meetings.
- Delivered a lecture on 'Current Endeavors in the field of Research and Development of Novel functionalized Products from Starch' in the Faculty Development Programme of National Institute of Technology Calicut, Kozhikode, Kerala, sponsored by the Department of Chemistry, National Institute of Technology Calicut, Government Engineering College Bharatpur and UKIERI during 17-22 June 2019.
- External member, selection committee of a Senior Research Fellow in Chemistry at ICAR-Indian Institute of Spices Research, Kozhikode on 22 November 2019.
- Member, Advisory Committee of a Ph.D. programme at Kerala Agricultural University, Vellayani.

Dr. T. Krishnakumar

- Delivered a lead lecture on 'Nutritional and health benefits of tuber crops with special reference to bioactive compounds' during National Seminar on 'Food for Health-Trends in Bioactive Compounds' at Periyar University, Salem, Tamil Nadu on 22 October 2019.
- Resource person, setting up final theory question paper for the three courses of Agricultural Engineering College and Research Institute (AEC&RI), Tamil Nadu Agricultural University, Coimbatore.
- Delivered an invited talk on 'Novel value addition technologies for agro-industrial transformation: Experience in tuber crops' during the National Symposium on Potential Crops for Food and Nutritional Security at Tamil Nadu Agricultural University during 14-15 December 2019.
- Technical committee member, SAGOSERVE, Salem, Tamil Nadu.
- Life member, International Society of Root Research, Germany.
- Passed the Hindi Praveen examination during May 2019.

Dr. Namrata A. Giri

- Executive Editor, South Asian Journal of Food Technology and Environment.
- Life member, Association of Food Scientists and Technologists (AFSTI).

Section of Extension and Social Sciences

Dr. Sheela Immanuel

- Resource person, PGDAEM-MANAGE correspondence course and delivered lectures of the course on Participatory approaches in Agricultural extension on 09 August 2019 at SAMETI, Anayara, Thiruvananthapuram.
- Interview board member, post of Senior Scientist and Head on 07 May 2019 at ICAR- KVK, Mitraniketan, Thiruvananthapuram.
- Chairperson, selection committee for the DPC of LDC to UDC on 4 October 2019 at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram.
- Chairperson, Selection committee of Photographer assessment on 9 October 2019 at ICAR-Indian Institute of Spices Research, Kozhikode.
- Reviewer, research papers for Marine Biological Association of India.
- Reviewer, research papers for Fishery Technology.

Dr. J. Sreekumar

- Conducted two sessions on Data analysis using SAS in the Workshop on 'Applied Statistics and Data Analysis for Science and Society' during

14-16 March 2019 organized by Department of Agricultural Statistics, College of Agriculture, Vellayani, Thiruvananthapuram.

- Guide, 2 M.Phil. students in Bioinformatics, University of Kerala for completing their project works.
- Evaluated the thesis entitled 'Comparison of methods for optimum plot size and shape for field experiments on paddy (*Oryza sativa*)' submitted by Smt. Athulya C.K. of Kerala Agricultural University for the degree of M.Sc. in Agricultural Statistics at Department of Agricultural Statistics, College of Agriculture, Vellayani and conducted the final viva voce examination.
- Member, Editorial Board of Journal of Tropical Agriculture of Kerala Agricultural University.

Dr. P. S. Sivakumar

- Delivered two lead papers on 'Technology commercialization and behavioural research methods' at the National Workshop on New Frontiers in Agricultural Extension during 30 May-01 June 2019 at MANAGE, Hyderabad, Telangana.
- Resource person, MANAGE-NIRDPR-MSU collaborative training programme on Building Evaluation Capacity: Short Course for Mid-Career Agricultural and Rural Development Professionals held at the National Institute of Rural Development and Panchayat Raj (NIRDPR) during 17-22 June 2019.
- Resource person, ICAR-Summer School Training on Quantitative Methods for Social Sciences organised by ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi during 21 September to 11 October 2019 and delivered a talk on 'Applications of structural equation modelling in social science research'.
- Delivered a lead talk at the International Conference on Extension for Strengthening Agricultural Research and Development (eSARD 19) during 14-16 December 2019 at KVK Mysuru, Karnataka.
- Delivered a keynote address on 'Fostering agricultural entrepreneurship through research institutions: Emerging trends, opportunities and challenges' at the valedictory function of 'A Confluence on Entrepreneurship' event during 27-28 December, 2019 at Tata Institute of Social Sciences, Tuljapur Campus, Maharashtra.
- External examiner, evaluation of three M.Sc. (Ag.) theses of College of Agriculture, Kerala Agricultural University, Vellayani.
- Reviewed two papers for the Elsevier owned International Journal 'Computers in Human Behaviour'.

Dr. D. Jaganathan

- Resource person, officers' training programme and delivered a lecture on 'Data collection methods in social research' for the Agriclinic and Agribusiness center scheme (AC & ABC) trainees on 28 February 2019 at College of Agriculture, Vellayani, Thiruvananthapuram.
- Resource person, PGDAEM-MANAGE correspondence course and delivered lectures of the course on 'Principles and practices of extension management' on 08 August 2019 at SAMETI, Anayara, Thiruvananthapuram.
- Expert, Scientific Advisory Committee Meeting of KVK, Kollam and KVK, Thiruvananthapuram during April and December 2019, respectively.
- Member, Editorial Board, Indian Society of Root Crops, Thiruvananthapuram.

LINKAGES AND COLLABORATIONS IN INDIA AND ABROAD

The Institute has established international collaborations with International Potato Centre (CIP), Lima, Peru; International Centre for Tropical Agriculture (CIAT), Cali, Columbia; CIRAD, France and EMBRAPA, Brazil. Presently the Institute has international collaborations through external funded projects viz., 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 Dept. of Horticulture, Dept. of Agriculture, Govt. of Odisha, Dept. of Agriculture, Govt. of Kerala, Govt. of Tamil Nadu and North Eastern states.

ICAR-CTCRI with its Intellectual Property and Technology Management Unit & Professional Services Cell (IPTMU & PSC) has developed collaboration with National Institute of Agricultural Extension Management (MANAGE), Hyderabad and Centre for Research on Innovation and Science Policy (CRISP), Hyderabad and conducted a training programme on Social Science Research Methodology. Collaborations were also developed with public sector agencies like Kerala State Industrial Development Corporation (KSIDC), Kerala Start-up Mission, Department of Agriculture, Government of Kerala; ICAR Research Complex for North Eastern Hills, Umiam, Meghalaya; North Eastern Hill University, Tura Campus, KVK, Tura, Horticulture Department, West Garo Hills and Meghalaya Basin Development Agency; Krishi Vigyan Kendra, Namsai, Arunachal Pradesh and Madurai Agribusiness Incubation Forum of

NABARD, Madurai for promoting agricultural entrepreneurship in the country. ICAR-CTCRI was an Eco-system partner for the 'IPitch' – a national level business plan competition organised by Villgro, Chennai. Functional collaborations were developed with College of Agriculture, Kerala Agricultural University, Vellayani to conduct Entrepreneurship Orientation Programmes for B.Sc. (Ag.) final year students. Under Tribal Sub Plan, linkages were developed with research organizations, NGOs and Department of Agriculture in Koraput, Kandhamal and Ranchi districts for the livelihood improvement of tribal farmers. Demonstrations on tuber crops based farming systems were conducted in farmers fields.

The Institute has MoU with College of Agriculture, Kerala Agricultural University, Vellayani for conducting courses and carrying out project work of M.Sc. Integrated Biotechnology students. 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 exists with Coconut Development Board for the validation and popularization of organic farming and customized fertilizers developed based on site specific nutrient management technologies in tropical tuber crops intercropped in coconut gardens. Moreover, AICRP on Tuber Crops at ICAR-CTCRI headquarters has collaboration with 21 centres spread over 18 states and one Union Territory.

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

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

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

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

Achievements of ICAR-AICRP on Tuber Crops

The 19th Annual Group Meeting of the All India Coordinated Research Project on Tuber Crops (AICRP TC) was held at ICAR-CTCRI, Thiruvananthapuram, Kerala during 13-15 June 2019. The Best Centre Award 2018-19 was presented to Navsari Agricultural University, Gujarat. A few publications and a CD on AICRP activities of Dr. RPCAU, Dholi, the first AICRP on Tuber crops centre were released. The main achievement during this year was recommendation of 14 tuber crops varieties for Central/State release after completion of AICRP trials. Of the 14 varieties, six were identified for Central and eight were identified for State release as detailed below:

List of varieties recommended for release during 19th Annual Group Meeting

Sl. No.	Variety Recommended	Accession number	Recommended States	Name of originating centre
Cassava				
1	TCa13-1	CAU C-1 (Nungha)	Manipur	CAU, Imphal
2	TCa13-7	9S-125	Kerala Manipur Chhattisgarh	ICAR-CTCRI, TVPM
3	TCa13-4	S-4	Chhattisgarh	ICAR-CTCRI, TVPM
Sweet potato				
4	TSp-12-6	BCSP-10	Bihar	BCKV, Kalyani
Aerial yam				
5	TDb13-1	DBSKKV Db-1	Maharashtra Chhattisgarh	Dr. BSKKV, Dapoli
6	TDb13-5	DBSKKV Db-10	Jharkhand	Dr. BSKKV, Dapoli
7	TDb13-6	IGDb-1	Chhattisgarh	IGKV, Jagdalpur
Greater yam				
8	TGy12-3	Da-342	Odisha Kerala Andhra Pradesh	ICAR-CTCRI, TVPM
9	TGy12-6	IGDa 5	Chhattisgarh Rajasthan	IGKV, Jagdalpur
10	TGy12-1	Da-406	Kerala	ICAR-CTCRI, TVPM
Taro				
11	TTr12-8	AR Coll-7	Bihar Jharkhand A&N Islands	ICAR, RC, Barapani
12	TTr12-4	BCC-9	West Bengal	BCKV, Kalyani
13	TCbl12-4	BCC-2	Bihar	BCKV, Kalyani
14	TCbl12-5	BCC-5	Maharashtra Telangana	BCKV, Kalyani


TCa 13-1


TCa 13-7


TCa 13-4


TSp-12-6

TDb 13-1

TDb 13-6


TGy 12-1


TGy 12-6


TGy 12-3


TTr 12-4

TCbl 12-4


TCbl 12-5

Tuber crops varieties recommended for release

Technologies recommended for adoption

Two technologies were also recommended for adoption as given below.

Management of yam anthracnose disease: Soil application and tuber treatment with *Trichoderma asperellum* along with spraying Carbendazim (0.05%) seven times (three at fortnightly interval after the initiation of symptom and further four at monthly interval) for anthracnose management in greater yam was recommended for the states of Telangana, Rajasthan and Chhattisgarh.

Integrated management of collar rot disease in elephant foot yam: Dipping the corms in 0.1% fungicide combination (Mancozeb 63% + Carbendazim 12%) before storing the corms, treating the corms in cowdung slurry and *Trichoderma* @ 5g/kg corm - 3 days before planting, drenching twice with 0.2% of fungicide combination) Mancozeb 63% + Carbendazim 12%) after intercultural operations and removal of infected plants carefully with an additional drenching of the fungicide to the surrounding plants for collar rot management in elephant foot yam was recommended for the states of Tamil Nadu, Andhra Pradesh, Bihar, Maharashtra, West Bengal, Jharkhand, Chhattisgarh, Gujarat, Andaman and Nicobar Islands, Himachal Pradesh, and Tripura.

PUBLICATIONS

Papers in Research Journals

Anitha M. Koshy, Varsha Joseph, Ravi, V. and Byju, G. 2018. Rapid method for estimation of total chlorophyll, chlorophyll a and b and carotene content in leaves of cassava and sweet potato using SPAD meter. *J. Root Crops*, **44**(1): 37-40 *(NAAS: 3.86)*.

Arya, R.S., Sheela, M.N., Jeeva, M.L. and Abhilash, P.V. 2019. Identification of host plant resistance to anthracnose in greater yam (*Dioscorea alata* L.). *Int. J. Curr. Microbiol. App. Sci*., **8** (8): 1690-1696. *(NAAS: 5.38)*.

Ashadevi, R.K., Koundinya, A.V.V., Das, A. and Chattopadhyay, S.B. 2019. A review on an underutilised multipurpose legume: rice bean. *Acta Hortic.*, **1241**: 57-64. 2019.1241.9.

Bansode, V., Chauhan, V.B.S., Pati, K., Bhuyar, K., Mahanand, S. and Nedunchezhiyan, M. 2019. Studies on standardization and physico chemical characteristics of elephant foot yam papad. *Int. J. Curr. Microbiol. App. Sci.*, **8**(5): 950-955 *(NAAS: 5.38)*.

Bansode, V., Chauhan, V.B.S., Pati, K., Giri, N., Krishnakumar, T., Bhuyar, K., Chinta, P., Nedunchezhiyan, M. and Sajeev, M.S. 2019. Development and quality evaluation of dahi fortified with beta carotene rich sweet potato juice variety *Bhu-Sona*. *Int. J. Curr. Microbiol. App. Sci*., **8**(7): 575-579 *(NAAS: 5.38)*.

Chauhan, V.B.S., Kumar, R., Behera, T.K., Yadav, R.K. and Verma, A.K. 2019. Inheritance of fruit weight and mode of gene action for yield contributing traits in tomato. *Res. J. Biotech.*, **14**(4): 73-78 *(NAAS: 6.00)*.

Chauhan, V.B.S., Kumar, R., Behera, T.K., Yadav, R.K., Kaur, C., Choudhury, H. and Verma, A.K. 2019. Inheritance of ascorbic acid and nature of gene action for nutritional traits in tomato. *Res. J. Biotech*., **14**(12): 1-7 *(NAAS: 5.00)*.

Geethu Mohan, Jinimol Raju, Shiny, R., Abhilash, P.V., Soumya, S., Sheela, M.N. and Byju, G. 2019. Biochemical, mineral and proximate composition of Indian cassava varieties. *Intl. J. Chem. Stud.*, **7**(4): 1059-1065 *(NAAS: 5.31)*.

Giri, N.A., Chintha, P. and Sajeev, M.S. 2019. Process optimization by response surface methodology and quality attributes of orange fleshed sweet potato (*Ipomoea batatas* L.) vacuum fried chips. *J. Food Measurement and Characterization*, **13**(3): 2367-2376 *(NAAS: 7.18)*.

Giri, N.A. and Sajeev, M.S. 2019. Physico-mechanical and nutritional evaluation of taro (*Colocasia esculenta* L.) flour based gluten free cookies. *Agricultural Research*, (DOI: 10.1007/s40003-019-00411-z) *(NAAS: 5.90)*.

Giri, N.A. and Sakhale, B.K. 2019. Development of sweet potato flour based high protein and low calorie gluten free cookies. *Curr. Res. Nutrition and Food Sci*., **07**(2): 427-435 *(NAAS: 4.04)*.

Giri, N.A. and Sakhale, B.K. 2019. Optimization of whey protein concentrate and psyllium husk for the development of protein-fiber rich orange fleshed sweet potato (*Ipomoea batatas* L.) bread by using response surface methodology. *J. Food Measurement and Characterization*, DOI: 10.1007/s11694-019-00304-3 *(NAAS: 7.18)*.

Giri, N.A. and Sakhale, B.K. 2019. Sweet potato (*Ipomoea batatas* L.): A valuable tropical tuber crop: A review. *The Pharma Innovation Journal*, **8**(6): 182-19 *(NAAS: 5.03)*.

Harikumar, P. and Sheela, M.N. 2019. Genetic diversity analysis in white yam (*Dioscorea rotundata* Poir.) using random amplified polymorphic DNA (RAPD) markers, *Ind. J. Pure App. Biosci.*, **7**(5): 30-35. *(NAAS: 4.74)*.

Harikumar, P. and Sheela, M.N. 2019. Identification of a novel single sequence repeat (SSR) marker linked to dwarf plant stature in white yam (*Dioscorea rotundata* Poir.). *Int. J. Curr. Microbiol. App. Sci.*, **8**(11): 151-158. *(NAAS: 5.38)*.

Harikumar, P. and Sheela, M.N. 2019. Inter simple sequence repeats (ISSR) marker based genetic diversity analysis in white yam (*Dioscorea rotundata* Poir.). *Int. J. Curr. Microbiol. App. Sci.*, **8**(11): 375-381. *(NAAS: 5.38)*.

Harish, E.R., Farhana, A.H. and Sangeetha, B.G. 2019. Screening potential microbes against whitefly (*Bemisia tabaci* (Gennadius)), the most important pest of cassava (*Manihot esculenta* Crantz). *J. Entomol. Zool. Stud.*, **7**(6): 601-606 *(NAAS: 5.53)*.

Harish, E.R., Mani Chellappan, Makeshkumar, T., Deepu Mathew, Ranjith, M.T. and Girija, D. 2019. Next generation sequencing reveals endosymbiont variability in cassava whitefly, *Bemisia tabaci*, across the agro-ecological zones of Kerala, India. *Genome*, **62**(9): 571-584 *(NAAS: 7.89)*.

Hegde, V., Koundinya, A.V.V., Sheela, M.N., Visalakshi Chandra, C., Mukherjee, A. and Darshan, S. 2019. Storage of cassava pollen for conservation of nuclear genetic diversity and overcoming hybridization barriers. *Indian J. Horti.*, **76** (1): 104-111 *(NAAS: 6.10)*.

Jaganathan, D., Sheela Immanuel, Sanket J. More and Sivakumar, P.S. 2019. Assessment of livelihood capitals of sweet potato and paddy growers in Karnataka. *Indian Res. J. Extension Edu.* **19** (4): 43-48 *(NAAS: 4.81)*.

Khan, R.M. Ahmad, I., Kumar, H.K.and Shukla, P.K. 2019. Infestation of *Meloidogyne enterolobii* in newly established/old guava orchards and nurseries in Madhya Pradesh, Rajasthan and Uttar Pradesh. *Ann. Pl. Prot. Sci.*, **27**(1)**:** 170-171 *(NAAS: 4.82)*.

Khan, R.M. Ahmad, I., Kumar, H.K., Singh, A. and Shukla, P.K. 2019. Identification of *Meloidogyne enterolobii* infesting guava using mitochondrial DNA based analysis and host status. *Ann. Pl. Prot. Sci.*, **27**(2)**:** 282-284 *(NAAS: 4.82)*.

Khapre, A.P., Deshpande, H.W., Katke S.D. and Giri, N.A. 2019. New era of smart packages in food industry: A review. *Intl. J. Chem. Stud.*, **7**(4): 210-213 *(NAAS: 5.31)*.

Koundinya, A.V.V., Ashadevi, R.K., Kumar, P.P. and Pandit, M.K. 2019. A review on under exploited nutrient rich perennial vegetables. *Acta Hortic.*, **1241**: 691-698.

Koundinya, A.V.V., Pandit, M.K., Dolui, S., Bhattacharya, A. and Hegde, V. 2019. Multivariate analysis of fruit quality traits of brinjal (*Solanum melongena* L.). *Indian J. Horti.*, **76**(1): 94-103 *(NAAS: 6.10)*.

Krishnakumar. T., Sajeev, M.S., Giri, N.A., Chintha, P. and Bansode, V. 2019. Development of mathematical model for cassava starch properties using response surface methodology. *Int. J. Curr. Microbiol. App. Sci.*, **8**(8): 2631-2646 *(NAAS: 5.38)*.

Krishnakumar. T., Sajeev, M.S., Saravanan Raju, Giri, N.A., Chintha, P., Senthil Kumaran, V. and Bansode, V. 2019. Engineering properties of different commercial grades of sago (sabudana). *Curr. J. Appl. Sci. Tech.*, **38**(3): 1-12 *(NAAS: 5.32)*.

Krishnan, J.U., Jayaprakas, C.A., Harish, E.R. and Rajeswari, L.S. 2019. Banana (*Musa* spp.)-an unseen umbrella crop? Insect diversity on *Musa* spp. in the Indo-Pacific region. *Oriental Insects*, 1-13. DOI: 10.1080/00305316.2019.1667926 *(NAAS: 6.20)*.

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

Lenka, S.K., Singh, A.K., Muthusamy, S.K., Smita, S., Chinnusamy, V. and Bansal, K.C.

2019. Heterologous expression of rice RNA-binding glycine-rich (RBG) gene *OsRBGD3* in transgenic *Arabidopsis thaliana* confers cold stress tolerance. *Funct. Plant Biol.*, **46**(5): 482-491 *(NAAS: 8.08)*.

Linu, M.S., Asok, A.K., Thampi, M., Sreekumar, J. and Jisha, M.S. 2019. Plant growth promoting traits of indigenous phosphate solubilizing *Pseudomonas aeruginosa* isolates from chilli (*Capsicum annuum* L.) rhizosphere. *Commun. Soil Sci. Pl. Analysis*, **50**(4): 444-457 *(NAAS: 6.54)*.

Manaswi, B.H., Pramod Kumar, Prakash, P., Anbukkani, P., Amit Kar, Jha G.K., Rao, D.U.M. and Lenin V. 2020. Impact of farmer producers organization on organic chilli production in Telangana. *Indian Journal of Traditional Knowledge*, **19**(1): 33-43 *(NAAS: 7.06)*.

Manaswi, B.H., Pramod Kumar, Prakash, P., Kar, A., Anbukkani, P., Jha, G.K. and Rao, D.U.M. 2019. Impact of farmer producer organisations on organic chilli (*Capsicum frutescens*) production in Telangana, *Ind. J. Ag. Sci.*, **89**(11): 98-102 *(NAAS: 6.23)*.

Mithra, M.G., Sajeev, M.S. and Padmaja, G. 2019. Fed-batch saccharification as a strategy towards reducing enzyme dosage and enhancing fermentable sugar yield from pretreated lignocellulo-starch biomass. *Waste and Biomass Valorization*, **10**: 3279-84.

Mithra, V.S.S., Raji, P., Sunitha, S., James George, Singh, P.P., Singh, R.S., Tarafdar, J., Mitra, S., Deo, C., Pareek, S., Lakshmi, B.K.M., Shiny, R. and Byju, G. 2019. Evaluation of a crop growth model for sweet potato over a set of agro-climatic conditions in India. *Curr. Sci.*,**117(**1): 110-113 *(NAAS: 6.88)*.

Muthusamy, S.K., Marathe, A., Mahajan, M., Sahu, B., Palaiyur, N.S., Kumar, J. and Kaushal, P. 2019. Gene trap strategies to unravel and characterize novel biotic-stress inducible genes in plants. *Res. J. Biotech.*, **14**(12): 168-175 *(NAAS: 6.00)*.

Pati, K., Munshi, A.D., Verma, M., Behera, T.K. and Arya, L. 2019. Genetic diversity of cucumber genotypes revealed by SSR markers and agronomic traits. *Genetika*, **51**(2): 405-416.

Pati, K., Zhang, F. and Batley, J. 2019. First report of genome size and ploidy of the underutilized leguminous tuber crop yam bean (*Pachyrhizus erosus* and *P. tuberosus*) by flow cytometry. *Plant Genet. Resour-C.*,**17**(5): 456-459 *(NAAS: 6.71)*.

Prakash, P., Pramod Kumar, Kar, A., Singh, A.K. and Anbukkani, P. 2019. Progress and performance of protected cultivation in Maharashtra. *Ind. J. Economics and Development*, **15**(4): 555-563 *(NAAS: 4.82)*.

Ravi, V., More, S.J., Saravanan, R., Byju, G., Nedunchezhiyan, M., Asha Devi, A. and Pallavi Nair, K. 2019. Potential increase in photosynthetic response of taro (*Colocasia esculenta* L.) to photon flux density and elevated CO_2. *J. Environ. Biol.*, **40**(1): 111-118. *(NAAS: 6.73)*.

Remya Remesh K.R., Byju, G., Sabitha Soman, Saravanan Raju and Ravi, V. 2019. Projected changes in mean temperature and total precipitation and climate suitability of yam (*Dioscorea* spp.) in major growing environments of India. *Curr. Hort.*, **7**(1): 28-42 *(NAAS: 3.71)*.

Sanket J. More, Divya Kumari, S., Suresh Kumar, J. and Ravi, V. 2019. Water stress revealed physiological and biochemical variations in taro [*Colocasia esculenta* (L.) Schott] varieties/ genotypes. *Int. J. Curr. Microbiol. App. Sci.*, **8**(8): 2242-2253. *(NAAS: 5.38)*.

Sheela Immanuel, Jaganathan, D., Sivakumar, P.S., Muthuraj, R. and Prakash, P. 2019. Livelihood assessment of cassava and paddy growing farmers in Tamil Nadu: A comparative analysis. *Ind. J. Pure Appl. Biosci.*,**7**(4): 90-98. *(NAAS: 4.74)*.

Srinivas Tavva, Singh, M., Rizvi, J., Saharawat, Y.S., Swain, N. and Shams, K. 2019. Potential of introducing improved production practices in food legumes in increasing food security in Afghanistan. *Sci. Agric.*,**76**(1): 41-46.

Sunitha, S. and Suresh Kumar, J. 2018. Productivity and profitability of elephant foot yam under drip and flood irrigation. *J. Root Crops*, **44**(1): 28-32 *(NAAS: 3.86)*.

Suresh Kumar J., More, S.J., Byju, G., Sunitha, S., Veena, S.S., Nedunchezhiyan, M. and Ravi, V. 2019. Effect of new generation herbicides on weed management, corm yield and economics of elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]. *Intl. J. Chem. Stud.*, **7**(3): 1213-1218 *(NAAS: 5.31)*.

Suresh Kumar J., Sofia Solomon, More, S.J. and Ravi, V. 2019. Effect of herbicide application on biochemical changes in weeds commonly infesting tuber crops growing fields. *Int. J. Curr. Microbiol. App. Sci.*, **7**(5): 677-682 *(NAAS: 5.38)*.

Suresh Kumar, J. and Pandit, M.K. 2019. Heterosis studies for earliness and yield related traits in sponge gourd [*Luffa cylindrica* (Roem.) L.]. *Int. J. Curr. Microbiol. App. Sci*., **8**(9): 169-177 *(NAAS: 5.38)*.

Suresh Kumar, J., Pandit, M.K. and Lakshmi Pathy, T. 2019. Genetic variability, diversity and character association in sponge gourd [*Luffa cylindrica* (Roem.) L.]. *Int. J. Curr. Microbiol. App. Sci.*, **8**(3): 278-290 *(NAAS: 5.38)*.

Susan John, K., Anju, P.S., Suja, G., Jeena Mathew and Shivay, Y.S. 2019. Zinc nutrition in tropical tuber crops: A review. *Ind. J. Agron.*, **64**(1): 1-10 *(NAAS: 5.46)*.

Swathi, B.S., Leksmi G.P.R. and Sajeev, M S. 2019. Cooking quality, nutritional composition and consumer acceptance of functional jack fruit pasta enriched with red *Amaranthus*. *Environmental Conservation Journal*, **20**(3): 89-97 *(NAAS: 4.52)*.

Thomas, B., Asha, K.I. and Radhika, N.K. 2019. Evaluation of intra and inter-specific variability among species of *Curcuma* using microsatellite markers. *J. Root Crops*, **44**(1): 12-18 *(NAAS: 3.86)*.

Verma, A.K., Sindhu, S.S., Singh, A., Kumar, A., Singh, A. and Chauhan, V.B.S. 2019. Conditioning effects of biodegradable superabsorbent polymer and vermiproducts on media properties and growth of gerbera. *Ecol. Eng.*, **132**: 23–30 *(NAAS: 9.02)*.

Viji, V.S., Veena, S.S., Karthikeyan, S. and Jeeva, M.L. 2019. Cassava based substrates - conducive media for mass multiplication of *Trichoderma asperellum*. *J. Root Crops*, **44**(1)**:** 41-46 *(NAAS: 3.86)*.

Vishnu, V.R., Renjith, R.S., Mukherjee, A., Anil, S.R., Sreekumar, J. and Jyothi, A.N. 2019. Comparative study on the chemical structure and *in vitro* anti-proliferative activity of anthocyanins in purple root tubers and leaves of sweet potato (*Ipomoea batatas*). *J. Ag. Food Chem.*, **67**(9): 2467-2475, *(NAAS: 9.41)*.

Yogi, V., Pramod Kumar, Prakash, P, Kar, A., Singh, D.R., Singh, R., Arya, P. and Awasthi, O.P. 2019. An economic evaluation of kinnow cultivation in north western India, *Ind. J. Ag. Sci.*, **89**(10): 132-135 *(NAAS: 6.23)*.

Paper presentation in Seminar/ Conference/ Symposia/ Workshop

Adithya Variyath, Veena, S.S., Jeeva, M.L. and Nath, V.S. 2019. Studies on postharvest rot in elephant foot yam, *Amorphophallus paeonifolius* (Dennst.) Nicolson. In: *TNAU - Corteva Plant Science Symposium Series: Crop genomics and Data Science- Challenges and Opportunities*. October 17- 18, 2019. p. 44.

Anuja, M.M., Murugesan, P., Hegde, V., Koundinya, A.V.V., Senthilkumar, K.M. and Sheela, M.N. 2019. Cryopreservation of true seeds and zygotic embryo of cassava on germination and seedling growth. In: *Abstracts of 8th Indian Horticulture Congress-2019. Shaping Future of Indian Horticulture*, 17-21 January 2019, Indira Gandhi Krishi Vishwavidyalaya, Raipur. pp. 37-38.

Asha Devi, A., Anjitha Nair, U.M., Veena, S.S., and Prakash Krishnan, B.S. 2019. Genetic diversity analysis of taro [*Colocasia esculenta* (L.) Schott] genotypes differing for TLB response using RAPD and SSR markers. In: *Proceedings, PROVECTUS PLANTAE'19 - International Conference on Exploring the Scope of Plant Genetic Resources*, 22-24 May 2019, Department of Botany, University of Kerala, Thiruvananthapuram. pp. 24-27.

Asha, K.I., Bimal Thomas and Krishna Radhika, N. 2019. Intra and inter-specific relationships among selected species of Curcuma in India. In: *Proceedings PROVECTUS PLANTAE'19- International Conference on Exploring the Scope of Plant Genetic Resources*, 22-24 May

2019, Department of Botany, University of Kerala, Thiruvananthapuram. pp. 28-32.

Aswathy B Nair, Veena, S.S., Karthikeyan, S., Sreelatha, G.L. and Vishnu, V.R. 2019. Microbial diversity in rhizosphere soils of tropical tuber crops: Utilization as bio-agents and its characterization. In: *National Symposium on 'Promotion of Eco-friendly and Sustainable Innovations'*, 25 July 2019, College of Agriculture, Vellayani.

Bansode, V.V., Chauhan, V.B.S., Pati, K. and Nedunchezhiyan, M. 2019. Studies on development of fibre rich pasta from sweet potato flour fortified with oat flour. In: *2nd International Conference on Recent Advances in Agricultural, Environmental and Applied Sciences for Global Development (RAAEASGD-2019)*, 27-29 September 2019, Solan, Himachal Pradesh. pp. 261.

Chauhan, V.B.S., Pati, K., Bansode, V.V. and Nedunchezhiyan, M. 2019. *In vitro* screening for salt tolerance in taro (*Colocasia esculenta*). In: *2nd International Conference on Recent Advances in Agricultural, Environmental and Applied Sciences for Global Development* (RAAEASGD-2019), 27-29 September 2019, Solan, Himachal Pradesh. pp. 258.

Femina, F.N., Veena, S.S., Karthikeyan, S. and Sreelatha, G.L. 2019. Successful colonization of *Piriformospora indica* in root cells of elephant foot yam and its plant growth promotion. In: *National Symposium on 'Promotion of Eco-friendly and Sustainable Innovations'*, 25 July 2019, College of Agriculture, Vellayani.

Harish, E.R., Mani Chellappan., Makeshkumar, T., Deepu Mathew and Ranjith, M.T. 2019. Molecular characterization of the main threat in cassava (*Manihot esculenta* Crantz) production, cassava whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) from different agro-ecological zones of Kerala, India and its significance. In: *The First International Conference on Biotechnology, Bioengineering, Biorefinery and Pollution Prevention,* 1-2 August 2019, Chulalongkorn University, Bangkok, Thailand. p. 49.

Harish, E.R., Mani Chellappan., Makeshkumar, T. and Ranjith, M.T. 2019. Biotype dependant variability in cassava whitefly (*Bemisia tabaci*) endosymbionts and its significance. In: *International Conference on Plant Protection in Horticulture: Advances and Challenges*, 24-27 July 2019, ICAR-IIHR, Bengaluru. p. 115.

Jaganathan, D., Sheela Immanuel, Koundinya, A.V.V. and Sivakumar, P.S. 2019. Livelihood assessment for technological interventions in elephant foot yam and banana cultivation in Andhra Pradesh. In: *International Conference on Extension for Strengthening Agricultural Research and Development* (eSARD 2019), 14-16 December 2019, Suttur, Mysuru, Karnataka.

Jaganathan, D., Sheela Immanuel, Sivakumar, P.S. and Muthuraj, R. 2019. Empowering farmers through participatory research with improved varieties of tuber crops. In: *International Conference on Extension for Strengthening Agricultural Research and Development* (eSARD 2019), 14-16 December 2019, Suttur, Mysuru, Karnataka.

Jeeva, M.L., Veena, S.S., Amrutha, P.R., Sujina, M.G., Shahana, N., Karthikeyan, S. and Vishnu, V.R. 2020. Scope of endophytes in tropical tuber crops for disease management. In: *Seventh International Conference on Phytopathology in Achieving UN Sustainable Development Goals*, 16-20 January 2020, ICAR-IARI, New Delhi. p. 296.

Kishore, P., Singh, D.R., Prakash, P. and Franco, D. 2019. Groundwater and energy nexus in irrigation development of India. In: *Eighth International Conference on Agricultural Statistics*, 18-21 November 2019, ICAR-IASRI, New Delhi.

Koundinya, A.V.V., Hegde, V., Senthilkumar, K.M., Prakash Krishnan, B.S., Sheela, M.N., Asha, K.I. and More, S.J. 2019. Molecular characterization and quantification of leaf retention of cassava under drought stress conditions, In: *Souvenir cum Lead and Oral Paper Abstracts*, 17-21 January 2019, Indira Gandhi Krishi Vishwavidyalaya, Raipur. pp. 65.

Krishna Radhika, N., Mukherjee, A., Sheela, M.N., Asha, K.I., Anil, S.R., Asha Devi, A., Senthilkumar, K.M. and Asha V.V. 2019.

Biotechnological explorations of unexplored tuber crops germplasm for a nourishing diet. In: *International Conference on New horizons in Biotechnology*, 20-24 November 2019, CSIR-National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram.

Krishna Radhika, N., Sheela, M.N., Asha K.I., Anil, S.R., Asha Devi A., Visalakshi Chandra C., Senthilkumar K.M. and Anjumol Abraham. 2019. Development of friable embryogenic callus - a reliable source of genetic transformation in cassava (*Manihot esculenta* Crantz) genotypes. In: *Proceedings PROVECTUS PLANTAE'19-International conference on Exploring the Scope of Plant Genetic Resources*, 22-24 May 2019, Department of Botany, University of Kerala, Thiruvananthapuram. pp. 396-399.

Krishnakumar, T. and Sajeev, M.S. 2019. Studies on pasting properties of the selective tuber starches and sago (sabudana). In: *Souvenir and Abstracts of National Conference on Challenges and Innovative Approaches in Agriculture and Allied Sciences Research*, 26-27 July 2019, Society for Biotic & Environmental Research (SBER), Sona College of Arts & Science, Salem, Tamil Nadu. p.175.

Kumar, H.K., Sangeetha, B.G., Tadigiri, S. and Makeshkumar, T. 2019. Isolation and identification of entomopathogenic nematodes from tuber crop ecosystems in Kerala. In: *National Symposium on Nematodes: A Threat to Food Security and Farmer's Livelihood*, 11-13 December 2019, Manipur University, Imphal. p. 48.

Laxminarayana, K. 2019. Influence of inorganic and organics on soil microbial activities, yield and quality of elephant foot yam – blackgram cropping system in Alfisols. In: *National Seminar on Developments in Soil Science – 2019*, 14 - 17 November 2019, Banaras Hindu University, Varanasi, Uttar Pradesh.

Linet K. Joseph and Veena, S.S. 2019. Comparative analysis of antimicrobial activities of 43 *Trichoderma* isolates against *Sclerotium rolfsii*, the pathogen causing collar rot in elephant foot yam. In: *National Symposium on 'Promotion of Eco-friendly and Sustainable Innovations'*, 25 July 2019, College of Agriculture, Vellayani.

Makeshkumar, T. and Jeeva, M.L. 2019. Viral diseases of tropical tuber crops and ways to reduce their impact on growers. In: *International Conference on Plant Protection in Horticulture: Advances and Challenges* (ICPPH 2019), 24-27 July 2019, ICAR-IIHR, Bengaluru, Karnataka.

Manaswi, B.H., Anbukkani, P., Prakash, P., Kar, A. and Jha, G. 2019. Improving access to finance through farmer producer organizations: A case study from FPOs of Telangana. In: *National Conference on XIV Agricultural Science Congress 2019*, 20-23 February 2019, NASC Complex, New Delhi.

More, S.J., Ravi, V. and Saravanan, R. 2019. Assessment of intrinsic water use efficiency (WUEi) and carbon isotope discrimination to determine their relationship with storage root yield in cassava. In: *Book of Abstracts of the National Seminar on Advances and Applications in Plant Science*, 6-8 February 2019, Department of Botany, University of Kerala, Thiruvananthapuram, Kerala. p. 31.

More, S.J., Ravi, V., Saravanan, R. and Suresh Kumar, J. 2019. Cassava under water deficit stress: Differential Carbon isotope discrimination, water use efficiency and photosynthetic efficiency. In: *Souvenir and Abstract Book of National Conference of Plant Physiology-Plant Productivity and Stress Management*, 19-21 December 2019, Department of Plant Physiology, Kerala Agricultural University, Thrissur. p. 36.

Murugesan, P. 2019. Climate change mitigation through horticultural genetic resources. In: *Book of Souvenir on UGC SAP National seminar on Climate Resilient Agriculture for Abiotic Stress*, 12-13 March 2019, Department of Genetics and Plant Breeding, Annamalai University, Chidambaram, Tamil Nadu. pp. 25-30.

Murugesan, P. 2019. Evaluation of seed quality in yam bean (*Pachyrhizus erosus* L.) germplasm for developing breeder seed standards. In: *Abstract of National Conference on Climate Smart Agriculture for Livelihood*

Security: Challenges and Opportunities, 13-14 September 2019, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu Agricultural University.

Murugesan, P., Aswathy, G.M., Sunilkumar, K., Bhagya, H.P., Ramajeyam, D., Ravichandran, G., Naveen Kumar, P. and Mathur, R.K. 2019. Preliminary evaluation of indigenously developed interspecific (O X G) oil palm hybrids for vegetative and bunch quality traits. In: *Abstracts of 8th Indian Horticulture Congress-2019. Shaping Future of Indian Horticulture*, 17-21 January 2019, Indira Gandhi Krishi Vishwavidyalaya, Raipur. p. 350.

Murugesan, P., Sheela, M.N., Asha, K.I., Anil, S.R., Koundinya, A.V.V., Senthilkumar, K.M., Vishalakshi Chandra, C., Muthuraj, R., Pati, K. and Hegde, V. 2019. Development of breeder seed standards and precocity of genetic vigour for sweet potato and yam bean-overview. In: *National Symposium on Potential Crops for Food and Nutritional Security*, 14-15 December 2019, Tamil Nadu Agricultural University, Coimbatore.

Murugesan, P. and Ramajeyam, D. 2019. Genetic resources of underutilized, wild horticultural crops with special emphasis to spices and plantation crops. In: *Book of Abstract and Souvenir of National symposium on Horticulture in the Vanguard of Climate Change and Urban Environment*, 7-8 February 2019, Department of Horticulture, Annamalai University, Chidambaram, Tamil Nadu. p. 10.

Murugesan, P. and Somasundaram, G. 2019. Prospects of exploring *Ganoderma* tolerance/ resistant exotic germplasm for introgression to oil palm hybrid seed production. In: *Proceedings of International seminar on Breeding for Ganoderma tolerance in oil palm*, Malaysian Palm Oil Board, 18-19 November 2019, Malaysia. pp. 40-47.

Murugesan, P. and Sunil Kumar, K. 2019. Wild American oil palm germplasm and prospects of production of premium palm oil. In: *Souvenir of National Conference on Climate Smart Agriculture for Livelihood Security: Challenges and Opportunities*, 13-14 September 2019, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu Agricultural University. pp. 127-132.

Nedunchezhiyan, M., Laxminarayana, K., Pati, K., Chauhan, V.B.S., Gowda, H.K. and Bansode, V.V. 2019. Sweet potato and yam bean for sustainable yield and soil conservation under hill farming. In: *Farmers First for Conserving Soil and Water Resources in Eastern Region (FFCSWR-2019)*, 6-8 February 2019, Koraput, Odisha. pp. 79.

Pati, K., Chauhan, V.B.S., Nedunchezhiyan, M., Laxminarayana, K., Gowda, K. and Bansode V.V. 2019. Genetic resources and conservation of climate resilient and nutritionally rich tuber crops for food and nutritional security of odisha. In: *Farmers First for Conserving Soil and Water Resources in Eastern Region* (FFCSWR-2019), 6-8 February 2019, Koraput, Odisha. pp. 79.

Prakash, P, Pramod Kumar and Kar, A. 2019. An empirical analysis on the performance of protected cultivation in Maharashtra, India. In: National *Conference on XIV Agricultural Science Congress 2019*, 20-23 February 2019, NASC Complex, New Delhi.

Prakash, P, Pramod Kumar, Kar, A. and Singh, A.K. 2019. Protected cultivation of rose under changing climate conditions: An economic analysis. In: *79th Annual Conference of Indian Society of Agricultural Economics*, 21-23 November 2019, Raipur, Chhattisgarh.

Prakash, P, Pramod Kumar, Kar, A., Singh, A.K. and Kishore, P. 2019. Adoption of protected cultivation technology in Maharashtra: Determinant and constraints. In: *79th Annual Conference of Indian Society of Agricultural Economics*, 21-23 November 2019, Raipur, Chhattisgarh.

Remya Remesh, K.R. and Byju, G. 2019. Effect of site-specific nutrient management on agronomic performance of white yam (*Dioscorea rotundata* Poir.). In: *Proc. National Seminar on 'Advances in Earth and Environmental Sciences'*, Salom, G.T.V. and Prince, S.G. (Eds.), 20 September 2019, University of Kerala, Thiruvananthapuram, Kerala. pp. 1-9.

Sajeev, M.S., Jyothi, A.N., Krishnakumar, T. and Giri, N.A. 2019. 'Novel value addition technologies for agro-industrial transformation: Experience in tuber crops'. In: *Abstracts of National Symposium on Potential Crops for Food and Nutritional Security*, 14-15 December, Indian Society of Genetics & Plant Breeding (ISGPB), South Chapter, Tamil Nadu Agricultural University. p. 201.

Sajeev, M.S., Jyothi, A.N., Krishnakumar, T. and Padmaja, G. 2019. Technological innovations in post harvest management and value addition in tropical tuber crops. In: *Souvenir and Abstracts of National Conference on Challenges and Innovative Approaches in Agriculture and Allied Sciences Research*, 26-27 July 2019, Society for Biotic & Environmental Research (SBER), Sona College of Arts & Science, Salem, Tamil Nadu. p. 79-86.

Sajeev, M.S. and Krishnakumar, T. 2019. Commercialization and successful incubation models- CTCRI experience. In: *Proceedings of the Model Training Course on Advanced Fish Drying and Chilling Technologies*, 26 August 2019, ICAR-CIFT, Kochi.

Sangeetha, B.G., Jayaprakas, C.A., Makeshkumar, T., Anil, S.R., Ajina Ajeem, Adithya, S., Hizaana Noushad and Pati, K. 2019. Validation of proteinase inhibitor genes expression in sweet potato plants related to *Cylas formicarius* (Fabricius) infestation. In: *International Conference PROVECTUS PLANTAE'19 on Exploring the Scope of Plant Genetic Resources*, 22-24 May 2019, Department of Botany, University of Kerala.

Santhosh Mithra, V.S. 2019. Climate change impacts and crop modelling. In*: National Conference of Plant Physiology-2019*, 19-21 December 2019, Thrissur, Kerala.

Santhosh Mithra, V.S. 2019. Data science for smart agriculture development. In*: Indo Data Week 2019: A Collaborative Programme between DAV Data Solutions, India and Indo-Nordic Innovation Acceleration Cluster (INIAC)*, 02-08 November 2019, Hyderabad, Telangana.

Senthilkumar, K.M. 2019. Genome analysis, identification and characterization of agronomically important genes in cassava (*Manihot esculanta* Crantz). In: *Proceedings 1st National Conference on Neglected and Underutilized Crop Species for Food, Nutrition, Energy and Environment (NUCS-FNEE-2019)*, 2 August 2019, NIPGR, New Delhi. pp. 7.

Senthilkumar, K.M., Sheela, M.N. and Makeshkumar, T. 2019. Comprehensive analysis of *MeNAC* family members and their tissue and stress-specific expression profiling in cassava (*Manihot esculenta* Crantz). In: *Proceedings PROVECTUS PLANTAE' 19-International Conference on Exploring the Scope of Plant Genetic Resources*, 22-24 May 2019, Department of Botany, University of Kerala, Thiruvananthapuram. pp. 537-539.

Shirly Raichal Anil, Krishna Radhika, N, Sreekumar, J., Sheela, M.N. and Mukherjee, A. 2019. Evaluation of sweet potato germplasm for storage root yield and related traits for utilization in crop Improvement programmes. In: *Proceedings PROVECTUS PLANTAE' 19-International Conference on Exploring the Scope of Plant Genetic Resources*, 22-24 May 2019, Department of Botany, University of Kerala, Thiruvananthapuram. pp. 434-437.

Suresh Kumar, J., Sunitha, S., Mamatha, K., Das, B., Sengupta, S., Kamalkumaran, P.R., Mitra, S., Tarafdar, J., Damodaran, V., Singh, R.S., Ashish, N., Ravinder, S. and Pradnya, G. 2019. Integrated weed management in elephant foot yam at different agro climatic conditions of India. In: *International seminar on Agriskills for Convergence in Research*, Industry & Livelihood (ACRIL), 28 November to 1 December 2019. West Bengal.

Tadigiri, S., Chawla, G., Somvanshi, V. and Rao, U. 2019. Studies on morphometrics and genetic variability among the pigeon pea cyst nematode, *Heterodera cajani* populations in India. In: *National Symposium on Nematodes*: *A Threat to Food Security and Farmer's Livelihood*, 11-13 December 2019, Manipur University, Imphal. p. 51.

Tadigiri, S., Mhatre, P.K. and Chimmili, S.R. 2019. Biosensors: engineered *Caenorhabditis elegans* as the sensing machinery. In: *International Conference on Global Research*

Initiatives for Sustainable Agriculture and Allied Sciences, 13-16 October 2019, ICAR-NAARM, Hyderabad, Telangana.

Tarafdar, J., Damodaran, V., Singh, R.S., Narayan A. and Gudadhe, P. 2019. Integrated weed management in elephant foot yam at different agroclimatic conditions of India. In: *International seminar on Agriskills for Convergence in Research, Industry & Livelihood (ACRIL)*, 28 November to 1 December 2019, West Bengal.

Visalakshi Chandra, C, Sheela, M.N., Mukherjee, A., Hegde, V., Koundinya, A.V.V., Murugesan, P., Krishna Radhika, N., Senthilkumar, K.M., Shanavas S., Prakash Krishnan B.S. and Senthil alias Sankar. 2019. Characterization for postharvest physiological deterioration tolerance and enhanced shelf life in cassava. In: *Proceedings PROVECTUS PLANTAE'19-International Conference on Exploring the Scope of Plant Genetic Resources*, 22-24 May 2019, Department of Botany, University of Kerala, Thiruvananthapuram. pp. 562-565.

Vivek Hegde, Koundinya, A.V.V., Sheela, M.N., Visalakshi Chandra, C., Senthilkumar, K.M. and Abhilash, P.V. 2019. Long-term pollen storage studies in cassava and greater yam. In: *Abstracts of 8th Indian Horticulture Congress-2019. Shaping Future of Indian Horticulture*, 17-21 January 2019, Indira Gandhi Krishi Vishwavidyalaya, Raipur. pp. 302-303.

Book Chapters

Berliner, J., Prakash, A. and Kumar, H.K. 2019. Entomopathogenic nematodes. In: *Biopesticides in Indian Agriculture*. Prakash, A., Rao, J., Shrivastava, S.K., Korada, R.R. and Mishra, V.K. (Eds). Azra Publications, Bhubaneshwar, pp. 255-290.

Giri, N.A. and Sakhale, B.K. 2019. A review on rheological properties of dough. In: *Engineering Properties of Agricultural Produce*. Chandra, S., Samsher and Goyal, S.K. (Eds). New India Publishing Agency, New Delhi 110 034, India, pp. 45-60.

Kumar, J.P.T., Senthilkumar, K.M. and Chidambaranathan, P. 2019. Micromics: A novel approach to understand the molecular mechanisms in plant stress tolerance. In: *Recent Approaches in Omics for Plant Resilience to Climate Change*. Wani, S. (Ed.). Springer Nature, USA, pp. 93-108. DOI: 10.1007/978-3-030-21687-0_6.

More, S.J., Ravi, V. and Saravanan, R. 2019. Tropical tuber crops. In: *Postharvest Physiological Disorders in Fruits and Vegetables*. de Freitas, S.T. and Pareek, S. (Eds.). CRC Press, Boca Raton, pp. 719-757. https://doi.org/10.1201/b22001.

Mukherjee, A., Sivakumar, P.S. and Sheela Immanuel. 2019. Tropical tuber: Journey from life saving food to future smart crops. In: *Shaping the Future of Horticulture*. Chadha K.L., Singh, S.K., Jai Prakash and Patel, V.B. (Eds.), Kruger Brentt publishers.

Murugesan, P., Koundinya, A.V.V. and Asha, K.I. 2019. Genetic resources of Chinese potato-constraints and utilisation strategies for abiotic stress. In: *Abiotic Stress Agriculture*. Prakash, M.K.V. (Ed.). International Book & Periodical Supply service, New Delhi, India, (ISBN 978-93-88892-47-6), pp. 81-91.

Suja, G. 2019. Organic farming in tropical tuber crops: Scope, prospects and practices. In: *Modern Concepts and Practices of Organic Farming for Safe and Sustainable Food Production*, Panwar, A.S., Dutta, D. and Ravisankar, N. (Eds.), ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut 250 110, India, pp. 410-432.

Popular Articles

Byju, G. 2019. Healthy diets for a zero hunger world. *Kerala Kaumudi*, 16 October 2019.

Byju, G. 2019. Insects as human food. *Kala Kaumudi*, 1 December 2019.

Byju, G. 2019. Vetiver, ideal bioengineering for soil conservation. *Krishiyankanam*, December-January 2020.

Byju, G. 2019. World Soil Day 2019: Stop soil erosion, save our future. *Kerala Karshakan*, December 2019.

Harish, E.R. and Jayaprakas, C.A. 2019. Important pests of tropical tuber crops and their management. (*Kizhanguvilakalile pradhana keedangalum niyanthranavum* In: Malayalam). *Krishi Jagran*, **3**(9): 38-41.

Koundinya, A.V.V., Sheela, M.N. and Hegde, V. 2019. Sree Athulya and Sree Apoorva: Triploid varieties of cassava (Telugu). *Krishijagran* **4**(10): 32-33.

Krishnakumar, T., Sajeev, M.S., Jaganathan, D., Senthilkumar, K.M. and Somasundram, G. 2019. Phytochemical functional foods-nutrition for health promotion. *Beverage & Food World*, **46**(6): 40-42.

Manimaran, B., Ramya, R.S., Mhatre, P.H., Tadigiri, S., Chavan, S.N. and Thorat, Y. 2019. Fungal secondary metabolites: the potential eco-safe pesticides for plant protection. *Biomolecule Reports*, BR/11/19/01.

Mhatre, P.H., Chavan, S.N., Divya K.L, Thorat, Y., Venkatesalam E., Tadigiri, S. and Manimaran, B. 2019. Biological control of plant parasitic nematode. *Krishisewa* (Hindi).

More, S.J. and Byju, G. 2019. Micro-food for tropical tuber crops (Hindi). *Krishi Jagran*, **25**(1): 68-69.

More, S.J. and Byju, G. 2019. SSNM in tropical tuber crops (Hindi). *Krishi Chetna*, **2**: 86-88.

Sajeev, M.S. and Krishnakumar, T. 2019. *Ulpanna vaividhya valkaranathiloode maracheeniye vanijya vilayakkam*. *Krishiyankanam*, (Malayalam) **2**(1):44-46.

Santhosh Mithra, V.S. 2019. Smart farming: smart way to progress (Malayalam). *Spice India*, **32**(5): 9-12.

Santhosh Mithra, V.S. 2019. Smart farming: smart way to progress (Tamil, Kannada, Telugu). *Spice India*, **32**(5): 11-14.

Santhosh Mithra, V.S. 2019. Smart farming: smart way to progress. (Hindi and Nepali). *Spice India*, **32**(5).

Seth, T., Pan. R.S., Roy, P.D., Das, R., Das, S., Visalakshi Chandra, C. and Lyngdoh, Y.A. 2019. Tuber crops as functional food for the tribals of Jharkhand: An appraisal. *Envis Jharkhand News*, pp. 20.

Sheela, M.N. 2019. *Kizhanguvarggangalile menmay-eriya noothana inangal*. (Malayalam) *Krishiya-nkanam*, **2**(1): 11-14.

Suja, G., Harishma S.J. and Saranya Krishnan, K. 2019. Chinese potato: Organic management (*Koorka*: *Jaivaparipalanam)* (Malayalam). *Kerala Karshakan*, **64**(12): 45.

Suja, G., Harishma, S.J. and Saranya Krishnan, K. 2019. Organic production of tropical tuber crops *(Kizhangu vilakal jaivareethiyal)* (Malayalam). *Kerala Karshakan*, **65**(2): 46-48.

Sunitha, S., Velmurugan, M., James George and Sheela. M.N. 2019. More crop per drop – experience in cassava. *Indian Horticulture*, **64**(2): 8-10.

Suresh Kumar, J. 2019. *Cheeda peedala bedada takkuva- Seema mirapa* (Telugu). (Less pest and disease crop- capsicum). *Nava Telangana News edition*, 1 August 2019.

Suresh Kumar, J. 2019. *Noone ginjala panta soya chikkudu* (Telugu). (Oil seed crop - soya bean). *Nava Telangana News edition*, 5 September 2019.

Suresh Kumar, J., Koundinya, A.V.V. and Muthuraj, R. 2019. *Dumpa pantalalo nanyamina vegavantamaina vittanotpatti vidhaanam* (Telugu). (Minisett technology for rapid multiplication of tuber crops). *Krishi Jagaran*, April 2019 issue, 19-22 pp.

Suresh Kumar, J., Sunitha, S. and Velumurugan, M. 2019. *Bindusedyam mariyu fertigation dwara karra pendalam lo adhika digubadi, aadayam mariyu pettubadi upayoga samardhyam penche vidhaanam* (Telugu). (Drip irrigation and fertigation for increasing the yield in cassava). *Krishi Jagaran*, July 2019 issue, 58-60 pp.

Tadigiri, S., Kumar, H.K., Chavan, S.N., Thorat, Y., Manimaran, B. and Mhatre, P.H. 2019. Nematode barcoding and its utility in taxonomy and quarantine significance. *Biomolecule Reports*, BR/10/19/05.

Thorat, Y., Borase, D.N., Holkar, S.K., Chavan, S.N., Tadigiri, S., Manimaran, B. and Mhatre, P.H. 2019. Integrated Pest management. *Vikaspedia*, 14 November 2019.

Folders/Leaflets/Pamphlets

Byju, G. 2019. *Tropical Tuber Crops for Health and Nutrition Security*. Farm Information Bureau, Government of Kerala.

Byju, G., Jaganathan, D. and Koundinya, A.V.V. 2019. *Agrotechniques of Tropical Tuber Crops*

(English). Technical leaflet 1/2019. ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Byju, G., Jaganathan, D. Koundinya, A.V.V. and Sangeetha, B.G. 2019. *Agrotechniques of Tropical Tuber Crops* (Malayalam). Technical leaflet 04/2019. ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Byju, G., Srinivas, T., Jaganathan, D., Senthilkumar, K.M., Sanket J. More, Krishnakumar, T. and Sangeetha, B.G. 2019. *ICAR-CTCRI-A Look at its Journey*. Folder 01/2019, ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Hegde, V. and Sheela, M.N. 2019. *Protection of Plant Varieties and Farmers Right's Act 2001* (Kannada). ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Jaganathan, D., Byju, G and Koundinya, A.V.V. 2019. *Agrotechniques of Tropical Tuber Crops* (Tamil). Technical leaflet 03/2019. ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Jaganathan, D., Sheela Immanuel, Muthuraj, R., Sivakumar, P.S., Prakash, P., Koundinya, A.V.V., Sanket J. More, Sheela, M.N. and Byju, G. 2019. *Farmer Participatory Demonstrations of Improved Technologies of Tropical Tuber Crops - A Success Story.* Extension folder No. 01/2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Jaganathan, D., Sheela Immanuel, Muthuraj, R., Sivakumar, P.S., Prakash, P., Koundinya, A.V.V., Sanket J. More, Sheela, M.N., Senthilkumar, K.M. and Byju, G. 2019. *Farmer Participatory Demonstrations of Improved Technologies of Tropical Tuber Crops - A Success Story* (Tamil). Extension folder No. 04/2019, ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Jaganathan, D., Sheela Immanuel, Muthuraj, R., Sivakumar, P.S., Prakash, P., Koundinya, A.V.V., Sanket J. More, Sheela, M.N. and Byju, G. 2019. *Farmer Participatory Demonstrations of Improved Technologies of Tropical Tuber Crops - A Success Story* (Telugu). Extension folder No. 05/2019, ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Jaganathan, D., Sheela Immanuel, Muthuraj, R., Sivakumar, P.S., Prakash, P., Koundinya, A.V.V., Sanket J. More, Sheela, M.N., Hegde, V. and Byju, G. 2019. *Farmer Participatory Demonstrations of Improved Technologies of Tropical Tuber Crops - A Success Story* (Kannada). Extension folder No. 06/2019, ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Jaganathan, D., Sheela Immanuel, Muthuraj, R., Sivakumar, P.S., Prakash, P., Koundinya, A.V.V., Sanket J. More, Sheela, M.N., Sangeetha, B.G. and Byju, G. 2019. *Farmer Participatory Demonstrations of Improved Technologies of Tropical Tuber Crops - A Success Story (Malayalam*). Extension folder No. 07/2019, ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Koundinya, A.V.V., Jaganathan, D. and Byju, G. *Agrotechniques of Tropical Tuber Crops* (Telugu). Technical leaflet No. 02/2019. ICAR –Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Sheela, M.N., Asha, K.I., Asha Devi, A., Shirly Raichal Anil, Krishna Radhika, N., Hegde, V., Prakash Krishnan, B.S. 2019. *Protection of Plant Varieties and Farmers Right's Act 2001* (Malayalam), ICAR – Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Sheela, M.N., Makeshkumar T., Krishna Radhika, N., Suresh Kumar, J., Sunitha, S., Asha, K.I., Asha Devi, A., Visalakshi Chandra, C., Shirly Raichal Anil and Abhilash, P.V. 2019. *New CMD Resistant Varieties of Cassava*. ICAR - Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Sheela, M.N., Makeshkumar, T., Krishna Radhika, N., Suresh Kumar, J., Sunitha, S., Asha K.I., Asha Devi, A., Visalakshi Chandra, C., Shirly Raichal Anil and Abhilash, P.V. 2019. *New CMD Resistant Cassava Varieties - AICRP on Tuber Crops.* ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Sheela, M.N., Visalakshi Chandra, C., Senthilkumar, K.M. and Jaganathan, D. 2019. *High Yielding and Cassava Mosaic Disease Resistant Varieties of Cassava* (Tamil) Extension folder No. 02/2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Sheela, M.N., Visalakshi Chandra, C., Senthilkumar, K.M. and Jaganathan, D. 2019. *High Yielding and Triploid Varieties of Cassava – Sree Athulya and Sree Apoorva* (Tamil), Extension folder No. 03/2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Sivakumar, P.S., Jaganathan, D., Muthuraj, R., Sheela Immanuel and Ravi, V. 2019. *Improved Technologies of Chinese Potato.* Extension folder in Tamil. ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Suresh Kumar, J. and Muthuraj, R. 2019. *Rapid Multiplication Method of Minisett Technique on Tuber Crops* (Telugu). ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Course/Training manuals

Sivakumar, P.S., Jaganathan, D., Sheela Immanuel, Muthuraj, R., Kesava Kumar, H. and Balasubramani, N. 2019. *Training Manual on Innovative Extension Approaches for Horticultural Crops with Special Reference to Tuber Crops*, 19-22 November 2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. 189 p.

Suja, G., Jaganathan, D., Ramesh, V. and Koundinya, A.V.V. 2019. *Model Training Course Manual on Organic Farming for Safe and Sustainable Food Production with Special Focus on Tropical Tuber Crops*, 1-8 November 2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. 200 p.

Suja, G., Suresh Kumar, J. and Ravi, V. 2019. *Training Manual of 38th FTF-ITT (Feed the Future-India Triangular Training) programme titled Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September 2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.309 p.

Chapters in Course / Training manuals

Asha, K.I., Shirly Raichal Anil, Asha Devi, A. and Murugesan, P. 2019. Management of genetic resources of tuber crops. In: *Manual of Feed The Future India Triangular Training (FTF - ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September 2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 8-17.

Jaganathan, D., Sheela Immanuel, Sivakumar, P.S. and Koundinya, A.V.V. 2019. Innovative technology transfer approaches for promotion of organic farming in tuber crops. In: *Model Training Course Manual on Organic Farming for Safe and Sustainable Food Production with Special Focus on Tropical Tuber Crops*, 1-8 November 2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 183-195.

Jeeva, M.L. and Veena, S.S. 2019. Screening and management of important fungal diseases of tropical tuber crops. In: *Manual of Feed The Future India Triangular Training (FTF - ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September 2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 198-211.

Jyothi, A.N. 2019. Novel industrial products from tuber starches. In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September 2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 239-247.

Krishnakumar, T. and Sajeev, M.S. 2019. Processing machineries in tropical tuber crops. In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September

2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 225-238.

Mohan, C., Krishna Radhika, N., Hegde, V. and Senthilkumar, K.M. 2019. Biotechnological interventions for genetic improvement of tuber crops. In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 36-69.

Nedunchezhiyan, M. and Suresh Kumar, J. 2019. Integrated farming system of tropical tuber crops. In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 186-192.

Sajeev, M.S. and Krishnakumar, T. 2019. Community incubation centres for on-farm processing of tuber crops. In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.pp. 295-298.

Sajeev, M.S., Namrata A.G. and Krishnakumar, T. 2019. Tropical tuber crops based ready to eat/serve products. In: *Manual of Feed The Future India Triangular Training (FTF - ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 257-264.

Santhosh Mithra, V.S. 2019. e-crop and organic farming. In: *Training Manual on Organic Farming for Safe and Sustainable Food Production with Special Focus on Tropical Tuber Crops*, 1-8 November 2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 172-177.

Saravanan Raju and Visalakshi Chandra, C. 2019. Postharvest physiological deterioration of cassava: current understanding, management and future perspectives. In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 284-294.

Sheela M.N., Shirly Raichal Anil, Visalakshi Chandra, C. and Koundinya A.V.V. 2019. Improved varieties of cassava and sweet potato. In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 18-29.

Sheela, M. N. and Asha Devi, A. 2019. Improved varieties of yams and aroids. In: *Manual of Feed The Future India Triangular Training (FTF - ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 30-35.

Sheela Immanuel, Sivakumar, P.S. and Jaganathan, D. 2019. Innovative extension approaches–Experiences of ICAR-CTCRI. *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 299-309.

Suja, G. and More, S.J. 2019. Best agronomic practices for tropical tuber crops. In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 70-78.

Suja, G. and More, S.J. 2019. Sustainable crop diversification involving tropical tuber crops. In: In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production,*

Processing and Value Addition in Tuber Crops, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 79-91.

Sunitha, S. and Suresh Kumar, J. 2019. Precision Farming in Tuber Crops. In: *Manual of Feed The Future India Triangular Training (FTF-ITT) Training Manual on Integrated Technology for Production, Processing and Value Addition in Tuber Crops*, 16-30 September, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 115-118.

Veena, S.S, Jeeva M.L. and Makeshkumar, T. 2019. Biointensive disease management in tuber crops. 2019. In: *Training Manual on Organic Farming for Safe and Sustainable Food Production with Special Focus on Tropical Tuber Crops*, 1-8 November 2019, ICAR–Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. pp. 65-72.

Institute Publications

Annual Report of ICAR-CTCRI, 2018-2019 (Bilingual)

Annual Report of AICRP on Tuber Crops, 2018-2019

Research Highlights ICAR-CTCRI, 2018-2019

ICAR-CTCRI News Letter July-December 2018, January-June 2019 (Bilingual)

45th Annual Institute Research Council Meeting, Salient Achievements, ICAR-CTCRI, 2018- 2019

45th Annual Institute Research Council Meeting, Proceedings and Activity Milestones, ICAR-CTCRI, 2018-2019

Technical Report of the 19th Annual Group Meeting of AICRP on Tuber Crops held at ICAR-CTCRI, Thiruvananthapuram.

Proceedings of 19th Annual Group Meeting of AICRP on Tuber Crops held at ICAR-CTCRI, Thiruvananthapuram, Kerala

Radio talk

Ramesh, V. 2019. A talk on 'Cassava farming in Pachamalai hills' at Akashavani, Salem on 5 July 2019.

Sheela, M.N. 2019. *Kizhangu vargangal gunamenmayum uthpadanasheshiyumulla nadeel vasthukkalude labhyadha* at AIR, Thiruvannathapuram on 12 July 2019.

Suja, G. 2019. A talk on 'Cropping systems involving tuber crops (*Kizhangu vila adishtitha vila sambradayangal*)' at AIR, Thiruvananthapuram on 14 September 2019.

Susan John, K. A talk on 'Role of tropical tuber crops in poverty alleviation' in connection with 'World Food Day' at AIR, Thiruvananthapuram on 17 October 2019.

Byju, G. A talk on 'Post-flood changes in soil properties' at Vayalum Veedum, AIR, Thiruvananthapuram on 28 October 2019.

Byju, G. A talk on World Soil Day 2019: Stop soil erosion, save our future at Njattuvela, AIR, Thiruvananthapuram on 5 December 2019.

TV talk

Ramesh, V. 2019. A talk on 'Importance of soil testing in varietal adoption in Pachamalai hills' in Doordarshan, Salem on 4 July 2019.

Byju, G. A talk on 'World Soil Day 2019: Stop soil erosion, save our future' in FIB Live TV programme, Thiruvananthapuram on 5 December 2019.

ONGOING PROJECTS

Institute Projects

Sl. No.	Project code	Project title	PI	Co-PIs
1.	HORTICARCTCRI SIL 2015 001 01457	Conservation and utilization of germplasm of tuber crops for sustaining production	M.N. Sheela	Archana Mukherjee, K.I. Asha, C. Mohan, A. Asha Devi, Shirly Raichal Anil, P. Murugesan, N. Krishna Radhika, Kalidas Pati, T. Makeshkumar, M.L. Jeeva, S.S. Veena, H. Kesava Kumar, V.B.S. Chauhan, K. Hanume Gowda, Vivek Hegde, C. Visalakshi Chandra, J. Sreekumar, A.N. Jyothi, A.V.V. Koundinya, K.M. Senthilkumar, B.G. Sangeetha, E. R. Harish
2.	HORTICARCTCRI SIL 2015 001 01458	Genetic improvement of tuber crops through conventional breeding and molecular approaches	Archana Mukherjee	M.N. Sheela, K.I. Asha, C. Mohan, A. Asha Devi, Shirly Raichal Anil, N. Krishna Radhika, Kalidas Pati, T. Makeshkumar, M.L. Jeeva, S.S. Veena, M. Nedunchezhiyan, K. Lakshminarayana, V.B.S. Chauhan, K. Hanume Gowda, Vivek Hegde, C. Visalakshi Chandra, J. Sreekumar, A.N. Jyothi, S. Sunitha, G. Suja, Saravanan Raju, K.M. Senthilkumar, A.V.V. Koundinya, V. Ravi, P. Murugesan, R. Muthuraj, E.R. Harish, P. Prakash
3.	HORTICARCTCRI SIL 2015 003 01459	Integrated crop, water and nutrient management for improving productivity of tropical tuber crops	G. Byju	V. Ravi, R. Muthuraj, G. Suja, M. Nedunchezhiyan, S. Sunitha, K. Laxminarayana, V. Ramesh, T. Makeshkumar, M. N. Sheela, Archana Mukherjee, A. Asha Devi, K. Susan John, Saravanan Raju, S.S. Veena, J. Sreekumar, A.N. Jyothi, V.S. Santhosh Mithra, P. Prakash, Sanket J. More, C. Visalakshi Chandra, J. Suresh Kumar, V.K. Dua (ICAR-CPRI, Shimla)

Sl. No.	Project code	Project title	PI	Co-PIs
4.	HORTICARCTCRI SIL 2015 004 01460	Studies on impact of climate change and devising mitigation and adaptation strategies for sustaining productivity of tuber crops	V. Ravi	Saravanan Raju, N. Krishna Radhika, R. Muthuraj, G. Byju, V.S. Santhosh Mithra, M.N. Sheela, M. Nedunchezhiyan, S. Sunitha G. Suja, V. Ramesh, Sanket J. More, J. Suresh Kumar, K. Laxminarayana, Prince Kumar (RS, ICAR-CPRI)
5.	HORTICARCTCRI SIL 2015 005 01461	Eco-friendly strategy for the management of insect pests in tuber crops	C.A. Jayaprakas	Archana Mukherjee, E.R. Harish, S.S. Veena, H. Kesava Kumar, T. Sirisha, J. Sreekumar, Shirly Raichal Anil, B.G. Sangeetha
6.	HORTICARCTCRI SIL 2015 006 01462	Development and refinement of integrated disease management and forecasting system for improved tuber crop production	M.L. Jeeva	S.S. Veena, M. Nedunchezhiyan, G. Byju, A.N. Jyothi, J. Sreekumar, K.I. Asha, V.S. Santhosh Mithra, T. Makeshkumar, R. Arutselvan, T. Sirisha, B.G. Sangeetha
7.	HORTICARCTCRI SIL 2015 009 01465	Cassava mosaic disease-variability, diagnostics, vector relation and management	T. Makeshkumar	M.L. Jeeva, M.N. Sheela, B.G. Sangeetha, E.R. Harish, C. Mohan, J. Sreekumar, C.A. Jayaprakas, K. Susan John, S. Sunitha, R. Muthuraj, Vivek Hegde, Saravanan Raju, K.M. Senthilkumar, R. Arutselvan, A.V.V. Koundinya
8.	HORTICARCTCRI SIL 2013012 01451	Development and refinement of post-harvest handling, storage and processing techniques for minimization of losses in tropical tuber crops and production of value added products	M.S. Sajeev	A.N. Jyothi, S.S. Veena, K.I. Asha, T. Krishnakumar, Saravanan Raju, G. Suja, V. Ramesh, G. Byju, C. Visalakshi Chandra
9.	HORTICARCTCRI SIL 2015 010 01466	Development of cassava starch based novel products and functional foods from other tuber crops	A.N. Jyothi	M.S. Sajeev, Venkataraman V. Bansode, K. Susan John, M. Nedunchezhiyan, T. Krishnakumar, P.S. Sivakumar

Sl. No.	Project code	Project title	PI	Co-PIs
10.	HORTICARCTCRI SIL 2015 008 01464	Developing methodologies and tools for assessment and transfer of tuber crops technologies	Sheela Immanuel	J. Sreekumar, V.S. Santhosh Mithra, T. Srinivas, P. Sethuraman Sivakumar, D. Jaganathan, P. Prakash, V. Ramesh, R. Muthuraj, H. Kesava Kumar, Sanket J. More, M. Nedunchezhiyan, M.S. Sajeev, G. Byju, C. Mohan, T. Makeshkumar, E.R. Harish,G. Suja, A.N. Jyothi, C.A. Jayaprakas, V. Ravi, M.N. Sheela, P. Murugesan, T. Krishnakumar, A.V.V. Koundinya, Venkataraman V. Bansode, K. Venkatesan (NAARM, Hyderabad)

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	Archana Mukherjee (Till October 2019) Kalidas Pati (November 2019 onwards)	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*)	Archana Mukherjee (Till October 2019) M. N. Sheela (Lead Centre) Kalidas Pati (Collaborating Centre) (November 2019 onwards)	Vivek Hedge M. Nedunchezhian 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	Archana Mukherjee K.I. Asha A. Asha Devi Shirly Raichal Anil Kalidas Pati N. Krishna Radhika	PPV & FRA, New Delhi
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. Sethuraman 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

Sl. No.	Title	PI	Co-PIs	Funding agency
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 polysulphate 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 profitability from coconut gardens through soil health management in tuber crops	G. Byju G. Suja	Archana Mukherjee D. Jaganathan	Coconut Development Board, Govt. of India
12.	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	V. Ravi Archana Mukherjee G. Byju J. Sreekumar	M.N. Sheela C.A. Jayaprakas Sheela Immanuel G. Suja K. Susan John V. Ramesh, R. Muthuraj, Saravanan Raju, Sanket J. More D. Jaganathan	RKVY-RAFTAAR, Govt. of Kerala
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

Sl. No.	Title	PI	Co-PIs	Funding agency
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.	ICAR-CTCRI -Tribal Sub Plan 'Livelihood improvement of tribal farmers through tuber crops technologies'	Nodal Officer: Sheela Immanuel PI: M. Nedunchezhiyan	Archana Mukherjee K. Laxminarayana Kalidas Pati V.B.S. Chauhan K. Hanume Gowda V.V. Bansode	ICAR, New Delhi
17.	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
18.	On-farm trials of cassava bio-pesticides against borer pests of banana in Kerala	C.A. Jayaprakas	E.R. Harish B.G. Sangeetha	Department of Agriculture and Farmers' Welfare, Govt. of Kerala
19.	High value compounds/ Phytochemicals	A.N. Jyothi	J. Sreekumar Shirly Raichal Anil	ICAR (Network Project)
20.	Techno-Incubation Centre	M.S. Sajeev	T. Krishnakumar	Small Farmers Agribusiness Consortium, Govt. of Kerala
21.	National Agricultural Innovation Foundation (NAIF) (Component 1 Innovation Fund)	P. Sethuraman Sivakumar	R. Muthuraj Vivek Hegde H. Kesava Kumar T. Krishnakumar D. Jaganathan R. Bharathan	ICAR – NAIF
22.	NAF - Component II - Agribusiness Incubator	P. Sethuraman Sivakumar	Sheela Immanuel	ICAR-IP & TM Unit
23.	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 (Women Scientist)	KSCSTE, Govt. of Kerala
24.	Smart-farming technologies in horticultural crops for improving rural agro system	V.S.S. Mithra	G. Byju J. Sreekumar D. Jaganathan	Kerala State Horticulture Mission
25.	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.S. Mithra	G. Byju T. Makeshkumar M.S. Sajeev E.R. Harish	Department of Science and Technology, Govt. of India

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

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

Programme	Particulars of the programme	Name of the participants
National Symposium on Horticulture in the Vanguard of Climate Change and Urban Environment	Department of Horticulture, Annamalai University, Chidambaram, Tamil Nadu 07-08 February 2019	Dr. P. Murugesan
Workshop on Agro-Entrepreneurship Development	P.N. Paniker Foundation, Thiruvananthapuram 08 February 2019	Dr. M.S. Sajeev
National Conference on Emerging Food Processing Technologies for Safe Food	Thangal Kunju Musaliar Institute of Technology, Kollam, 09 February 2019	Dr. M.S. Sajeev
National Agri-Business Entrepreneurship Conclave (NABEC-2019): Building Agri-Business Start-Up Ecosystem	Umiam, Meghalaya, 09-11 February 2019	Dr. Archana Mukherjee Dr. P.S. Sivakumar
International Conference on Agricultural Extension and Advisory Services: Innovation to Impact	National Institute of Agricultural Extension Management, Hyderabad, 12-14 February 2019	Dr. P.S. Sivakumar
National Productivity Week	ICAR–Central Tuber Crops Research Institute, Thiruvananthapuram, 12-18 February 2019	All Scientists
State Level Technical Workshop on Organic Farming & GAP for Quality Production	Institute of Management in Government, Thiruvananthapuram, 15 February 2019	Dr. G. Suja
National Science Day	ICAR-Central Tuber Crops research Institute, Thiruvananthapuram, 19-22 February 2019	All Scientists
XIV Agricultural Science Congress-2019	NASC Complex, New Delhi 20-23 February 2019	Dr. P. Prakash
Prime Minister's Kisan Samman Nidhi Yojana (PM-KISAN) cum Live Web Telecast	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 24 February 2019	All Scientists
National Symposium on Recent Challenges and Opportunities in Sustainable Plant Health Management	Banaras Hindu University, Varanasi 26-28 February 2019	Dr. T. Makeshkumar
Hindi Workshop	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 28 February 2019	All Scientists
K.V. George Memorial Lecture Series-X	St. Thomas College, Kozhencherry, Pathanamthitta, Kerala, 01 March 2019	Dr. Archana Mukherjee Dr. Sheela Immanuel
23rd Plantation Crops Symposium (PLACROSYM XXIII)	Chikkamagaluru, Karnataka 06-08 March 2019	Dr. P. Murugesan
Special Meeting in Connection with the Harvest of Organic Yams and Establishment of Tuber Crop Museum	Open Jail and Correctional Home, Nettukaltheri, Thiruvananthapuram, 07 March 2019	Dr. Archana Mukherjee Dr. G. Byju Dr. G. Suja

Programme	Particulars of the programme	Name of the participants
International Women's Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 08 March 2019	All Scientists
Kerala Agro Food Pro 2018	Department of Industries, Thrissur, 12 March 2019	Dr. M.S. Sajeev
National Seminar on Climate Resilient Agriculture for Abiotic Stress	Department of Plant Breeding and Genetics, Annamalai University, Chidamabaram, Tamil Nadu 12-13 March 2019	Dr. P. Murugesan
National Seminar on Viral Genomics: Its Implications in Viral Diagnosis and Disease Control	Inter University Centre for Genomics and Gene Technology, University of Kerala, Karyavattom, Thiruvananthapuram, 14 March 2019	Dr. T. Makeshkumar Dr. E.R. Harish Dr. H. Kesava Kumar Dr. B.G. Sangeetha
Workshop on Applied Statistics and Data Analysis for Science and Society	Department of Agricultural Statistics, College of Agriculture, Kerala Agricultural University, Vellayani,14 March 2019	Dr. Archana Mukherjee
National Conference on Agri-Nutrition	Ministry of Women and Child Development, Govt. of India, The Ashok Hotel, New Delhi 15 March 2019	Dr. A.N. Jyothi
Annual Action Plan Meeting of KVKs of Kerala & Lakshadweep	Karshaka Bhavanam, Kerala Agricultural University, Thrissur, 18-20 March 2019	Dr. G. Suja
Young Innovators Meet	Kerala Development and Innovation Strategic Council, Thiruvananthapuram, 20 March 2019	Dr. Archana Mukherjee Dr. Sheela Immanuel
Workshop on Intellectual Property Valuation of Agricultural Technologies	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 22 March 2019	Dr. Archana Mukherjee Dr. Sheela Immanuel Dr. P.S. Sivakumar Dr. R. Muthuraj Dr. D. Jaganathan Dr. H. Kesava Kumar
61st Meeting of Board of Studies of College of Agriculture	College of Agriculture, Vellayani, Thiruvananthapuram, 28 March 2019	Dr. M.N. Sheela
45thAnnual Institute Research Council Meeting	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 04-06 April 2019	All Scientists
Institute Biosafety Committee Meeting	ICAR-Indian Institute of Spices Research, Kozhikode, 10 April 2019	Dr. T. Makeshkumar
Scientific Advisory Committee Meeting, Krishi Vigyan Kendra (KVK), Kollam	Sadanandapuram, Kollam, 12 April 2019	Dr. D. Jaganathan
Institute Management Committee Meeting	ICAR-Sugarcane Breeding Institute, Coimbatore 24 April, 2019	Dr. V. Ramesh
Hindi Praveen Contact Programme-II	AG's Office, Thiruvananthapuram 25-26 April 2019	Dr. M.L. Jeeva Dr. T. Makeshkumar Dr. C. Mohan Dr. D. Jaganathan Dr. T Krishnakumar Dr. H. Kesava Kumar Dr. S. Karthikeyan

Programme	Particulars of the programme	Name of the participants
KSIDC Core Committee Meeting	Kerala State Industrial Development Corporation, Thiruvananthapuram, 03 May 2019	Dr. Sheela Immanuel
Meeting on Geo-tagging of Assets under RKVY	Department of Agriculture (PPM Cell), Govt. of Kerala, Thiruvananthapuram, 07 May 2019	Dr. Sanket J. More
World No Tobacco Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 31 May 2019	All Scientists
Meeting on Evaluation of ATMA Performance	Department of Agriculture, Agriculture Technology Management Agency, Thiruvananthapuram 4 June 2019	Dr. Sheela Immanuel
World Environment Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 05 June 2019	All Scientists
Kerala State Biodiversity Board - Consultative Workshop on Custodian Farmers and their Role in Biodiversity Conservation	PWD Rest House Auditorium, Thycaud, Thiruvananthapuram, Kerala, 05 June 2019	Dr. M.N. Sheela Dr. B.G. Sangeetha
Mid- Term Review Meeting of ICAR Regional Committee-II	ICAR-Central Inland Fisheries Research Institute, Barrackpore, West Bengal, 12 June 2019	Dr. K. Laxminarayana
AICRP Annual Group Meeting	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 13-15 June 2019	Dr. Archana Mukherjee Dr. V. Ravi Dr. M. Nedunchezhiyan Dr. C.A. Jayaprakas Dr. M.N. Sheela Dr. Sheela Immanuel Dr. S. Sunitha Dr. M.S. Sajeev Dr. M.L. Jeeva Dr. K.I. Asha Dr. A. Asha Devi Dr. J. Sreekumar Dr. V.S. Santosh Mithra Dr. R. Muthu Raj Dr. Kalidas Pati Dr. J. Suresh Kumar
Shri. H. H. Visakham Thirunal Endowment lecture - Science & Technology for National Development and Role of Indian Space Programme	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 15 June 2019	All Scientists
Review meeting of Foreign aided projects	Krishi Anusandhan Bhavan-II, New Delhi 18-19 June 2019	Dr. Shirly Raichal Anil
Seminar on Need for Reforms in Fertilizer Policy for Promoting Balanced Use of Nutrients	Central Residency, Thiruvananthapuram 21 June 2019	Dr. Sheela Immanuel

Programme	Particulars of the programme	Name of the participants
International Yoga Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 21 June 2019	All Scientists
Institute Management Committee Meeting	ICAR-Indian Institute of Spices Research, Kozhikode, 27 June 2019	Dr. T. Makeshkumar
Seminar on Improved Technologies of Elephant Foot Yam with Special Reference to Fertilizer Best Management Practices	Krishi Bhavan, Aliparamba, Malappuram 27 June 2019	Dr. G. Byju Dr. D. Jaganathan
IMPCC Meeting	Doordarshan Office, Thiruvananthapuram 11 July 2019	Dr. Sheela Immanuel
International Conference on Plant Protection in Horticulture: Advances and Challenges	ICAR-Indian Institute of Horticultural Research, Bengaluru, 24-27 July 2019	Dr. C.A. Jayaprakas Dr. T. Makeshkumar Dr. E.R. Harish
ICAR-CTCRI 56th Foundation Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 27 July 2019	All Scientists
Seminar on Improved Technologies of Horticultural Crops with Special Reference to Tuber Crops	Ryali, East Godavari, Andhra Pradesh 01 August 2019	Dr. G. Byju Dr. D. Jaganathan Dr. A.V.V. Koundinya
Mainstreaming Agrobiodiversity in India	Centre for Development Studies, Ulloor, Thiruvananthapuram, 21 August 2019	Dr. Shirly Raichal Anil
Review Meeting of Vayalum Veedum of All India Radio (AIR) of Thiruvananthapuram	Centre for Environment and Development, Vattiyoorkavu, Thiruvananthapuram 27 August 2019	Dr. D. Jaganathan
Meeting on Agriculture Development in Kerala	Dept. of Agriculture, Thycaud Guest House, Thiruvananthapuram, 27 August 2019	Dr. Sheela Immanuel
First Meeting of TOLIC 2019-2020	Chief PMG's Office, Thiruvananthapuram 28 August 2019	Dr. A. Asha Devi Smt. T.K. Sudhalatha
Consultative Meeting on Biodiversity Conservation	Kerala State Agricultural Production Commissioner, Thiruvananthapuram, 30 August 2019	Dr. M.N. Sheela
Workshop on Radiation Technology Applications in Agriculture	Central Horticultural Experiment Station, Indian Institute of Horticultural Research, Bhubaneswar 04 September 2019	Dr. V.V. Bansode
Global Micronutrient Summit 2019	Hotel Leela Palace, New Delhi 05-06 September 2019	Dr. K. Susan John
Hindi Fortnight Celebrations	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 14-28 September 2019	All Scientists
Institute Management Committee Meeting	ICAR-Central Plantation Crops Research Institute, Kasaragod, 21 September 2019	Dr. T. Makeshkumar

Programme	Particulars of the programme	Name of the participants
2nd International Conference on Recent Advances in Agricultural, Environmental & Applied Sciences for Global Development	Dr. Y.S. Parmer University of Agriculture and Forestry, Nauni, Himachal Pradesh 27-29 September 2019	Dr. V.V. Bansode
Valedictory Function of the Hindi Fortnight Celebration of NCESS	National Centre for Earth Science Studies, Thiruvananthapuram, 27 September 2019	Dr. A. Asha Devi Smt. T.K. Sudhalatha
Review Meeting of Coconut Development Board project	Govt. Guest House, Kovalam, Thiruvananthapuram, 30 September 2019	Dr. G. Byju Dr. G. Suja Dr. D. Jaganathan
150th Birth Anniversary Celebrations of Father of Nation	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 02 October 2019	All Staff
Workshop on Enriching Custodian Farmers with PPV & FR Act to Safeguard Valued Plant Genetic Resources towards Green Prosperity	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 10-11 October 2019	All Scientists
International Conference on Global Research Initiatives for Sustainable Agriculture & Allied Sciences	ICAR–National Academy of Agricultural Research Management, Hyderabad, 13-16 October 2019	Dr. S. Tadigiri
QRT meeting of ICAR-CTCRI and AICRP Tuber Crops	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 15-16 October 2019	All Scientists
Stakeholders Interface Meet on Performance Evaluation to maximize Farmers Income, Better Livelihood with Tuber Crops & Allied Technological Interventions	Regional Centre, ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha, 19 October 2019	Dr. V.V. Bansode
National Seminar on Food for Health-Trends in Bioactive Compounds	Department of Food Science & Nutrition, Periyar University, Salem, Tamil Nadu, 22 October 2019	Dr. T. Krishnakumar
Workshop on Financial Management for Agristartups	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 25 October 2019	All Scientists
Vigilance Awareness Week	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 30 October 2019	All Staff
62nd meeting of the Board of Studies	College of Agriculture, Kerala Agricultural University, Thiruvananthapuram 07 November 2019	Dr. M.N. Sheela
Indo Data Week 2019: Collaborative Programme between DAV Data Solutions, India and Indo-Nordic Innovation Acceleration Cluster (INIAC)	Hyderabad, Telangana, 08 November 2019	Dr. V.S. Santhosh Mithra

Programme	Particulars of the programme	Name of the participants
Short Course on Making greater use of biocontrol agents in organic agriculture	Assam Agricultural University, Jorhat 4-13 November 2019	Dr. H. Kesava Kumar
Meeting of Core Committee of KSIDC	Kerala State Industrial Development Corporation, Thiruvananthapuram, 07 November 2019	Dr. Sheela Immanuel
XIV Annual Group Meeting of the All India Network Programme on Organic Farming (AI-NPOF)	ICAR- Central Island Agricultural Research Institute, Port Blair, Andaman & Nicobar Islands 11-17 November 2019	Dr. G. Suja
79th Annual Conference of Indian Society of Agricultural Economics	Raipur, Chhattisgarh, 21-23 November 2019	Dr. P. Prakash
Hindi workshop on Official Language Policy/ Administrative Terminology	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 23 November 2019	All Scientists
24th ICAR Regional Committee Meeting of Zone-III	Assam Administrative Staff College, Guwahati, Assam and ICAR Research Complex for NEH Region, Umiam, Meghalaya, 23-24 November 2019	Dr. K. Laxminarayana
District Collector's Review cum Farmers Grievance Meeting	Collectorate Office, Salem, Tamil Nadu 29 November 2019	Dr. P.S. Sivakumar Dr. R. Muthuraj
National Workshop on DNA Sequencing and Analysis	Department of Biotechnology, University of Kerala, Karyavattom, Thiruvananthapuram 2-7 December 2019	Dr. T. Makeshkumar Dr. B.G. Sangeetha
Workshop on Genotyping of Whitefly Species Complex & its Associated Endosymbionts	ICAR-Indian Agricultural Research Institute, New Delhi, 05-06 December 2019	Dr. E.R. Harish
National Workshop on Tools and Techniques in Advanced Plant Science Research	Department of Botany, University of Kerala, Kariavattom, Thiruvananthapuram 5-12 December 2019	Dr. Sanket J. More
KAU Institute Biosafety Committee Meeting	College of Agriculture, Kerala Agricultural University, Thiruvananthapuram 06 December 2019	Dr. T. Makeshkumar
Tuber Crops Day	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 10 December 2019	All Staff
Scientific Advisory Committee Meeting of Mitraniketan Krishi Vigyan Kendra, Thiruvananthapuram	Vellanadu, Thiruvananthapuram 10 December 2019	Dr. D. Jaganathan
IV National Workshop for Nodal Officers/Officer In charge of Data Management	New Delhi, 10-11 December 2019	Dr. V.S. Santhosh Mithra
National Symposium on Nematodes: A Threat to Food Security & Farmer's Livelihood	Senate Hall, Earth Sciences Building, Manipur University, Imphal, Manipur 11- 13 December 2019	Dr. H. Kesava Kumar Dr. S. Tadigiri

Programme	Particulars of the programme	Name of the participants
National Symposium on Potential Crops for Food and Nutritional Security	The Indian Society of Genetics and Plant Breeding, South Chapter, Tamil Nadu Agricultural University, Coimbatore, 14-15 December 2019	Dr. T. Krishnakumar
International Conference on Extension for Strengthening Agricultural Research and Development (eSARD 2019)	Suttur, Mysuru, 14-16 December 2019	Dr. P.S. Sivakumar Dr. D. Jaganathan
Review Meeting of AIR	Oil Palm India Limited, Kottayam, Kerala 19 December 2019	Dr. G. Suja
National Conference of Plant Physiology-Plant Productivity and Stress Management	Department of Plant Physiology, Kerala Agricultural University, Thrissur, 19-21 December 2019	Dr. V.S. Santhosh Mithra Dr. Sanket J. More

VISITS ABROAD

Name of the scientist	Period	Place of visit	Purpose
Dr. M.N. Sheela	3-4 September 2019	Zollikoffen, Switzerland	Participated and presented the deputation reports on the Indo Swiss Cassava Network Review meeting at HAFL
	12-14 September 2019	Vientiane, Laos	As Expert, attended the meeting in connection with the launching of the project entitled 'Establishing Sustainable Solution to Cassava Diseases in the Mainland Southeast Asia'
Dr. C.A. Jayaprakas	27 May - 04 June 2019	Chinese Academy of Tropical Agricultural Sciences (CATAS), Beijing, China	Participated in the Seminar on Agricultural Technology Innovation for South Asian Countries
	23-25 September 2019	Valencia, Spain	Participated and delivered a talk entitled, 'Cassava (*Manihot esculenta* Crantz) - a future crop for harvesting insecticidal molecules against pests of horticultural crops' in the Global Conference on Plant Science and Research
Dr. P. Murugesan	18-19 November 2019	Kula Lumpur Convention Centre (KLCC), Kula lumpur, Malaysia	Delivered an invited talk on 'Prospects of exploring ganoderma tolerance/resistant exotic germplasm for introgression to oil palm hybrid seed production' in the International Seminar on Breeding for Ganoderma Tolerance in Oil Palm
Dr. T. Makeshkumar	2-5 September 2019	HAFL, Bern, Switzerland	To attend the final review meeting of Indo-Swiss Cassava Network project meeting
Dr. E.R. Harish	1-2 August 2019	Chulalongkorn University, Bangkok, Thailand	Participated and presented a research paper entitled,'Molecular characterization of the main threat in cassava (*Manihot esculenta* Crantz) production, cassava whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) from different agro-ecological zones of Kerala, India and its significance' in the International Conference

Dr. B.G. Sangeetha	19 August - 12 September 2019	Chinese Academy of Tropical Agricultural Sciences (CATAS), Hainan Province, The People's Republic of China	Attended a training course on 'Integrated pest management technology of tropical crops for developing countries'

Dr. M.N. Sheela with cassava experts at Vientiane, Laos

Dr. E.R. Harish presenting a research paper at Chulalongkorn University, Bangkok

DISTINGUISHED VISITORS

- Shri. Justice (Retd.) P. Sathasivam, Honourable Governor of Kerala.
- Shri. Alphons Kannanthanam, Hon'ble Minister of State for Tourism (Independent Charge), New Delhi.
- Padma Bhushan Dr. B.N. Suresh, Professor & Hon'ble Chancellor, Indian Institute of Space Science and Technology, Thiruvananthapuram.
- Dr. Trilochan Mohapatra, Secretary, Department of Agricultural Research and Education & Director General, Indian Council of Agricultural Research, New Delhi.
- Dr. Abhilaksh Likhi, Joint Secretary (Cooperation), Ministry of Agriculture and Farmers Welfare, Government of India.
- Dr. Anand Kumar Singh, Deputy Director General (Horticulture Science), Indian Council of Agricultural Research, New Delhi.
- Dr. N.K. Krishnakumar, Regional Representative in South & Central Asia, Bioversity International & Former DDG (Hort. Sci.), Indian Council of Agricultural Research, New Delhi.
- Dr. V.P. Singh, South East Asian Representative of the International Center for Tropical Agriculture (CIAT), New Delhi.
- Smt. Shardha Sampath, Chief Post Master General, Kerala Circle, Thiruvananthapuram.
- Shri. Loknath Behera, IPS, Director General of Police, Kerala Police, Kerala.
- Dr. P. Rethinam, Former ADG, ICAR; Chairman, CDB, GOI & Executive Director, APCC, Jakarta, Indonesia
- Dr. Purnachandra Rao, Director, National Centre for Earth Science Studies, Thiruvananthapuram.
- Dr. R.C. Agrawal, Registrar General, PPV & FRA, New Delhi.
- Dr. Ravi Prakash, Registrar, PPV & FRA, New Delhi.
- Dr. T. Janakiram, ADG (Hort. Sci.), ICAR, New Delhi.
- Dr. C. Devakumar, Former ADG (EP & D), ICAR, New Delhi.
- Prince Aditya Varma, Kowdiar Palace, Thiruvananthapuram.
- Dr. Ramabhau Tumadu Patil, Former Director, ICAR-Central Institute of Post Harvest Engineering and Technology, Ludhiana.
- Dr. M. Anandaraj, Former Director, ICAR-Indian Institute of Spices Research, Kozhikode.
- Dr. S. Arulraj, Former Director, ICAR-Indian Institute of Oil Palm Research, Pedavegi, Andhra Pradesh.
- Dr. S.K. Naskar, Former Director, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram.
- Prof. P.K. Gupta, Hon. Emeritus Professor & INSA Hon. Scientist, Meerut University, Meerut.

- Dr. H.P. Maheswarappa, Project Co-ordinator (AICRP on Palms), ICAR-Central Plantation Crops Research Institute, Kasaragod.
- Dr. S.K. Nanda, Former Project Co-ordinator (AICRP on PHT), ICAR-Central Institute of Post Harvest Engineering and Technology, Ludhiana.
- 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. M. Pitchaimuthu, Principal Scientist, Division of Vegetable Crops, ICAR-Indian Institute of Horticultural Research, Bengaluru.
- Shri. J. Sajeev, Managing Director, Horticorp, Government of Kerala.
- Prof. (Dr.) K.N. Harilal, Member, Kerala State Planning Board, Thiruvananthapuram.
- Dr. V.K. Venugopal, Former Professor and Head, Department of Soil Science and Agricultural Chemistry, Kerala Agricultural University.
- Dr. P. Kalia, Emeritus Scientist & Former Head, Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi.
- Dr. C. Palaniswami, Principal Scientist & Head (Crop Production), ICAR-Sugarcane Breeding Institute, Coimbatore.
- Dr. Goldi Tewari, Program Manager, FTF-ITT programme, MANAGE, Hyderabad.

ICAR-CTCRI STAFF MEMBERS

Managerial Personnel

Dr. Archana Mukherjee	:	Director (upto 31.10.2019)
Dr. V. Ravi	:	Director (Acting) (w.e.f. 01.11.2019)
Dr. James George	:	Project Coordinator (upto 31.01.2019)
Dr. V. Ravi	:	Head, Crop Production
Dr. C.A. Jayaprakas	:	Head (Acting), Crop Protection & Central Public Information Officer
Dr. M.N. Sheela	:	Head (i/c), Crop Improvement
Dr. Sheela Immanuel	:	Head (i/c), Extension and Social Sciences
Dr. M. Nedunchezhiyan	:	Head (i/c), Regional Centre, Bhubaneswar
Dr. M. S. Sajeev	:	Head (i/c), Crop Utilization
Dr. Saravanan Raju	:	Vigilance Officer (upto 20.05.2019)
Dr. J. Sreekumar		Vigilance Officer (w.e.f. 21.05.2019)
Shri. Abhishek Rana	:	Senior Administrative Officer (Upto 02.07.2019)
Shri. Ramdeen	:	Senior Administrative Officer (w.e.f. 03.07.2019)
Shri. P. Krishnakumaran	:	Finance and Accounts Officer

Personnel

HEADQUARTERS, Thiruvananthapuram	
Director	**Dr. Archana Mukherjee** (Rtd. 31.10.2019)
Director (Acting)	**Dr. V. Ravi** (w.e.f. 01.11.2019)
AICRP on Tuber Crops	
Dr. James George (Rtd. on 31.01.2019)	Principal Scientist & Project Coordinator
Dr. S. Sunitha	Principal Scientist
Dr. Suresh Kumar J.	Scientist
Division of Crop Improvement	
Dr. M. N. Sheela	Principal Scientist & Head (i/c)
Dr. P. Murugesan	Principal Scientist
Dr. 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. K. Sunil Kumar (w.e.f. 23.08.2019)	Principal Scientist
Dr. V. Ramesh	Principal Scientist
Dr. R. Muthuraj	Principal Scientist
Dr. Sanket J. More	Scientist
Division of Crop Protection	
Dr. C.A. Jayaprakas	Principal Scientist & Head (Acting)
Dr. M.L. Jeeva	Principal Scientist
Dr. S.S.Veena	Principal Scientist
Dr. T. Makeshkumar	Principal Scientist
Dr. E.R. Harish	Scientist
Dr. H. Kesava Kumar	Scientist
Dr. B.G. Sangeetha	Scientist
Dr. Sirisha Tadigiri	Scientist
Shri. R. Arutselvan	Scientist
Division of Crop Utilization	
Dr. M.S. Sajeev	Principal Scientist & Head (i/c)
Dr. A.N. Jyothi	Principal Scientist
Dr. Saravanan Raju	Senior Scientist
Dr. Namrata Ankush Giri	Scientist
Ms. Pradeepika Chintha	Scientist
Dr. T. Krishnakumar	Scientist
Section of Extension and Social Sciences	
Dr. Sheela Immanuel	Principal Scientist & Head (i/c)
Dr. T. Srinivas (upto 30.11.2019)	Principal Scientist
Dr. J. Sreekumar	Principal Scientist
Dr. V.S. Santhosh Mithra	Principal Scientist
Dr. P. Sethuraman Sivakumar	Principal Scientist
Dr. D. Jaganathan	Scientist
Dr. P. Prakash	Scientist
Library/PME Unit	
Shri. R. Bharathan	Chief Technical Officer
Smt. T.K. Sudhalatha	Assistant Chief Technical Officer
Shri. V.S. Sreekumar	Senior Technical Officer
Smt. B.S. Deepa	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. I. Puviyarasan	Assistant Chief Technical Officer
Shri. M. Kuriakose	Assistant Chief Technical Officer
Shri. C.S. Salimon	Assistant Chief Technical Officer
Shri. V.R. Sasankan	Senior Technical Officer
Shri. B. Renjith Kishor	Senior Technical Officer
Shri. V. Ganesh	Technical Officer
Shri. Patric M. Mascrene	Technical Officer
Shri. S. Natarajan	Technical Officer
Shri. A.S. Manikuttan Nair	Technical Officer
Shri. G. Suresh	Senior Technical Assistant
Dr. S. Shanavas	Senior Technical Assistant
Shri. B.S. Prakash Krishnan	Senior Technical Assistant
Shri. G. Shajikumar	Senior Technical Assistant
Shri. L. Luke Armstrong	Technical Assistant
Dr. S. Karthikeyan	Technical Assistant
Smt. K. Pallavi Nair (upto 10.06.2019)	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. Abhishek Rana (upto 02.07.2019)	Senior Administrative Officer
Shri. Ramdeen (w.e.f. 03.07.2019)	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. J. Unni (Deputation w.e.f. 21.11.2019)	Assistant

Shri. K. Unnikrishnan Nair	Assistant
Shri. S. Hareendrakumar	Assistant
Shri. Arjun Murali	Assistant
Shri. S. Sreekumar	Assistant
Smt. V. Sathyabhama	U. D. C. (promoted to Assistant w.e.f. 24.12.2019)
Shri. O.C. Ayyappan	U. D. C.
Shri. R.S. Adarsh	U. D. C.
Shri. C. Chandru	L. D. C. (promoted to U.D.C. w.e.f. 05.10.2019)
Shri. N. Jayachandran	L. D. C.
Smt. C.G. Chandra Bindu	L. D. C.
Canteen Staff	
Shri. S. Radhakrishnan Nair	Skilled Support Staff
Skilled Support Staff	
Smt. S. Ushakumari	Skilled Support Staff
Shri. P. Udayakumar	Skilled Support Staff
Shri. K. Saratchandra Kumar	Skilled Support Staff
Shri. G. Madhu	Skilled Support Staff
Shri. A. Chandran	Skilled Support Staff
Smt. C.T. Chellamma (Rtd. on 30.04.2019)	Skilled Support Staff
Smt. M. Syamala	Skilled Support Staff
Shri. T. Lawrence	Skilled Support Staff
Shri. K. Sivadas	Skilled Support Staff
Smt. J. Thenmozhi (Rtd. on 31.03.2019)	Skilled Support Staff
Shri. L. Samynathan	Skilled Support Staff
Shri. S. Sreekumaran	Skilled Support Staff
Shri. K. Chandran	Skilled Support Staff
Ms. Rohini K. Nair	Skilled Support Staff (promoted to L.D.C. w.e.f. 24.12.2019)
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. D. Arunraj	Skilled Support Staff (promoted to L.D.C. w.e.f. 26.12.2019)
Shri. Sreenath Vijay	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

REGIONAL CENTRE, Bhubaneswar	
Scientific Staff	
Dr. M. Nedunchezhiyan	Principal Scientist & Head (i/c)
Dr. K. Laxminarayana	Principal Scientist
Dr. Kalidas Pati	Scientist
Dr. Vijay Bahadur Singh Chauhan	Scientist
Shri. Venkatraman V. Bansode	Scientist
Shri. K. Hanume Gowda	Scientist
Field / Farm / Lab. Technical Staff	
Shri. N.C. Jena	Technical Officer
Shri. Pramod Kumar Mati	Technical Officer
Shri. Bibhuti Bhusan Das	Technical Officer
Shri. Bharat Kumar Sahoo	Senior Technical Assistant (promoted to Technical Officer w.e.f. 04.04.2019)
Shri. Sushanta Kumar Jata	Senior Technical Assistant
Shri. Raja K.	Technical Assistant
Shri. Keshab Paikaray	Senior Technician
Administration and Accounts	
Shri. P. K. Acharya	Private Secretary
Shri. A. Lakshmana Rao	Assistant
Skilled Support Staff	
Shri. Akshayakumar Nayak (Rtd. on 28.02.2019)	Skilled Support Staff
Shri. Purna Samal	Skilled Support Staff
Shri. Bhajaman Malik (Rtd. on 31.08.2019)	Skilled Support Staff
Shri. Sauri Pradhan	Skilled Support Staff
Shri. Ramesh Nayak (Rtd. on 31.03.2019)	Skilled Support Staff
Shri. Babuli Sethi	Skilled Support Staff
Shri. Fakir Charan Bhoi	Skilled Support Staff
Shri. Samsuddin Khan	Skilled Support Staff
Shri. Prakash Kumar Nayak	Skilled Support Staff

OTHER INFORMATION

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

The ICAR-CTCRI in collaboration with Madurai Agri-Business Incubation Forum of NABARD, Madurai, organised a 'Field day-cum-Agripreneur Meet on Chinese Potato' at Alvan Thulukapatti, Ambasamudram, Tirunelveli District, Tamil Nadu on 11 January 2019. Dr. V. Ravi, Head, Division of Crop Production presided over the event in the presence of Dr. Sheela Immanuel, Head, Extension and Social Sciences, Dr. R. Muthuraj and Dr. P. Sethuraman Sivakumar, Principal Scientists and Dr. D. Jaganathan, Scientist as well as Smt. S. Subavasugi, Assistant Director (Horticulture), Pappakudi. During the meeting, the farmers were imparted training on scientific cultivation and quality seed production of Chinese potato. The farmers were also taken to the sites of Frontline Demonstrations of Sree Dhara and were explained about the superiority of Sree Dhara over local varieties. About 100 farmers and entrepreneurs from various villages of Ambasamudram participated in the event.

Field day on Chinese potato at Alvan Thulukapatti

National Productivity Week Celebrations

The National Productivity week 2019 was celebrated during 12-18 February 2019, by ICAR-CTCRI, Sreekariyam. The theme for the National Productivity week was 'Circular economy for productivity and Sustainability'. A 'Slogan' writing competition was organized on the theme. Dr. Archana Mukherjee, Director, ICAR-CTCRI delivered the key note address where she requested the staff and students to make circular economy a part of our day-to-day life. Dr. V. Ravi, HoD, Crop Production, gave his special remarks on the theme. He also stressed the need for circular economy in our daily life. The director gave away the prizes to the best selected entries of the 'Slogan competition'. Many students from nearby schools also attended.

National Productivity Week Celebrations 2019

National Science Day Celebrations (NSD-2019) with Students

The National Science Day (NSD) Celebrations 2019 was organized by ICAR-CTCRI during 19-22 February 2019. The programme was co-sponsored by Kerala State Council for Science, Technology and Environment and supported by Department of Science & Technology, Government of India. Dr. Shirly Raichal Anil, Principal Scientist was the Programme Co-ordinator and Dr. V. Ramesh, Principal Scientist was the General Convenor of the NSD-2019 Celebrations at ICAR-CTCRI. 'Communicating Science for All' was the theme for the National Science Day. The NSD celebration was inaugurated on 19 February 2019. Sixty students from two schools in Thiruvananthapuram namely, The School of the Good Shepherd and the Loyola School were present. Two students from each of these schools delivered talk on the theme.

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

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

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

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

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

PM-KISAN launch through video conference at ICAR-CTCRI

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

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

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

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

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

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

International Women's Day Celebrations 2019

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

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

the achievements of ICAR-CTCRI over the last 55 years. The Chief Guest of the programme was Smt. Shardha Sampath, Chief Post Master General, Kerala Circle. She stated that women empowerment should be made evident in all spheres of life. Two senior lady staff members of the Institute, who were due to retire were honoured during the occasion for their meritorious service to the Institute. Various competitions were also conducted and the prizes for the winners were given away by the Chief Guest. Dr. B.G. Sangeetha, Scientist proposed the vote of thanks.

International Women's Day celebrations

Institute Management Committee (IMC) Meeting

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

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

15.	Shri. P.C. Noble, Assistant Administrative Officer, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
16.	Shri. T. Vijayakumara Kurup, Assistant Administrative Officer, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
17.	Shri. Abhishek Rana, Senior Administrative Officer, ICAR-CTCRI, Thiruvananthapuram	Member Secretary

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

Workshop on Intellectual Property Valuation of Agricultural Technologies

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

Participants of the workshop

45th Meeting of Annual Institute Research Council

The 45th meeting of the Annual Institute Research Council of ICAR-CTCRI was held during 4-6 April 2019 under the chairmanship of Dr. Archana Mukherjee, Director. In her remarks, Director emphasized the need for reorienting the R & D activities to generate more technologies which would help the farming communities. She also insisted upon the need for commercializing the technologies generated at ICAR-CTCRI to generate resources for the Institute. Ten ongoing Institute projects, covering 56 activities was presented by the principal investigators. The projects were thoroughly discussed and the suggestions were recorded and documented in the proceedings. In her concluding remarks, the Director expressed happiness in the successful conduct of the meeting and thanked all the external experts' viz., Dr. S.G. Nair, Dr. Ashalatha S. Nair, Dr. C.S. Ravindran, Dr. M.S. Palaniswami, Dr. K. Umamaheswaran, Dr. S.K. Nanda, Dr. S.N. Moorthy, Dr. M. Anantharaman and Dr. N. Kishore Kumar

Inaugural address by Director, ICAR-CTCRI

Dr. Archana Mukherjee, Director addressing the gathering

for accepting the invitation and providing valuable inputs for improving the research projects.

19th Annual Group Meeting of the All India Coordinated Research Project on Tuber Crops

The 19th Annual Group Meeting of ICAR-All India Coordinated Research Project on Tuber Crops (ICAR-AICRP TC) was held at ICAR-CTCRI, Thiruvananthapuram during 13-15 June 2019. The meeting was inaugurated by Dr. T. Janakiram, Hon'ble ADG (HS-I), ICAR, New Delhi. The meeting was presided over by Dr. Archana Mukherjee, Director and Project Coordinator, ICAR-CTCRI. ADG in his inaugural address emphasized the importance of developing technologies for doubling farmers income, farm mechanisation, micro irrigation and focus on production of disease free quality planting material and nutrient use efficient varieties of tuber crops. He also highlighted exploring the use of artificial intelligence, ICT, drones and sensor technologies wherever possible. Scientists from 21 AICRP TC centres spread across 18 states and one union territory (A & N Islands) participated in the meeting. The AICRP centre functioning at Navsari Agricultural University (NAU), Gujarat bagged the best centre award for the year 2018-19. A CD on fifty years achievements by AICRP centre at Dr. Rajendra Prasad Central Agricultural University, Dholi and few other publications were released on the occasion. Dr. M.N. Sheela, Head, Division of Crop Improvement and PI, AICRP centre, Thiruvananthapuram welcomed the gathering and Dr. S. Sunitha, Principal Scientist, PC unit proposed the vote of thanks.

Best Centre Award 2018-19 being presented to Navsari Agricultural University, Gujarat

H.H. Sree Visakham Thirunal Endowment Lecture-2019

The Indian Society for Root Crops (ISRC) and ICAR-CTCRI jointly conducted the 10th H.H. Sree Visakham Thirunal Endowment Lecture on 15 June 2019 to commemorate the great visionary, the Maharaja of the erstwhile state of Travancore, Sree Visakham Thirunal Rama Varma. Dr. M.N. Sheela, Secretary, ISRC welcomed the gathering. The event was presided over by Dr. Archana Mukherjee, Director, ICAR-CTCRI and President, ISRC. The function was inaugurated by Dr. A.K. Singh, Hon'ble DDG (HS & CS), ICAR, New Delhi. Hon'ble Prince Aditya Varma, Kowdiar Palace, Thiruvananthapuram who has keen interest in agriculture and farming was the guest of honour. The endowment lecture was delivered by Padma Bhushan Dr. B.N. Suresh, Professor & Hon'ble Chancellor, Indian Institute of Space Science and Technology. In his lecture, he deliberated how space science can modernize agricultural technologies to improve the productivity and doubling of farmers' income. Dr. V.P. Singh, South East Asian Representative of CIAT, New Delhi, Dr. N.K. Krishna Kumar, Former DDG (ICAR) & Representative of Bioversity International, New Delhi and Dr. T. Janakiram, ADG (HS-1) addressed the gathering. Scientists from 21 different AICRP-TC centres spread across 18 states and 1 union territory of the country were special invitees for the function. The meeting concluded with the vote of thanks by Dr. J. Sreekumar, Vice-President, ISRC.

Inaugural event of the 10th H.H. Sree Visakham Thirunal Endowment Lecture

Seminar on Improved Technologies of Tuber Crops with Special Reference to Fertilizer Best Management Practices

Seminar on 'Improved Technologies of Tuber Crops with Special Reference to Fertilizer Best Management Practices' was organized on 27 June 2019 at Krishi Bhavan, Aliparamba, Malappuram.

Dr. G. Byju, Principal Scientist and Dr. D. Jaganathan, Scientist, ICAR-CTCRI, Agricultural Officer, Krishi Bhavan and officials from M/S Linga Chemicals, Madurai, Tamil Nadu were the resource persons for the seminar. An exhibition was also organized for the benefit of more than 120 farmers and other stakeholders.

Seminar at Aliparamba, Malappuram

Foundation Day Celebrations 2019

The 56th Foundation Day of ICAR-CTCRI was celebrated on 27 July 2019. Shri. Justice (Retd.) P. Sathasivam, Honourable Governor of Kerala was the Chief Guest of the function and inaugurated the Foundation Day. He also inaugurated the Farmers Facilitation Centre and Roof Top Solar Project in the campus. A publication titled 'ICAR-CTCRI a look at its journey' was released and Best Employee Awards were presented by the Hon'ble Governor. In his inaugural address, he emphasized the important role agriculture plays in ensuring food and nutritional security. He appraised the importance of integrating roots and tubers for sustainable livelihoods under the scenario of global climate change. He urged the scientific community to offer significant long-lasting solutions for the farmers to bank upon and exhorted to reduce the 'distance' between policies and scientific research to ensure better access to benefits and research outputs for the farmer. Hon'ble Governor also stressed upon the need for 'credible technologies' to ensure better health, wealth and inclusive growth for farmers. Dr. Trilochan Mohapatra, Secretary, DARE & Director General, ICAR presided over the function. In his presidential address he reiterated the urgent need for doubling the farmers income (DFI) by 2022, the flagship programme of Govt. of India. He also informed that greater emphasis should be given on biofortification of crops to improve the nutritional quality. The ICAR has released 35 biofortified varieties, including two varieties of sweet potato, Bhu Sona and Bhu Krishna, enriched with beta carotene and anthocyanin, respectively. Dr. Anand Kumar Singh, Deputy Director General (Horticulture Science), ICAR, New Delhi, offered the special address. He highlighted that tuber crops contributed 6% of the total vegetable production of the country and that research should focus on development of biofortified varieties, technologies for DFI and strategies to combat malnutrition and poverty. Dr. Archana Mukherjee, Director, ICAR-CTCRI delivered the welcome address and Dr. V. Ravi, Principal Scientist & Head, Division of Crop Production proposed the vote of thanks.

Inauguration of Foundation Day at ICAR-CTCRI by the Hon'ble Governor of Kerala

Inauguration of Roof Top Solar Project at ICAR-CTCRI by the Hon'ble Governor of Kerala

The exchange of MoUs between the Start-up entrepreneurs and ICAR-CTCRI and honouring of the Start-up entrepreneurs were the other highlights of the programme. Exhibition stalls showcasing the various activities of ICAR Institutes in Kerala were also arranged during the occasion. About 75 farmers participated in the Foundation Day Celebrations and visited the research laboratories, fields and interacted with the scientists of ICAR-CTCRI and other ICAR Institutes in Kerala.

Seminar on Improved Technologies of Horticultural Crops with Special Reference to Tuber Crops

The Institute organised a one day seminar on 'Improved Technologies of Horticultural Crops with Special Reference to Tuber Crops' at Ryali, Atreyapuram Mandal in East Godavari District of Andhra Pradesh on 01 August 2019, in collaboration with Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh. Dr. B.V.K. Bhagwan, Head, HRS, Dr. YSR Horticultural University, Kovvur inaugurated the seminar and released two technical leaflets about 'Agrotechniques of tuber crops' in Telugu and English. Soil health cards were distributed to the farmers. Dr. G. Byju, Principal Scientist, ICAR-CTCRI presided over the inaugural session. Classes on different topics related to the region were taken by Dr. G. Ramanandam, Head and Dr. N.B.V. Chalapathi Rao, HRS, Dr. YSR Horticultural University, Ambajipeta; Dr. K. Ravindra Kumar, HRS, Kovvur; Dr. D. Jaganathan and Dr. A.V.V. Koundinya, Scientists, ICAR-CTCRI; Mr. R. Devanand Kumar, Asst. Dir. (Hort), Amalapuram; Mr. P.B.S. Amarnath, Hort. Officer, Kothapetta and Mrs. M. Babitha, Hort. Officer, Inavilli. Officials from Mondelez International and Aries Agro Pvt. Ltd. also attended the meeting. About 120 farmers participated in the one-day seminar. East Godavari district is famous for elephant foot yam, yam and cassava cultivation. High yielding varieties, agrotechniques, crop protection measures and scope for value addition were discussed.

Seminar at Ryali, East Godavari, Andhra Pradesh

Entrepreneurship Development Programme for Agricultural Students

The IPTMU & PSC of ICAR-CTCRI and Section of Extension and Social Sciences organised an 'Entrepreneurship Development Programme for

EDP programme for B.Sc. Agri students of College of Agriculture, Vellayani

Agricultural Students' in collaboration with College of Agriculture, Vellayani, Kerala Agricultural University during 4-7 September 2019. The event was the fifth edition of the ICAR-CTCRI & KAU Collaborative EDP, and about 110 B.Sc. (Ag.) students of College of Agriculture, Vellayani participated in the programme.

38th Feed The Future–India Triangular Training programme

The International Training programme on 'Integrated Technology for Production, Processing and Value Addition in Tuber Crops' under the 38th Feed The Future - India Triangular Training Programme was held at ICAR-Central Tuber Crops Research Institute during 16-30 September 2019. The training programme was inaugurated on 17 September 2019. Dr. V. Ravi, Principal Scientist & Head, Division of Crop Production & Programme Coordinator of FTF-ITT at ICAR-CTCRI delivered the welcome address. Dr. Goldi Tewari, Programme Manager presented an overview of FTF-ITT programme. Twenty nine participants from 11 countries viz., Malawi, Kenya, Mozambique, Uganda, Botswana, Liberia, Sri Lanka, Nepal, Myanmar, Combodia and Afghanistan attended the training.

Dr. Archana Mukherjee, Director, ICAR-CTCRI delivered the presidential cum inaugural address and released the study material. Dr. Sheela Immanuel, Head, Extension and Social Sciences delivered the vote of thanks. Thirty three theory classes on tuber crops production technologies, and value addition were taken for the trainees. The valedictory function was held on 30 September 2019. Mr. Keith E. Simmons, Mission Director, USAID, India; Smt. V. Usha Rani IAS, Director General, MANAGE; Mr. Mustafa and Mr. Vamshi Reddy, invitees of US Aid-India, New Delhi were the special guests. Certificates were distributed to the trainees including special appreciation certificates for various meritorious performances. Mr. Keith E. Simmons, Mission Director, USAID India, the Chief Guest delivered the keynote address.

Executives who participated in the 38th FTF-ITT programme

Regional Workshop on 'Enriching Custodian Farmers with PPV&FR Act to Safeguard Valued Plant Genetic Resources Towards Green Prosperity'

ICAR-CTCRI hosted the PPV&FRA sponsored Regional Workshop on 'Enriching Custodian Farmers with PPV&FR Act to Safeguard Valued Plant Genetic Resources Towards Green Prosperity' during 10-11 October 2019. Dignitaries from PPV&FR authority, New Delhi, Resource personnel from various ICAR institutions, Kerala Agricultural University and Kerala state Government participated in the workshop. The aim of this workshop was to sensitize farmers about the importance of conservation of crop diversity and to create awareness among the farmers about their rights as per the Protection of Plant Varieties and Farmers Rights Act of Government of India. Dr. M.N. Sheela, Nodal Officer, DUS Centre, ICAR-CTCRI welcomed the guests. Dr. Archana Mukherjee, Director, ICAR-CTCRI delivered the presidential address. The workshop was inaugurated by Dr. R.C. Agrawal, Registrar General, PPV&FRA. He narrated the different activities of PPV&FRA and its role on protection of farmers varieties. Dr. Ravi Prakash, Registrar, PPV&FRA delivered the special address. Two hundred and ninety farmers from Karnataka and Kerala attended the workshop. Five government Institutions and nineteen farmers participated in the exhibition. A wide array of variability of tuber crops, vegetables and spices were displayed. Dr. Ravi Prakash led the technical session on Registration of farmers varieties. Technical bulletin on PPVFRA act and registration of farmer's varieties in Kannada & Malayalam languages were released. A Panel Discussion and interaction with farmers ensued lead by Dr. M.N. Sheela, ICAR-CTCRI, Dr. V.G. Jayalakshmi, Professor (Research co-ordination & Head, Seeds Division, Kerala Agricultural University and Dr. K. Pradeep, Principal Scientist, ICAR-NBPGR. The plant genome savoir awardees viz., Joida community representatives; Sri. N.M. Shaji, Wayanad and Shri R. Raveendran, Pongummood were felicitated during the workshop.

Release of Technical bulletin

Guests with the Plant Genome Saviour awardees

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-Central Tuber Crops Research Institute (ICAR-CTCRI) and AICRP TC for the period 01.04.2014 to 31.03.2019. The QRT team comprised of experts in different fields 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 Chairman and Director of ICAR-CTCRI had a preliminary discussion with Deputy Director General (Horticulture Science) at New Delhi on 17 July 2019 and the composition of the team was finalized by the Subject Matter Division. The visits of QRT to ICAR-CTCRI, Thiruvananthapuram, Kerala; Regional Centre of ICAR-CTCRI, Bhubaneshwar, Odisha and coordinating centres of AICRP Tuber Crops were started from 15 October 2019. The team visited ICAR-CTCRI, Thiruvananthapuram, Kerala; Regional Centre of ICAR-CTCRI, Bhubaneswar, Odisha and AICRP Tuber Crops Centres at NAU, Navsari, Gujarat; SKLTSHU, Rajendranagar, Hyderabad, Telangana; Dr. YSR Horticultural University, Horticultural Research Stations (HRS) at Kovvur and Peddapuram, Andhra Pradesh; Regional Centre of ICAR-CTCRI, Bhubaneswar, Odisha and AAU, Jorhat, Assam. The team also interacted with various other stakeholders in six meetings organized at Hyderabad, Kovvur, Peddapuram, Bhubaneswar, Jorhat and Thiruvananthapuram. In addition, one Workshop on 'Current status, problems and future prospects of tuber crops in North East region' was also organized at Assam Agricultural University, Jorhat, Assam.

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 integrated for the preparation of the QRT report.

QRT meeting at ICAR- CTCRI, Thiruvananthapuram

QRT meeting at RC, ICAR-CTCRI, Bhubaneswar

Stakeholders Interface meet on Performance Evaluation to Maximize Farmer's Income, Better Livelihood with Tuber Crops and Allied Technological Interventions

Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar organized a Stakeholders Interface meet on 'Performance Evaluation to Maximize Farmer's Income, Better Livelihood with Tuber Crops and Allied Technological Intervention' on 19 October 2019. Dr. Trilochan Mohapatra, Secretary, DARE and DG, ICAR, Govt. of India inaugurated the programme. He emphasized the importance of tuber crops for food and nutritional security of Odisha and other parts of India. He also enlightened about the production of quality planting materials, scientific production technologies, value added products of different tuber crops. Dr. Archana Mukherjee, Director, ICAR-CTCRI, Thiruvananthapuram, Kerala highlighted about value added products developed from different tuber crops particularly biofortified β-carotene rich orange flesh and anthocyanin rich purple flesh sweet potato varieties. Dr. M. Nedunchezhiyan, Head (I/C) of Regional Centre, ICAR-CTCRI, Bhubaneswar, Odisha stressed on the importance of integrated farming system for doubling farmers income and different technological intervention for scientific production technology of tuber crops.

Dr. D.P. Ray, Former Vice Chancellor, OUAT, Bhubaneswar, Odisha, Dr. S.K. Ambast, Director, ICAR-IIWM, Bhubaneswar, Dr. K. Srivastava. Director (A), ICAR-CIWA, Bhubaneswar, Dr. Bindu R. Pillai, Director (A), ICAR-CIFA, Bhubaneswar and Dr. Gobind Acharya, Head (I/C), CHES (ICAR-IIHR) briefed about the importance of tuber crops in changing climatic conditions and role of tuber crops towards doubling farmers income in Odisha and other parts of India. Scientists from ICAR-CTCRI Regional Centre, ICAR-NRRI, ICAR-IIWM, ICAR-CIWA and CHES-ICAR-IIHR were also present in the programme. Around 100 farmers from different districts of Odisha participated in the programme.

Stakeholders interface meet at Bhubaneswar

Vigilance Awareness Week

The Institute observed the Vigilance Awareness Week 2019 during 28 October - 02 November 2019 as per the directive of the Central Vigilance Commission and in pursuance of the said directive issued by the Indian Council of Agricultural Research, New Delhi. The theme chosen for the Vigilance Awareness Week was 'Integrity - A way of Life'. Dr. Archana Mukherjee, Director administered the 'Integrity Pledge' to all the staff of the Institute on 28 October 2019. Staff and students participated in creative activities like poster making competition and elocution competition to create awareness amongst all the sections of employees. The programme was inaugurated by Shri. Loknath Behera, IPS, The Police Chief and DGP,

Inaugural address by Shri. Loknath Behera, IPS, The Police Chief and DGP, Govt. of Kerala

Govt. of Kerala on 30 October 2019. Dr. Archana Mukherjee, Director, presided over the function, Dr. J. Sreekumar, Principal Scientist & Vigilance Officer, ICAR-CTCRI welcomed the gathering and the meeting was concluded with the vote of thanks by Dr. C. Visalakshi Chandra, Scientist.

Model Training Course on Organic Farming (MTC 2019)

A Model Training Course (MTC-2019) entitled 'Organic Farming for Safe and Sustainable Food Production with Special Focus on Tropical Tuber Crops' was conducted for eight days during 1-8 November 2019 at ICAR-Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram. The training was sponsored by the Directorate of Extension, Ministry of Agriculture & Farmer's Welfare, Govt. of India. Twenty two participants, mostly Agricultural / Horticultural officers / Assistant Directors of Agriculture / Horticulture and Scientists from KVKs, from eight states of India, viz., Chhattisgarh, Kerala, Karnataka, Madhya Pradesh, Maharashtra, New Delhi, Odisha and Tamil Nadu attended the training. The main aim was to impart training on the latest advances in organic farming of major food and horticultural crops and novel techniques for safe, sustainable and environmentally benign food production, which would ultimately help in the growth of the organic sector. The Course Director of MTC was Dr. G. Suja, Principal Scientist, Division of Crop Production and Course Co-ordinators were Dr. V. Ramesh, Principal Scientist, Division of Crop Production and Dr. D. Jaganathan, Scientist, Section of Extension & Social Sciences, ICAR-CTCRI. A total of 35 sessions (23 theory and 12 practicals) were handled by 21 resource persons (12 in-house and 9 guest faculties). The training helped a great deal to enhance the knowledge and skills of the participants in organic farming.

Collaborative training on Innovative Extension Approaches

ICAR-CTCRI and MANAGE Collaborative National training on 'Innovative Extension Approaches for Horticultural Crops with Special Reference to Tuber Crops' was organised during 19-22 November 2019. The participants were imparted basic and advanced skills on different innovative extension approaches. Dr. G.S. Unnikrishnan, Director, SAMETI, Govt. of Kerala was the Chief Guest for the inaugural session. Eminent resource persons, Dr. C. Bhaskaran, Former Head, College of Agriculture, Vellayani, Dr. M. Anantharaman, Former Head, Extension & Social Sciences, ICAR-CTCRI, Scientists from other ICAR Institutes and Institute faculty handled the classes.

Inaugural session of ICAR-CTCRI and MANAGE Collaborative National training

Participants of MTC on organic farming with faculty of ICAR-CTCRI

A total of 25 participants attended the four days programme.

World Soil Day 2019

World Soil Day 2019 was conducted at ICAR-CTCRI on 5 December 2019. The World Soil Day pledge in English and Malayalam was administered. Professor (Dr.) K.N. Harilal, Member, Kerala State Planning Board was the Chief guest of the function and he delivered the keynote address focussing on the 'Significance of soil in the well being of the Universe as whole'. Dr. V.K. Venugopal, Former Professor and Head, Department of Soil Science and Agricultural Chemistry, Kerala Agricultural University delivered the lecture befitting to the theme of the year World Soil Day 'Stop pollution, save future life'. The function was attended by farmers of Pothencode, Sreekariyam, Kazhakottom Panchayats, students of Loyola School and Bethlehem English Medium School, Sreekariyam and PG students of the Department of Environmental Science, Kerala University. Soil health cards were distributed to the farmers of Pothencode Panchayat. The function was presided by Dr. V. Ravi, Director (A), ICAR-CTCRI, welcomed by Dr. (Mrs.) Susan John, K., Principal Scientist & Nodal Officer of the Soil Health Card Programme and Dr. V. Ramesh, Principal Scientist proposed vote of thanks.

Inaugural event of the World Soil Day 2019

Tuber Crops Day 2019

The ICAR-Central Tuber Crops Research Institute (CTCRI), Kerala and the ICAR-Indian Society for Root Crops (ISRC), jointly celebrated the 'Tuber Crops Day' on 10 December 2019. The Chief Guest, Shri. J. Sajeev, Managing Director, Horticorp, Government of Kerala emphasized on the importance of tuber crops in food security. He stressed that tuber crops are safe foods in the present day. Shri. Sajeev stated that the country is moving towards traditional foods and hence, tuber crops are in the phase of reinvention. He also assured that the Horticulture Corporation can support in marketing of excess tuber crops produced by the farmers.

Dr. V. Ravi, Director (A), ICAR-CTCRI briefed about the Institute's achievements. He highlighted about the nutritional values and climate resilience nature of these crops. He underlined the Rashtriya Krishi Vikas Yojana project's socio economic impact on the tribal population's lives in Kerala. He also outlined the establishment of seed villages for meeting the demands of planting materials among the tuber crops farmers. Dr. J. Sreekumar, Principal Scientist & Vice-President, ICAR-ISRC in his welcome speech mentioned about the significance of the *Thrikarthika* Day. He also acknowledged the state Government of Kerala for recognizing the day as the 'Tuber Crops Day'. The progressive tuber crops farmers were also felicitated during the occasion. The Scientists briefed about the Institute's research activities and clarified the

Inauguration event of Tuber Crops Day 2019

Participants of the Tuber Crops Day 2019

doubts of the farmers during the Scientists'- Farmers' Interaction Session. Around 100 farmers, scientists and students participated in the programme.

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

The second meeting of RAC VIII was held during 16-17 December 2019 at ICAR-CTCRI, Thiruvananthapuram. The meeting was chaired by Dr. G. Kalloo, Former DDG (Hort. Sci.), ICAR. The team made an extensive field and laboratory visits. Dr. G. Suja, Member Secretary, welcomed the Chairman and members of RAC and all the Scientists. Dr. V. Ravi, Director (A), ICAR-CTCRI, made a presentation on Institute profile, significant research achievements and technologies developed, technologies commercialized, publications, infrastructure developed, equipments procured, planting material production, field level demonstrations / OFTs conducted and other general activities like MGMG, SHC and *Swachh Bharath*. Dr. S. Sunitha, Principal Scientist, Project Co-ordinator's Cell, AICRP on Tuber Crops also briefed about the activities and achievements of AICRP on tuber crops. The action taken report of the first meeting of RAC VIII was presented by the Member Secretary, which was discussed and approved. The project leaders presented the salient achievements of 10 ongoing Institute projects and 25 externally funded projects and the targets for 2019-20. Based on the presentations and discussions, RAC members emphasised the research focus in the following areas and also made few research advisory notes. They are germplasm mining for identification of genes for biotic and abiotic stress resistance and micronutrients/nutraceuticals using modern techniques such as genomics, breeding for nutrient use efficiency, pre-breeding may be employed for the development of genetic stocks for further use in breeding programme to introgress biotic (weevil resistance, CMD, anthracnose, collar rot, TLB, etc) and abiotic stress resistance (drought and salinity) and quality traits (starch, proteins, etc.), gene editing technologies such as CRISPR-CAS may be explored for starch modification in tuber crops, improvement of underutilized tuber crops and their role in nutritional sector, development of cropping system and farming system models for higher yields, precision farming and vertical farming studies, climate resilient tools in tuber crops in addition to other ongoing crop production programmes on soil, water, weeds etc. for adaptation and intervention in sustainable production of tuber crops. Etiology, epidemiology, biology and management of emerging diseases in cassava, elephant foot yam and taro, integrated management strategies for pests and diseases involving crop combinations, biological inputs and minimum use of chemicals, developing thermoplastic starch compositions for films and sheets into utility articles to substitute/replace conventional plastics and assessment of impact of ICAR-CTCRI technologies on the livelihood of tuber crop farmers.

The following members were present:

1. Dr. T. Janakiram, ADG (Hort. Sci.), ICAR
2. Dr. C. Devakumar, Former ADG (EP & D), ICAR
3. Dr. M. Anandaraj, Former Director, ICAR-IISR
4. Dr. S. Arulraj, Former Director, ICAR-IIOPR
5. Dr. S.K. Nanda, Former PC, AICRP on PHT, ICAR-CIPHET
6. Dr. P. Kalia, Emeritus Scientist & Former Head, ICAR-IARI

Research Advisory Committee meeting in progress

Members of the VIII RAC during field visit

7. Advocate Shri. Ranjit Sreenivas, Non-official member
8. Dr. Anil Vaidyamangalam, Non-official member
9. Dr. V. Ravi, Director, ICAR-CTCRI
10. Dr. G. Suja, Principal Scientist, ICAR-CTCRI (Member Secretary)

Library Corner

Library continued the information support services to the research and training activities of the Institute. In addition to the routine services, the major activities undertaken were:

Purchase of Publications for Research Purpose

The total budget allotted to the library was utilized for the purchase of books and magazines (Kerala Karshakan, Kheti and Phal-Phool, etc.)

In addition, the following services were also made available to the users of the library

1. **Circulation of books**: A total of 105 books were issued to the users on loan and it was recorded properly in the books issue register.
2. **CeRA:** As part of literature search, the staff and students of the Institute used jgateplus.com platform for downloading articles from CeRA.
3. **Ready-reference service**: Provided ready assistance and solutions to the user's various queries. These include enquiries in person or over the phone regarding any 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 1657 users availed the facility of reference services from the library.
4. **Reading and reference facilities to the research students within and outside the Institute**: Services were extended to the students from Colleges and University Departments, who undertook their B. Sc., M. Sc. and Ph. D. project works under the guidance of the Institute Scientists during 1-3 months to 3-5 years. They were given necessary guidance in the use of reference resources and photocopying facility.
5. **Photocopying:** Library continued to provide photocopying service to the Institute staff and other library users on official/payment basis. During this period, 20,345 copies were provided against their work indents, which included official copies and private copies.

Hindi Corner

Three Hindi Workshops were held during the year on 28 February 2019; 27 June 2019 and 23 November 2019 by the Official Language Implementation Committee (OLIC). The first workshop was conducted by Smt. P.A. Usha, Asst. Director(OL), All India Radio, Thiruvananthapuramon on the topic, 'Noting and drafting'. Second workshop was conducted by Shri. N. Samraj, Retd. Rajbhasha Adhikari, Southern Railway, Thiruvananthapuram on the topic, 'Official Language Policy/Noting, Drafting' and the third workshop was conducted by Shri. R. Jayapal, Senior Hindi Officer, IIST, Valiamala, Thiruvananthapuram on the topic 'Official Language Policy/Administrative Terminology.

Four OLIC meetings were also conducted during the period on 26 March 2019, 22 June 2019, 25 September 2019 and 21 December 2019. Various issues related to Official Language Implementation was discussed during these meetings.

The Hindi Fortnight 2019 was celebrated during 14-28 September 2019 where, various competitions were held for the staff and children. Thirty-nine participants actively participated and bagged various prizes, which was distributed during the valedictory function on 23 November 2019. Dr. V. Ravi, Director (A) and Chairman (OL), ICAR-CTCRI presided over the function and distributed prizes and certificates to the winners/participants and exhorted the staff to boost Hindi implementation work. Shri. R. Jayapal, Senior Hindi Officer, IIST, Valiamala, Thiruvananthapuram was the Chief Guest.

During the period, nine staff members enrolled for the 2018-19 course in Prabodh/Praveen Hindi correspondence course conducted by the Central Hindi Training Institute, New Delhi in which seven staff members viz., Dr. M.L. Jeeva, Dr. T. Makeshkumar, Dr. C. Mohan, Dr. Saravanan Raju, Dr. D. Jaganathan, Dr. H. Kesavakumar and Dr. T. Krishnakumar passed the Praveen examination and were awarded incentives and personal pay.

State of art of *Mera Gaon Mera Gaurav*

ICAR-CTCRI, Thiruvananthapuram and its Rregional Centre have implemented the MGMG initiative in collaboration with other stakeholders viz.,

Department of Agriculture, Krishi Vigyan Kendra, grama panchayat, input dealers, progressive farmers, SHGs, etc. During 2019, interface meetings, training programmes, demonstration on improved practices, farm advisory visits, mobile advisory services were organized in the selected villages for the benefit of farming community. A total of 45 scientists adopted 51 villages for the overall development of the villages through various programmes as given below.

Activities undertaken

S. No.	Name of the activity	No. of activities conducted	No. of farmers participated & benefitted
1	Visit to village by teams	40	1163
2	Interface meeting/ *Goshthies*	36	1170
3	Training organized	27	1420
4	Demonstrations conducted	27	27
5	Mobile based advisories	328	328
6	Literature support provided	71	660
7	Awareness created	32	1303
	Total	**561**	**6071**

General awareness created among the farmers in the MGMG villages were, use of fungicides for elephant foot yam disease, Use of *Menma, Nanma* and *Shreya* for the control pests in banana and sucking insects in vegetables, improved agro-techniques of tropical tuber crops, improved varieties and advanced nutrient management techniques in tuber crops, correction of soil acidity and balanced application of fertilizers based on soil test data, production technologies for cassava, sweet potato, and yams, collar rot management in elephant foot yam, post-harvest disease management in aroids, tuber crops processing and value addition, integrated pests & disease management in tropical tuber crops, SSNM of cassava, information regarding the methods and dosage of fertilizer and herbicide application, knowledge on new varieties of tuber crops and advances in nutrient management and selection of pest and disease free planting materials.

The major problems identified in the MGMG villages were, labour shortage, price fluctuations, climate change, nematode and secondary fungal infection in elephant foot yam, soil acidity and nutritional disorders, luxuriant weed growth under climate change, cassava mosaic disease in cassava, sweet potato weevil, pest and diseases, non availability of quality planting materials, banana pseudostem weevil, sooty mould in all crops, anthracnose in greater yam, fungal infection in elephant foot yam and lack of short duration cassava varieties, lack of irrigation facilities and nutritional deficiencies.

Linkages were created with ATMA, Thiruvananthapuram, Krishi Bhavan, Pothencode, Krishi Bhavan, Kazhakootam, VFPCK, KAU, Orissa University of Agriculture and Technology, Veterinary hospital, State horticulture department, KVK, Mitraniketan, Department of Veterinary and Animal Sciences, MATSYAFED, Thiruvananthapuram, Department of Fisheries and Panchayat Vikasana Samithi.

Farm Advisory visit

Diagnostic field visit

Planting material distribution in MGMG village

Training programme on Improved technologies of tuber crops

Swaccha Bharat Abhiyan

ICAR-CTCRI is dedicatedly involved in various activities related to 'Swaccha Bharat Mission', the nation-wide cleanliness programme conceptualised by the Hon'ble Prime Minister of India. Since its inception in 2014 at ICAR-CTCRI, various cleanliness initiatives has been implemented such as

- Swachh Bharat Abhiyan was conducted weekly on every saturday of the week for half an hour and all the staff members were instructed to clean their respective labs and sitting areas.
- On the last working day of every month, Swaccha Bharat Abhiyan was conducted for one hour during which all the staff members were involved in cleaning the campus as a whole.
- Attendance register was maintained to ensure presence of members.
- Dust bins 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, main road, processing complex, canteen and field.
- Plastics, bottles, papers etc were collected and destroyed completely by using incinerator.
- Old and broken items, furniture, glassware and plastic were replaced.

Swachhata Hi Seva-2019

ICAR-CTCRI was dedicatedly involved in various activities related to 'Swachhata hi Seva' campaign, from September 11 to 02 October 2019. The fortnightly Swachhata hi Seva-2019 campaign at ICAR-CTCRI, Thiruvananthapuram was inaugurated by Dr. Archana Mukherjee, Director during which, the Swachhata pledge was administered. To uphold and disseminate the message of swachhata campaign, awareness programmes were organised at Headquarters, Thiruvananthapuram and Regional Centre, Bhubaneswar. An awareness rally was conducted by the staff and students of ICAR-CTCRI in connection with Swachhata hi Seva 2019. Various competitions such as poster making, slogan writing and elocution competitions for staff, students and family members of staff were conducted to spread awareness on single use plastic ban and plastic free India. Cleanliness drive was conducted both within and outside the campus premises to create awareness to the public. The valedictory function was on 02 October 2019 and mass planting of trees was conducted. Dr. Archana Mukherjee, Director, ICAR-CTCRI presided over the programmes and distributed prizes to the winners of various competitions held in connection with Swachhata Hi Seva-2019.

Swachhata Pakhwada-2019

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) addressed the staff members of ICAR-CTCRI about the importance of observing Swachhata Pakhwada and also briefed on the activities to be carried out during 16 to 31 December 2019 in the Headquarters as well as at the Regional Centre. The Swachhata awareness banner was kept for display at the main entrance of the Institute and other prominent places for public view. In connection with Swachhata Pakhwada

Swachhata Hi seva team

Swachhata rally led by Dr. Archana Mukherjee, Director

Massive tree planting programme led by
Dr. Archana Mukherjee, Director

Painting competition for kids

Swachhata Hi Seva programme at RC,
ICAR-CTCRI, Bhubaneswar

2019, cleanliness drive was conducted to remove plastic wastes from both inside and outside of the Institute premises. All the staff of ICAR-CTCRI were involved in the cleaning and removal of plastic wastes from campus both at HQ and RC.

Swachhata Pledge being administered by
Dr. V. Ravi, Director (A)

Cleaning of premises

Dr. V. Ravi, Director leading the cleaning drive of premises

Field Level Demonstrations/OFTs Conducted

Demonstrations on improved varieties of cassava, sweet potato, taro and Chinese potato; Fertilizer best management practices in elephant foot yam and greater yam; Integrated management of mealybug in cassava using cassava based bio-formulations were established in Tamil Nadu, Kerala and Andhra Pradesh with 40 farmers for proving the technical feasibility and economic viability of the improved technologies. Farmers were trained to adopt scientific crop management practices. Pests and diseases viz., mealy bug, 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. V. Ravi, Dr. Sheela Immanuel, Dr. R. Muthuraj, Dr. P.S. Sivakumar and Dr. D. Jaganathan conducted farm advisory visits among farmers of Chinese potato in Tirunelveli district of Tamil Nadu during January 2019.
- Farm advisory visits among elephant foot yam growers were conducted by Dr. G. Byju, and Dr. D. Jaganathan in Ernakulam and Malappuram districts of Kerala during June 2019.
- Farm advisory visits among elephant foot yam growers were conducted by Dr. G. Byju, Dr. D. Jaganathan and Dr. A.V.V. Koundinya in East Godavari and West Godavari districts of Andhra Pradesh during April, August and November 2019.
- A team consists of Dr. R. Muthuraj, Dr. D. Jaganathan and Dr. H. Kesava Kumar conducted farm advisory visits among tuber crops growers of Kanyakumari district of Tamil Nadu during August 2019.
- Farm advisory visits among elephant foot yam and greater yam growers were conducted by Dr. G. Byju, Dr. G. Suja and Dr. D. Jaganathan in Kollam district of Kerala during October 2019.
- Diagnostic field visits were conducted by Dr. P.S. Sivakumar and Dr. R. Muthuraj to Chinese potato areas in Tirunelveli district of Tamil Nadu to identify the reasons for non-tuberisation of Chinese potato during December 2019.
- A team consists 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 December 2019.

Tirunelveli

Ernakulam

East Godavari

West Godavari

Kanyakumari

Kollam

Amboori, Thiruvananthapuram

Kuttichal, Thiruvananthapuram

Recreation Club Corner

The New Year was welcomed with a get-together of all club members. Republic day function on 26 January 2019 was also organized with great pomp and joy and after the message by the Director, the club members along with their family enjoyed breakfast arranged by the club. The Independence Day function was organized on 15 August 2019 by the recreation club of ICAR-CTCRI. Staff members who retired from ICAR-CTCRI service were also felicitated by the Recreation Club of ICAR CTCRI.

Participations in Exhibitions

ICAR-CTCRI participated in the following exhibitions for the benefit of stakeholders. Large number of farmers, college and school students, industrialists and other general public acquired knowledge on improved technologies of tuber crops.

- Karshika Mela during 31 December 2018 to 6 January 2019 at New Man College ground, Thodupuzha, Idukki, Kerala.
- Krushi Odisha organized by the Department of Agriculture & Farmers Empowerment, Government of Odisha during 15-19 January 2019 at Biju Patnaik Play Ground, Bhubaneswar, Odisha.
- World Conference on Brackishwater Aquaculture (BRAQCON 2019) during 22-25 January 2019 at ICAR-Central Institute of Brackishwater Aquaculture, Chennai, Tamil Nadu.
- National Horticultural Fair during 23-25 January 2019 at ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru.
- Exhibition in connection with Krishi Mela on 02 February 2019 at Berhampur, Chatrapur, Ganjam district, Odisha.
- National Conference on Farmers First for Conserving Soil and Water Resources in Eastern Region (FFCSWR-2019) during 06-08 February 2019 at Koraput, Odisha.
- Technology and Machinery Demonstration Mela 2019 during 15-16 February 2019 at Njarakkal, Kochi.
- Krishidham Expo during 15-17 February 2019 at ICAR-Central Potato Research Institute, Regional Station, Modipuram, Meerut, Uttar Pradesh.
- Exhibition in connection with Tribal Sub Plan Programme during 18-19 February 2019 at ICAR-CIFA, Bhubaneswar.
- Agriculture Exhibition on 26 February 2019 at ICAR-NRRI, Cuttack, Odisha.
- Exhibition in connection with Kanakolsavam 2019 during 5-15 April 2019 at Kanakakunnu palace, Thiruvananthapuram.
- Exhibition organized by AICRP on rice during 31 May-01 June 2019 at ICAR-NRRI, Cuttack.
- Exhibition in connection with seminar on Improved Technologies of Tuber Crops with Special Reference to Fertilizer Best Management Practices on 27 June 2019 at Krishibhavan, Aliparamba, Malappuram.
- Exhibition in connection with 56th Foundation Day Celebrations on 27 July 2019 of ICAR-CTCRI at ICAR-CTCRI, Sreekariyam, Thiruvananthapuram.
- Exhibition in connection with seminar on Improved Technologies of Horticultural Crops with Special Reference to Tuber Crops on 01 August 2019 at Ryali, East Godavari district of Andhra Pradesh.
- Exhibition in connection with Science Show-MCXIBAS 2019 during 20-24 August 2019 at Malankara Catholic College, Kaliakavilai, Kanyakumari district.
- Exhibition in connection with Regional Workshop on 'Enriching custodian farmers with PPV&FR Act to safeguard valued plant genetic resources towards green prosperity' during 10-11 October 2019 at ICAR-CTCRI, Thiruvananthapuram.
- Exhibition in connection with 10th Krishi Fair (A National level Agriculture Exhibition) from 21-25 October 2019 at Saradhabali, Puri.
- Exhibition in connection with Inauguration of Agri Business Incubator on 30 October 2019 at ICAR-CTCRI, Thiruvananthapuram.
- Exhibition on 06 December 2019 at ICAR-National Rice Research Institute, Cuttack.
- AGREX 2019: Agri–Horticultural Industrial Exhibition at SDV College ground, Alappuzha, Kerala during 21-23 December 2019.
- Karshikamela Exhibition at Newman College, Thodupuzha, Idukki, Kerala during 27 December 2019 to 01 January 2020.

National Horticultural Fair at Bengaluru

Krishidham Expo at Modipuram

Krishi Fair at Puri

Kanakolsavam at Thiruvananthapuram

वर्ष 2019 के दौरान इस संस्थान में की गयी राजभाषा कार्यान्वयन से सम्बन्धित कार्यक्रम

राजभाषा कार्यान्वयन समिति की बैठक का आयोजन

इस संस्थान की निदेशक महोदया, डॉ० अर्चना मुखर्जी की अध्यक्षता में, ता. 26.03.2019, ता. 22.06.2019, ता. 25.09.2019 और डॉ. वे. रवि (कार्यकारी) निदेशक की अध्यक्षता में, ता. 21.12.2019 को राजभाषा कार्यान्वयन समिति की बैठकों का आयोजन किया गया। इस अवसर पर राजभाषा कार्यान्वयन से संबंधित विभिन्न मुद्दों पर विचार–विमर्श किया गया। उसके आधार पर उक्त मुद्दों के अनुपालन किया जा रहा है।

हिन्दी कार्यशाला का आयोजन

क) केंद्र सरकार की राजभाषा नीति के अनुपालन में इस संस्थान के सभी कर्मचारियों केलिए ता. 28.2.2019 को "टिप्पण/आलेखन" पर एक दिन की हिन्दी कार्यशाला आयोजित किया गया। डॉ. अर्चना मुखर्जी, निदेशक और अध्यक्ष (राजभाषा), भा.कृ.अनु.प–केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनन्तपुरम ने अध्यक्षीय भाषण दिया। उन्होंने हिन्दी के महत्व पर प्रकाश डालते हुए समारोह का उद्घाटन किया। डॉ. ए. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) सभा का स्वागत किया। श्रीमती. पी. ए. उषा, सहायक निदेशक (राजभाषा), आकाशवाणी, तिरुवनंतपुरम "टिप्पण/आलेखन" पर क्लास ली। कुल 31 प्रतिभागियों कार्यशाला में भाग लिये।

ख) ता. 27.06.2019 को 'राजभाषा नीति/टिप्पण, आलेखन' पर एक दिन की हिन्दी कार्यशाला आयोजित किया गया। डॉ. वे. रवि, निदेशक (कार्यकारी), भा.कृ.अनु.प–केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनन्तपुरम ने अध्यक्षीय भाषण दिया। उन्होंने हिन्दी के महत्व पर प्रकाश डालते हुए समारोह का उद्घाटन किया। डॉ. ए. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभा का स्वागत किया, विशेष रूपसे श्री. एन. सामराज, सेवानिवृत्त राजभाषा अधिकारी, दक्षिण रेलवे, तिरुवनंतपुरम का स्वागत किया। श्री. एन. सामराज ने "राजभाषा नीति/टिप्पण, आलेखन" पर क्लास लिया। कुल 33 प्रतिभागियों ने कार्यशाला में भाग लिए। श्रीमती. टी. के. सुधालता, सहायक मुख्य तकनीकी अधिकारी (हिंदी) ने धन्यवाद प्रस्ताव पेश किया।

ब) ता. 23.11.2019 को "राजभाषा नीति/प्रशासनिक शब्दावली" पर एक दिन की हिन्दी कार्यशाला आयोजित किया गया। डॉ. वे. रवि, निदेशक (कार्यकारी), भा.कृ.अनु.प–केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनन्तपुरम ने अध्यक्षीय भाषण दिया। डॉ. ए. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभा का स्वागत किया। श्री. आर. जयपाल, वरिष्ठ हिन्दी अधिकारी, आई. आई. एस. टी., वलियमला, तिरुवनंतपुरम द्वारा क्लास लिया। कुल 34 प्रतिभागियों ने कार्यशाला में भाग लिए।

हिन्दी पखवाड़ा समारोह का आयोजन

ता. 14–28 सितम्बर 2019 को हिन्दी पखवाड़ा मनाया गया। इस संस्थान की स्टाफ और बच्चों के लिए विविध हिंदी प्रतियोगिताएं आयोजित की गई। 1. निबंध लेखन 2. अनुवाद 3. भाषण 4. कविता–पाठ 5. सुलेख 6. खुला मंच 7. अन्ताक्षरी 8. सिर्फ एक मिनट आदि प्रतियोगिताएं आयोजित की गई। ये निम्नलिखित 5 श्रेणियों केलिए आयोजन किया गया (वैज्ञानिक, तकनीकी/प्रशासनिक, कुशल सहायक कर्मचारी, अस्थायी कर्मचारी एवं बच्चों)। प्रतियोगिताओं में कुल 39 प्रतिभागियों ने भाग लिये।

हिन्दी पखवाड़ा का समापन समारोह/पुरस्कार वितरण ता. 23.11.2019 को आयोजित किया गया। डॉ. वे. रवि, निदेशक (कार्यकारी), भा.कृ.अनु.प–केंद्रीय कंद फसल अनुसंधान संस्थान, तिरुवनन्तपुरम, बैठक की अध्यक्षता की और हिंदी समारोह के संबंध में आयोजित विभिन्न प्रतियोगिताओं के विजेताओं को पुरस्कार/प्रमाण पत्र वितरण किये। श्री. आर. जयपाल, वरिष्ठ हिन्दी अधिकारी, आई. आई. एस. टी., वलियमला, तिरुवनंतपुरम, मुख्य अतिथि थे।

तिरुवनंतपुरम नगर राजभाषा कार्यान्वयन समिति के बैठकें

इस संस्थान के निदेशक और अध्यक्ष (राजभाषा), डॉ. अर्चना मुखर्जी, डॉ. ए. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) और श्रीमती. टी. के. सुधालता, सहायक मुख्य तकनीकी अधिकारी (हिंदी) तिरुवनंतपुरम नगर राजभाषा कार्यान्वयन समिति द्वारा आयोजित सभी बैठकों में भाग लिये।

प्रोत्साहन योजना

हिन्दी में काम करनेवाले कर्मचारियों को प्रोत्साहन योजना में नकद पुरस्कार दिये गये। इस वर्ष दो प्रतिभागियों को पुरस्कार दिये गये।

अन्य सार्वजनिक कार्यकलापें

इस संस्थान की सभी रबड़ की मोहरें, नाम पट्ट, साइन बोर्ड, फॉर्म, पत्रशीर्ष 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। प्रबोध/वीण पत्राचार पाठ्यक्रमों के तहत नामंकन किए गए 9 स्टाफ सदस्यों मई 2019 के दौरान आयोजित हिन्दी परीक्षा में भाग लिये। 7 स्टाफ सदस्यों ने परीक्षा पास किए और नकद पुरस्कार/वैयक्तिक वेतन आदि पुरस्कार प्राप्त किए।

IMPORTANT EVENTS AND ACHIEVEMENTS

Events

Events	Date
Refresher Training on 'Improved technologies of tuber crops' for Technical personnel of ICAR- CTCRI	08 to 10 January 2019
Field Day-cum-Agripreneur Meet on Chinese potato at Tirunelveli	11 January 2019
Enhancing Personal Efficiency in Job Performance for Skilled Support Staff of ICAR-CTCRI	04-06 February 2019
National Productivity Week Celebrations at ICAR-CTCRI, Thiruvananthapuram	12-18 February 2019
Pradhan Mantri Kisan SAmman Nidhi (PM-KISAN)-cum-Live Web Telecast	24 February 2019
Stakeholders Interface in connection with International Women's day	08 March 2019
Institute Management Committee Meeting	18 March 2019
Workshop on Intellectual Property Valuation of Agricultural Technologies	22 March 2019
45th meeting of the Annual Institute Research Council of ICAR-CTCRI	4-6 April 2019
The 19th Annual Group Meeting of ICAR-All India Coordinated Research Project on Tuber Crops	13-15 June 2019
10th H.H. Sree Visakham Thirunal Endowment Lecture	15 June 2019
56th Foundation Day of ICAR-CTCRI	27 July 2019
38th Feed The Future - India Triangular Training Programme	16-30 September 2019
Quinquennial Review Team meeting	15-16 October 2019
Vigilance Awareness Week 2019	28 October - 02 November 2019
Model Training Course on 'Organic Farming for Safe and Sustainable Food Production with Special Focus on Tropical Tuber Crops'	01-08 November 2019
ICAR-CTCRI and MANAGE Collaborative National training on 'Innovative Extension Approaches for Horticultural Crops with Special Reference to Tuber Crops'	19-22 November 2019
World Soil Day	05 December 2019
Tuber Crops Day	10 December 2019
Second Meeting of RAC VIII of ICAR-CTCRI	16-17 December 2019

Achievements

Particulars	Nos.
Institute projects	8
Flagship projects	2
External aided projects	25
Tuber crops germplasm maintained in the field gene bank	5651
Tuber crops varieties recommended for release	2
Technologies commercialized	3
External fund mobilised (₹ lakhs)	264.98
Revenue generated (₹ lakhs)	65.80
B. Sc. students guided	214
M. Sc. students guided	50
Ph. D. scholars guided	20
Ph. D. awarded	3
PDF guided	3
Farmers visited the Institute	1050
Students visited the Institute	2031
Officers visited the Institute	210
Trainings conducted	87
Institute staff members trained	73
Awards received	14
Publications in peer reviewed journals	56
Papers presented in conferences / seminars / symposia / workshops etc.	53
Book chapters	7
Popular articles	26
Folders, leaflets, pamphlets	19
Radio talks	6
TV programme	2
Scientists visited abroad	6
Dignitaries visited the Institute	33
Exhibitions organized	22
FLDs conducted	40

LIST OF VARIETIES OF ICAR-CTCRI REGISTERED WITH ICAR-NBPGR

Sl. No.	Crop Name	Botanical Name	National Identity	Donor Identity	Variety Name	Ingr. No.	Year	Pedigree	Developer	Developing Institute	Novel Unique Features
1	Cassava	*Manihot esculenta*	IC0586850	Triploid Cassava: 4-2	Sree Athulya	10144	2010	OP-4 (2x) X Sree Visakham (4x)	M.T. Sreekumari K. Abraham M. Unnikrishan S. Ramanathan	ICAR-CTCRI Thiruvananthapuram, Kerala	Higher yield and high extractable starch
2	Cassava	*Manihot esculenta*	IC0586851	Triploid Cassava: 5-3	Sree Apoorva	10145	2010	Ambakkadan (2x) X Sree Sahya (4x)	M.T. Sreekumari K. Abraham M. Unnikrishan 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 Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar, Odisha	High β carotene (13-14.5 mg 100 g^{-1}) and salinity tolerance
4	Sweet potato	*Ipomoea batatas*	IC0593651	ST-13	Bhu Krishna	13021	2013	JP-13	S.K. Naskar Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar, Odisha	High anthocyanin (85-90 mg 100 g^{-1}) and salinity tolerance
5	Sweet potato	*Ipomoea batatas*	IC0593652	ST-10	Bhu Swami	13022	2013	JP-10	S.K. Naskar Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar, Odisha	High extractable starch (20-21%)

'Produce Tuber
Ensure food, nutrition and livelihood security'

For further details please contact

E-mail: director.ctcri@icar.gov.in
Website: http://www.ctcri.org

भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch