CTCRI/QSF/RP/400

वार्षिक प्रतिवेदन

Annual Report

2015 - 2016

भाकृअनुप-केन्द्रीय कंद फसल अनुसंधान संस्थान

(भारतीय कृषि अनुसंधान परिषद)

श्रीकारियम तिरुवनंतपुरम 695 017 केरल भारत

ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE

(Indian Council of Agricultural Research)

An ISO 9001-2008 Certified Institute

Sreekariyam Thiruvananthapuram 695 017 Kerala India

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16 June 2016

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Preface

The year 2015-2016 was yet another eventful period in the history of ICAR-Central Tuber Crops Research Institute and it is with great pleasure that I present this Annual Report. Tuber crops production in the country is 92.34 lakh tons, which accounts for only 5.7% of the total vegetable production. Nevertheless, a surge in vegetable production including root and tubers is expected in the near future, due to the declining trend in the production of cereals and pulses. Besides, the expanding horizon of value addition in tubers, is yet another avenue that is expected to boost their area coverage and production.

Tropical root and tubers are the third important food crop of mankind, after cereals and legumes and are either a staple or subsidiary food for about one-fifth of the world population. Ever since its establishment in the year 1963, ICAR-CTCRI has been facilitating scientific production and utilization of these crops for food, nutrition and livelihood security.

During the reporting year, the germplasm wealth continued to be enriched, totaling to 5618. Two new cassava varieties, Sree Raksha 1 and Sree Raksha 2, which are resistant to cassava mosaic disease were recommended for release in the recently held annual group meeting of AICRP on Tuber Crops. Besides, promising elite genotypes of early maturing sweet potato, β-carotene and anthocyanin rich sweet potato, hybrids of greater yam with tolerance to anthracnose, high yielding dwarf and semi-dwarf white yam hybrids with excellent cooking quality and taro accessions moderately resistant to taro leaf blight were identified Sustainable resource management technologies, viz., nutrient (N & K) efficient cassava genotypes, salt tolerant sweet potato, use of thippi compost as an alternative organic manure source, cropping system consisting of rice-short duration cassava + black gram, irrigation water saving techniques for elephant foot yam, site specific nutrient management schedules, customized fertilizers for cassava and elephant foot yam, weed management practices for elephant foot yam and organic management of minor tuber crops have been developed.

Strategies for management of sweet potato weevil using sex pheromones, repellents and EPNs, bio-intensive management of taro leaf blight, collar rot of elephant foot yam and yam anthracnose and exploitation of cassava based bio-formulation for pest management in vegetables were some of the major achievements from the crop protection side. Technologies for the production of taro flour based gluten free cookies and bread, sweet potato nutribar, protein rich sweet potato muffins, sweet potato gluten free cookies, curcuma starch based extrudates, lacto-pickle from yam bean, particle boards from cassava stems, solid adhesive from oxidized cassava starch, water soluble curcumin loaded on a modified nano cassava starch for pharmaceutical application were the major research highlights in the utilization front.

Real-time agro-advisories as SMS to farmers through the electronic device (E-Crop) that was developed at the Institute has been found to be very helpful to farmers. A nutrient decision support system in CD, CASSNUM version 1.1, developed and released for site specific nutrient management of cassava, deserves special mention. The Tribal Sub Plan programme at Regional Centre, Bhubaneswar, in collaboration with four NGOs progressed well to the benefit of the tribals. The Techno-Incubation Centre, enhanced the visibility of the Institute among the public and the media by imparting several training programmes on value addition and motivating the trainees for entrepreneurship. Hosting of the Tuber Food Fest-2016 was yet another feather in the cap of achievements in which, various tuber food preparations and value added products from 20 states were exhibited, attracting a huge crowd.

I am extremely grateful to Dr. S. Ayyappan and Dr. Trilochan Mohapatra, the former and the present Secretary, DARE and Director General, ICAR respectively, for their wise counsel and advises. I also place on record my deepest sense of appreciation and gratefulness to Dr. N. K. Krishna Kumar, DDG (Horticultural Science) for his constant support and guidance. I am thankful to Dr. T. Janakiram, ADG (HS I), and other Officers and Staff of the SMD for their timely help and interventions. I also record on my personal behalf and on behalf of the Institute, our sincere gratitude to Dr. S. K. Chakrabarti, the former Director, ICAR-CTCRI, for his able ledership and invaluable contributions in bringing the Institute to its present glory. I appreciate the sincere efforts made by Dr. G. Suja and her team in compiling this Annual Report and publishing it on time.

16 June 2016

James George
Director (Acting)

Executive Summary

Crop Improvement

A total of 5618 accessions comprising 1271 cassava, 1124 sweet potato, 1110 yams, 671 edible aroids, 200 minor tuber crops and 1242 collections from regional centre were maintained and conserved in the field gene bank. Thirty nine different tuber crops were added to the germplasm collections from various places. Augmentation of sweet potato germplasm was done with the addition of six accessions from Joida Taluk, Uttara Kannada, Karnataka and two from Sirsi, Karnataka. Eight accessions of greater yam, three accessions of lesser yam, one accession of potato yam, seven taro (Karnataka and Nagaland), four elephant foot yam (Joida, Karnataka; Udaipur, Rajasthan and Vizhinjam, Kerala), one tannia and two *Alocasia* (Karnataka and West Bengal) were added to the germplasm collection. At the Regional Centre, the genetic resources were enriched with the addition of seven new accessions, which included sweet potato (2), taro (3) and yam (2). The DNA bank was augmented with 20 cassava, 130 yam, 30 taro, 42 elephant foot yam and seven arrowroot accessions.

A total of 1271 accessions of cassava comprising of the indigenous, exotic, landraces and breeding lines were characterized for five qualitative above ground vegetative plant traits viz., early stem, leaf, petiole and lamina-petiole joint colour as well as cassava mosaic disease incidence (CMD) under field epiphytotic conditions. The analyzed data indicated that 288 accessions showed high incidence of CMD, while 513 accessions were free of any symptoms in the early stages of plant growth. The stem colour showed a wide range of variation from brownish, greyish, orange to violet. The leaf colour also showed much variation from green in 56 accessions to brownish green in 1045 accessions, while lamina-petiole joint colour varied from green in 457 accessions to purple in 714 accessions. Eighty exotic accessions of cassava were screened both in the field as well as through PCR technique for cassava mosaic virus and fifteen were found free from symptoms.

In sweet potato, consistency of cooked tubers, texture and sweetness were assessed as per IPGRI descriptors. Among the orange-fleshed accessions, SD-11, SD-24, SP-10 and 148/12 were having very high starch and taste, but sweetness was high for SD-24. Among the white/yellow-fleshed, JASM5C, 526/12 and OP-S1 were tasty with medium to high starch and very high sweetness. Accessions 112/11 and AF3 have high starch and low sweetness. Molecular characterization of greater yam accessions (73), white yam (30), lesser yam (10) and wild yams were undertaken using 10 polymorphic SSR and 15 ISSR primers. The study identified a high yielding, highly divergent white yam genotype, DR-17 that could be used for the genetic improvement program in future. Seven sets of duplicates could be identified in greater yam. Among 64 accessions of greater yams screened for *in vitro* detached leaf assay for anthracnose resistance, 14 accessions showed high resistance to *Colletotrichum gloeosporioides* with no lesions. Screening of lesser yam accessions (50 acc.) for yam mild mosaic virus using DAS ELISA showed the presence of virus in 60% of the samples.

Molecular characterization using 10 polymorphic SSR markers were done for 30 taro accessions from Kerala. All the primers gave polymorphic bands. The PIC value ranged from 0.639 to 0.857. The highest heterozygosity was obtained for the primer uq 97-256 with a value of 0.871 and the lowest was obtained for the primer uq 84-207 with a value of 0.694. Number of alleles per locus ranged from 1.90-4.56 with the maximum alleles shown by uq 97-256 and the minimum showed by uq 84-207 and uq 201-302. No duplicates could be identified. Two hundred and twelve taro accessions were subjected to field screening for taro leaf blight, of which, 56 were highly susceptible, 18 susceptible and 138 showed tolerance.

Molecular characterization using nine ISSR markers were done for 12 elephant foot yam accessions including cultivars and wild ones. The similarity coefficient ranged from 0.62-0.93. No duplicates could be identified.

Seven arrowroot germplasm collections from different states were characterized for 20 (5 quantitative and 15 qualitative) above ground vegetative plant traits. The plant height, stem diameter, leaf lamina length and width varied. These seven arrowroot accessions were screened using 12 ISSR markers, which produced 124 bands of which 66 were polymorphic. The accessions formed two major clusters with two outliers in the grouping. Cluster 1 and II consisted of two and three accessions respectively having 72% similarity. The similarity coefficient based on ISSR markers ranged from 0.61 to 0.88. The accessions from Kerala and Maharashtra remained as outliers with only 65% similarity.

Under *in vitro* conservation of germplasm, 211 accessions of sweet potato including 65 accessions from NBPGR and accessions from pre-identified core collections, released varieties of tuber crops; cassava (2 breeding lines, 13 varieties, 3 landraces and 18 accessions); sweet potato (9 varieties); yams (7 accessions and 10 breeding lines) are also being maintained *in vitro*. At the Regional Center, 38 sweet potato, 21 taro, 12 cassava, 5 yam, 5 Chinese potato, 2 elephant foot yam, and 5 yam bean varieties and prerelease varieties as well as elite lines are being maintained *in vitro* at Regional Centre. Eight hundred and seventy five cultures of released and exotic lines are maintained under *in vitro* conditions at Regional Centre.

In cassava, 572 hybrid seedlings were produced by crossing early bulking clones. Out of these, 10 hybrids were observed with starch>30%. Six new hybrid seedlings had dark yellow flesh colour. In the experiment for improving the starch quality of CMD resistant cassava, friable embryogenic callus (FEC) was initiated in CMD resistant cassava 9S-127. For increasing the starch content in CMD resistant cassava lines, the *Agrobacterium* EHA105 having *glgC* gene was confirmed for the presence of *glgC* gene and also positively confirmed the revived colony as *Agrobacterium* through molecular and biochemical methods i.e., PCR with *Agrobacterium* specific primers and 3-ketolactose test. This culture was used for transforming TMS60444 cassava FEC.

For pyramiding of cassava mosaic resistant genes, *cmd1* and *cmd2*, a total of 325 seedlings of cassava were raised from crosses between TMS 30572 x CR43/11, TMS 96/1089A x CR43/11 and its reciprocal crosses. One hundred and fifty hybrids were identified with both *cmd1* and *cmd2* gene.

Using bioinformatics tools, fifty six SNPs were identified in cassava, of which 30 SNPs were non-synonymous and 26 were synonymous SNPs. Out of the five SNPs validated in the wet lab, one SNP (SNP896) was able to clearly differentiate between the resistant and susceptible varieties.

Of the 357 SSR's identified in cassava using MISA, 217 were mono, 132 were di, 139 were tri, 3 were tetra, 1 was penta, 3 was hexa and 42 were complex SSRs. Five sequences which had high hit percentage were validated and the SSR (SSR2063) was able to clearly differentiate between the resistant and susceptible varieties.

Of the 619 genotypes of sweet potato (265 germplasm + 29 OP lines + 325 diallele bred hybrids) evaluated for early maturity with other valued traits, 26 were observed to be of early maturing types, 19 with 75 days including C_1 of F_1 and 7 with 90 days maturity. Out of a stock of 265 genotypes of sweet potato evaluated, 22 were observed to be promising (orange-3, rest white). Those on evaluation in the succeeding year, 75 days maturity was observed only in 7 lines (1-orange and 6–white-fleshed lines). In sweet potato, open pollination generated 29 breeding lines of which 9-purple, 9-white, 11–orange-fleshed were evaluated consecutively for the 4th clonal generation, 90 days maturity was observed in 5-purple and 2-white

fleshed lines. Of the 500 seedlings of sweet potato, clonal generation was raised from 325 seedlings. Progressive evaluation of clonal generations of F1 Hybrids of those revealed 75 days maturity in 12 lines with yield of 20.40 to 25.60 t ha^{-1}. Of which, flesh colour was observed to be orange-4, light purple-1, light orange-1 and white-6. Of the 12 lines of sweet potato, 4 lines (orange-2, white-1, light purple-1) had no weevil attack even during dry spell. All these when harvested after 110 days of planting showed less than 10% infestation. All the improved lines of sweet potato evaluated from germplasm collections, OP or diallel bred gave yield more than 17 t ha^{-1}, starch (>16%), β-carotene (>10 mg $100g^{-1}$) and anthocyanin contents (>75 mg $100g^{-1}$). Few such lines had high starch >18%, β-carotene (>14 mg $100g^{-1}$) and anthocyanin (>1g $100mg^{-1}$). All these lines are also observed with less (<8%) weevil infestation

Seven hybrids of greater yam showed high resistance to anthracnose. Among white yam hybrids evaluated, Drh-1150 produced the highest tuber yield (61.70 t ha^{-1}) followed by Drh-1125 (59.70 t ha^{-1}). The dwarf white yam hybrids viz., Drd-1038, Drd-1110, Drd-1835, Drd-920, Drd-1089 and Drd-1078 had excellent cooking quality. The semi dwarf SD-15 also was a high yielder.

Of the nineteen taro accessions screened artificially, six (IC087153, IC012601, IC012294, IC310104, TCR-267 and TCR-326) showed moderate resistance to taro leaf blight. Preliminary work on identification of molecular markers linked to TLB showed that ISSR primer UBC 825 and $(AG)_9AC$ gave an extra band in all the six resistant accessions selected in the 685 bp and 808 bp regions, respectively. Taro evaluation trials showed that IC211587 outperformed Sree Rashmi (Check) having an average cormel yield of 11.62 t ha^{-1}. The percentage oxalate content ranged between 0.19 to 0.31% on dry wt. basis and all had good cooking quality

In elephant foot yam breeding, the corm weight was recorded in the F1C1 (Family 1) and F1 progeny (Family 2). The corm weight ranged from 0.2 to 100 g in the former and in the latter it ranged from 0.40 to 93.68 g. Preliminary evaluation trial in tannia with seven accessions showed that the average cormel yield/plant ranged from 14.40 g (Xa-12) to 85.80 g (Xa-MNS/14-1).

Biochemical analysis of seven arrowroot accessions showed that the total starch content ranged from 15.61% (M5) to 20.21% (M1), while the total sugars ranged from 0.11% (M5 and M7) to 0.12% (others). In yam bean, five best F_1 hybrids were identified and selected based on yield evaluation (3 x 10, 9 x 10, 3 x 5, 3 x 8 and 3 x 9). Tuber yield in yam bean ranged from 43.33 t ha^{-1} (3 x 9) to 46.66 t ha^{-1} (3 x 10) as compared to 27.77 t ha^{-1} in RM-1 as a check variety. Starch content in yam bean ranged from 11.12-17.33% and sugar content ranged from 5.88-8.06%.

Crop Production

Rice (var. Kanchana)-short-duration cassava (var. Sree Vijaya) + black gram (Co-7) resulted in higher energy equivalent, tuber equivalent yield (38.86 t ha^{-1}), production efficiency (107.94 kg ha^{-1} day^{-1}) and profitability (added profit of Rs. 52,107 ha^{-1} over sole cassava) besides saving nutrients, half FYM and N and full P to short-duration cassava in this system. Sustainability of cassava for continuous cultivation was confirmed even after the 11^{th} season crop with a tuber yield of 15.17 t ha^{-1}, without any manures or fertilizers. Application of NPK @ 125:50:125 kg ha^{-1} produced significantly the highest tuber yield of 32.85 t ha^{-1}. Soil test based application of NPK @ 78:0:94 kg ha^{-1} along with FYM @ 5 t ha^{-1} (22.27 t ha^{-1}), recommended POP (FYM @ 12.5 t ha^{-1} + NPK @ 100:50:100 kg ha^{-1}) (27.62 t ha^{-1}) and NPK @ 50:25:100 (25.18 t ha^{-1}) were on par with respect to tuber yield.

Different organic manure sources viz., green manuring *in situ* with cowpea (@ 4.87 t ha^{-1} on DW basis) (26.89 t ha^{-1}), vermicompost, @ 3.91 t ha^{-1} (27.27 t ha^{-1}) and coir pith compost @ 4.6 t ha^{-1} (25.78 t ha^{-1}) were found as substitutes to FYM @ 12.5 t ha^{-1} (27.62 t ha^{-1}) in

cassava production. Organic manures alone (crop residue as cassava leaf residue @ 3.75 t ha^{-1} (DW basis) and stem residue @ 10.43 t ha^{-1}(DW basis) + coir pith compost @ 4.60 t ha^{-1}+ vermicompost @ 3.91 t ha^{-1} and ash @ 2.70 t ha^{-1}) also resulted in an yield (23.06 t ha^{-1}) on par with the recommended POP (27.63 t ha^{-1}). Evaluation of the N efficiency potential of the K efficient genotypes indicated that W-19 (30.23 t ha^{-1}) and CR 43-8 (31.69 t ha^{-1}) were good performers.

Thippi compost (C:N ratio of 8:1 and N, P, K, Ca, Mg, Fe, Mn, Cu, Zn contents of 1.32, 3.82, 0.40, 2.18, 0.96, 1.11, 0.08%, 11.23 and 89.93 mg kg^{-1} respectively, which is 3.5, 49, 7, 32.5, 8, 185, 100, 2.5 and 12 times than thippi prepared from cassava starch factory solid waste) tested in cassava for two seasons revealed that thippi compost (24.66 t ha^{-1}) was an alternative to FYM (26.64 t ha^{-1}), green manuring *in situ* with cowpea (27.18 t ha^{-1}), crop residue incorporation (25.03 t ha^{-1}), vermicompost (22.15 t ha^{-1}) and coir pith compost (21.78 t ha^{-1}), NPK up to 75% (26.55 t ha^{-1}), $MgSO_4$ @ 20 kg ha^{-1} (27.94 t ha^{-1}) and $ZnSO_4$ @12.5 kg ha^{-1} (24.44 t ha^{-1}).

Fertigation studies conducted in cassava indicated that different levels of N and K (75, 100 and 125 kg ha^{-1}) were on par with respect to tuber yield. The interaction, 125 kg ha^{-1} N and 75 kg ha^{-1} K produced maximum tuber yield (50.30 t ha^{-1}). However, all the interactions, except 75 kg ha^{-1} each of N and K, were on par.

A nutrient decision support system in CD, CASSNUM version 1.1, for site specific nutrient management of cassava was developed. Eighteen different NPK recommendations for site specific nutrient management of cassava and nine different NPK recommendations for elephant foot yam were developed for the major growing environments of India.

Methodology for cassava acreage estimation by remote sensing and GIS was developed using Landsat 8 OLI satellite imagery along with inverse multiquadratic based Possibilistic c-Means classifier. At optimized weighted constant for inverse multiquadratic based Possibilistic c-Means for 4 date combination, the total estimated area was found to be 4234.10 ha and 2175.63 ha for white Thailand and Mulluvadi respectively. The total estimated area under cassava in Salem district in 2014 is 8324.20 ha. The best suitable date combination for identification of cassava was found to be of 4 dates that are 4 February, 8 April, 15 August and 22 January 2015.

There was no influence of different tillage levels on cassava tuber yield in the first year of study, whereas different types of mulches significantly influenced the yield in the order porous ground cover (GC)>crop residue (CR)>no mulch (NM). Soil hydraulic properties viz., field saturated hydraulic conductivity (HC), matric potential (MP), and sorptivity (SS) estimated under different tillage and mulching treatments showed that HC and SS of conventional tillage was found to be 14 and 28% higher as compared to minimum tillage, whereas 18% increase in matric potential was observed under GC as compared to NM.

The first year study for evolving best management practice for cassava and elephant foot yam involving soil test based application of NPK, lime @ 1 t ha^{-1} for correcting surface acidity, gypsum @ 2 t ha^{-1} for correcting subsoil acidity, $MgSO_4$ @ 80 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1} and borax @ 10 kg ha^{-1} gave significantly higher yield for elephant foot yam in two Agro-ecological units (AEU) of Kerala. Application of N, P_2O_5 and K_2O @ 50: 40: 75 kg ha^{-1}, respectively was optimum to realize higher yields of good quality sweet potato tubers in the natural saline soils under island ecosystem of Andaman.

A field experiment was conducted for inducing early and uniform sprouting in elephant foot yam. Corm treatment with GA3 @ 200 ppm produced significantly higher corm yield (10.21 t ha^{-1}) followed by IAA @ 100 ppm (7.31 t ha^{-1}). Corms treated with thiourea at 0.5% produced significantly higher number of corms (10059 per ha).

Different water saving techniques were tried along with micro irrigation in elephant foot yam. There was no significant difference in corm yield among the different water saving techniques compared to full irrigation at 100% CPE. Maximum corm yield was obtained with irrigation at 50% CPE along with crop residue mulching (51.15 t ha^{-1}) followed by irrigation at 50% CPE with plastic mulching (48.90 t ha^{-1}). The rainfed crop produced the lowest corm yield of 26.50 t ha^{-1}. The data indicated the possibilities of irrigation water saving with different techniques. Studies on root distribution pattern of elephant foot yam under irrigated and rainfed conditions showed that root length was more under rainfed conditions and attained maximum when the canopy was fully emerged, which was maintained up to 5 months after planting (MAP) and thereafter started declining. However, root dry matter was more under irrigated conditions and reached maximum at 3 MAP.

In the process of developing customized fertilizers for elephant foot yam, the rates of NPK was standardised as NPK @ 142:12.5:160 kg ha^{-1} for AEU3 and 156:12.5:180 kg ha^{-1} for AEU 9 (based on the rate trials conducted) and the rate of secondary nutrients viz., Ca, Mg and micronutrients viz., Zn and B was standardized as dolomite @ 1.5 t ha^{-1}, $MgSO_4$ @ 120 kg ha^{-1}, $ZnSO_4$ @ 30 kg ha^{-1} and borax @ 18.75 kg ha^{-1} for the two AEUs of Kerala.

The use of weed control ground cover resulted in higher weed control efficiency (96.90%) and higher corm yield (37.40 t ha^{-1}) in elephant foot yam. Though maximum gross return (Rs 5,60,600 ha^{-1}) was obtained under weed control ground cover treatment, higher benefit:cost ratio (2.31) was obtained under two rounds of manual weeding (30 and 60 days after planting (DAP)) + glyphosate (90 DAP) treatment due to low cost of cultivation.

In greater yam + maize intercropping system, drip irrigation at 100% CPE resulted in higher maize yield. However, greater yam yield (34.90 t ha^{-1}) and tuber equivalent yield (37.80 t ha^{-1}) were higher at 100% CPE during 1-90 DAP + 80% CPE during 91-270 DAP. Drip fertigation of N-P_2O_5-K_2O 160-90-160 kg ha^{-1} resulted in higher maize, greater yam and tuber equivalent yield, which was on par with N-P_2O_5-K_2O 140-90-140 kg ha^{-1}. Drip irrigation at 100% CPE during 1-90 DAP + 80% CPE during 91-270 DAP along with fertigation of N-P_2O_5-K_2O 140-90-140 kg ha^{-1} resulted in higher water and nutrient use efficiency as well as B:C ratio (2.82).

Organic production technologies developed for yams and cassava were validated in organically raised 48 year old coconut plantation at ICAR-CPCRI, Kasaragod. Yield under organic mode (0.97 and 0.75 respectively of conventional) was on a par with chemical system in both yams (7.18 and 7.44 t ha^{-1}) and cassava (8.06 and 10.86 t ha^{-1}) intercropped in coconut. Based on two years' experimentation at ICAR-CTCRI in Chinese potato, organic production technologies involving FYM @ 10 t ha^{-1}, green manure, neem cake @ 1 t ha^{-1} and ash @ 2 t ha^{-1} or biofertilizers (*Azospirillum*, P solubilizer and K solubilizer @ 3 kg ha^{-1} each) were developed; yield under organic management (13.94 t ha^{-1}) was 10.50% higher over conventional system (12.61 t ha^{-1}).

Sixteen soil samples (0-30 cm depth) from areas adjacent to mines and industrial areas of Koraput district, Rayagada district and Jagatsinghpur districts of Odisha including one soil sample representing arable land were collected and characterized for physico-chemical properties, enzyme activities and the pattern of accumulation of heavy metals due to pollutants.

Studies to develop integrated soil and water conservation strategies for rainfed hill cassava production systems indicated that soil moisture content under ground cover sheets was 30.60% higher and soil temperature lower by 9.50% as compared to control. The cassava tuber yield in farmer's vs scientific practice were 24.40 and 28.90 t ha^{-1}; sheet vs no sheet (control) treatment were 32.60 and 21.60 t ha^{-1} respectively. Ground cover sheets

along with scientific nutrient management practices at Pachamalai hills proved to be an ideal technology for rainfed hill cassava cultivation, especially in mild to moderate sloping lands in Eastern Ghats of Tamil Nadu.

A total number of 145 micro plants of different cassava varieties were indexed against cassava mosaic virus through micro propagation technique in the tissue culture laboratory. A total of 50 numbers of elephant foot yam (var. Gajendra) were also indexed. Cassava varieties, Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Swarna were planted in 2.70 acres. A total of 50,000 cassava stems of good quality were produced. Quality planting materials of elephant foot yam var. Gajendra were multiplied in 3.60 acres. A total of 13 tons of elephant foot yam was produced. Greater yam multiplication was taken up in a total area of 2.05 acre with Sree Keerthi, Sree Roopa and Sree Shilpa varieties and the production was 7 tons. Taro var. Muktakesi was planted in an area 0.20 acre and the production was 300 kg.

Crop Protection

Survey of sweet potato weevil in Dhenkanal, Boudh, Angul, Kalahandi, Koraput, Navranpur, Bargarh districts of Odisha showed yield loss ranging from 15 to 75%. Sweet potato weevil were collected from different states of India through AICRP centres. The genomic DNA was isolated and the mitochondrial cytochrome oxidase (MtCOX1) gene was amplified by PCR, cloned and the sequences obtained were aligned using BIOEDIT software. All the samples were identified as *Cylas formicarius* with 98-99% similarity. The samples collected from different states showed variation within the sequences.

There was no significant morphological variation (body size, number of antennal segments, size of hind tarsus and genitalia) among the whiteflies collected from different cassava growing regions of Kerala. Molecular studies of whiteflies collected from ICAR-CTCRI campus using SSR markers and mtCOI gene sequencing showed that they were *Bemisia tabaci* with minor variations among them and belonged to Aisatic biotype.

The synthetic pesticides, Profenophos 40EC + Cypermethrin 4EC (combination product) @ 400 g ai ha^{-1}, Emamectin benzoate 5SG @ 11 g ai ha^{-1}, Spinosad 45 SC @ 50g ai ha^{-1}, and Cartap hydrochloride 50 SP @ 500 g ai ha^{-1} resulted in very low infestation of sweet potato weevil, 0.20%, 0.33%, 0.87% respectively, against control (42.93%). Sex pheromone technology demonstrations for sweet potato weevil were conducted in sweet potato fields in Dhenkanal, Bargarh, Navranpur and Koraput districts of Odisha. In Dhenkanal, farmers used the sex pheromone in 500 ha @ 10 per ha, which reduced the weevil population and tuber damage (86%) significantly. The cost of pheromone traps including lures, plastic boxes etc. was only Rs. 400 per ha.

Sweet potato weevil repellents, humulene and gurjunene were formulated in alginate microbeads (liquid formulation). As the microbeads were not economically viable, an alternate formulation was explored. Powder formulations of weevil repellents, humulene and gurjunene, were prepared in β-cyclodextrin complexes. The formulation was evaluated in field conditions on sweet potato. Efficacy of α-humulene in powder formulation was greater than α-gurjunene. Both the compounds resulted in 14 to 20% weevil infestation.

Entomopathogenic nematodes (EPNs) brought from ICAR-NBAIR, Bangalore, reduced sweet potato weevil during kharif season. EPNs @ 20 kg ha^{-1} resulted in 10.67% weevil damage, whereas, the highest was recorded in control plot with 52.67% weevil damage to tubers.

With the collaboration of ICAR-IARI Regional Station Wellington, Nilgiris, the dose of *Menma* was standardised for the management of aphids in mustard and *Shreya* for mealy bugs in okra, brinjal and tomato.

In a field experiment with susceptible, recovery and resistant lines of cassava, the disease incidence was

remaining the same in susceptible cultivar for the entire crop growth period, whereas the recovery lines showed remission of symptoms from 5-6th month after planting and resistant lines remained symptom free. The qPCR studies showed drastic reduction in virus load during the remission of symptom and at the end of crop cycle virus load started rebuilding in the recovery cultivars. The siRNA were isolated from these samples to understand the molecular mechanism.

From the 2500 cassava hybrid seedlings developed through crossing of genotypes with resistance from different sources, seedlings free from CMD symptoms with good plant type and tuber characters were selected (404 number) for the first clonal evaluation and CMD screening. Thirty promising seedlings were subjected to multiplex PCR and grafting and were free from CMV.

Soil and foliar application of nutrients (N, P, K, Ca, Si, Zn, Mn, Cu, B) in alternate weeks under controlled condition (in lysimeter) indicated that the nutrients viz., Zn, Si, B, P and Ca had positive effect on tolerance to CMD in the most susceptible variety, Sree Visakham. The same trend was observed in the qPCR analysis of virus load in the treated plants at different duration. There was a significant reduction in virus load in Zn, Si and Ca treatments.

Disease free cassava plants vars. Sree Vijaya and Sree Jaya obtained from Bhubaneswar were planted in field and monitored periodically. The rate of reinfection was nil up to three months and it was 16 and 18% at 4th month and 38 and 41% at 8th month of planting, respectively. Planting of infected material showed symptoms at first month itself and the incidence was 65 and 73% respectively in both the varieties at 8th month.

A new virus, sweet potato virus G was detected from sweet potato. The diagnosis of sweet potato feathery mottle virus and sweet potato leaf curl virus using designed primers was validated. Three viruses from lesser yam, viz., *Yam mild mosaic virus* (YMMV), *Yam macluravirus* and *Yam badnavirus* were identified. The specific primers were designed for YMMV and *Yam macluravirus* and tested in lesser yam samples. YMMV was diagnosed from lesser yam tubers and validated with more samples. The ELISA and PCR based techniques for diagnosing Dasheen mosaic virus in elephant foot yam were developed. The tubers from tissue cultured virus free elephant foot yam plants were multiplied under field condition.

Application of boron and silicon reduced taro leaf blight (TLB) incidence and percent disease incidence (PDI) was significantly less in boron and silicon applied plants (3.13 to 16.20) compared to NPK alone received plants (24.62). Three isolates of *Bacillus amyloliquefaciens* and vermicompost were evaluated along with mefenoxam to manage TLB incidence. Even though, there was no significant difference in PDI among the treatments, least PDI and highest yield was noticed in plants treated with *B. liquefaciens* (13-14). In another study, six *Trichoderma* isolates, which showed antagonistic ability to targeted pathogens under *in vitro* condition were characterized using ITS sequencing. The isolates were identified as *Trichoderma harzianum* (3), *T. erinaceum, T. virens* and *T. viride.* These isolates were evaluated for their efficiency to suppress TLB incidence and based on suppression as well as growth promotion, *T. virens* was selected for further study.

Studies were conducted to exploit the efficiency of *Piriformospora indica* (an endophyte with properties of AMF). Malt Extract agar (MEA) and Jaggery Agar medium produced maximum mycelial aggregation at 28°C. Soil inoculation procedure was standardized and *P. indica* was found to be efficient in promoting growth in the taro varieties tested. Root colonization ability of the endophyte was studied in taro varieties, Muktakeshi and Sree Kiran, by trypan blue staining. The presence was confirmed by Pitef1amplification and Confocal imaging also.

Available 71 bacterial isolates, which suppressed mycelial growth of *Sclerotium rolfsii* and

Phytophthora colocasiae were screened for N fixation, P and K solubilisation on selective media and 17 isolates showed desired characters and were selected for further study. During the reporting period, 63 microbial isolates were obtained from different parts of the country. Thirteen bacterial isolates and two *Trichoderma* isolates were short listed based on suppression of *Sclerotium rolfsii* and *Phytophthora colocasiae*.

B. amyloliquefaciens, T. asperellum, dolomite and vermicompost were evaluated with mancozeb + carbendazim to manage collar rot incidence in elephant foot yam. Even though, there was no significant difference in disease incidence among the treatments, least incidence and highest yield was noticed in plants treated with *B. liquefaciens* (13-14).

The pathogenecity test of *Colletotrichum gloeosporioides* causing greater yam anthracnose using whole plant assay and detached leaf method was standardised. The field experiment for the second season with three varieties, viz., Oriss Elite, Sree Karthika and Sree Keerthi, to study the disease progress in relation with weather parameters showed that Sree Karthika and Sree Keerthi were highly tolerant to anthracnose, whereas Orissa Elite was highly susceptible. The disease starts after rainfall and shoots up during July (third month of planting) and becomes severe when rainfall and rainy days are more in October (eighth month of planting). The soil application of *Nanma* (one litre of 0.5% per plant) and tuber treatment with *Nanma* (0.5% for 10 min.) along with spraying of carbendazim @ 0.05%, seven times showed the maximum reduction in disease intensity and increase in yield compared to control, which was on par with soil and tuber treatment with *Nanma*; soil and tuber treatment with *Trichoderma asperellum* @ 50 g of 10^{7} cfu g^{-1} and tuber treatment @ 5 g in fresh cowdung slurry per kg of tuber along with spraying of carbendazim seven times. The inorganic fraction of toxic metabolite of *Colletotrichum gloeosporioides* was purified using silica gel column and the bio-efficacy was tested in detached greater yam leaves. LC-MS and HPLC of the fraction has been done for further identification. Putative Resistant Gene Analouge (RGA) sequences in greater yam were amplified using degenerate primers, cloned, sequenced and analysed.

Crop Utilization

The tuber crop products such as taro flour based gluten-free cookies, gluten free taro flour bread, sweet potato flour based Indian flat bread (*Chappati*), protein rich sweet potato muffins, sweet potato nutri bar and sweet potato gluten free cookies and curcuma starch based extrudates were developed. Yam bean (*Pachyrrhizus erosus*) tubers were pickled by lactic fermentation and it was found that the antioxidant protecting properties of fermented product confirmed its health benefits.

A power weeder developed by Industrial Extension Centre of CIAE, Coimbatore was evaluated at ICAR-CTCRI farm. It was found that the weeder was suitable to address the weeding requirement of cassava planted on mounds in hilly terrains with mean weeding index of 91.90%. Cost of weeding by machine worked out to be Rs.6,123 ha^{-1}, while that of manual method was Rs. 25,000 ha^{-1}, which denoted 75.50% of cost-saving, 90.90% of time-saving and 95.50% of energy saving.

Particle boards were developed from dried and powdered cassava stem incorporating different types of binding materials viz., urea formaldehyde, phenol formaldehyde and melamine urea formaldehyde. Maximum density was obtained (1167 kg m^{-3}) for the board made with resin urea formaldehyde. It was found that starch can be used as a binding material along with limited amount of resin to get comparable physico-functional properties of particle boards. A solid adhesive mix, which was devoid of caustic alkali has been prepared from oxidized cassava starch. This solid mix can be stored easily and can be mixed at the time of use. Moisture resistant corrugating adhesive has been successfully formulated using native cassava starch, which exhibited very good tack and fast drying properties.

A study was undertaken to screen 61 cassava genoypes for post-harvest physiological deterioration (PPD) performance. Eleven genotypes were identified with low PPD incidence under storage. Tissue imprinting to localize enzyme activity, NIR spectroscopy combined with chemometric tools and HPTLC techniques were successfully employed to assess PPD.

Bio-films containing α-amylase treated cassava starch were developed. Analysis of various physico-mechanical and functional properties showed that the pullulanase modified starch offers better scope for the production of biodegradable packing materials.

RS4 type resistant starch was made by octenyl succinylation of cassava and sweet potato starches. The cooked starches of octenyl succinylated cassava starch showed slowly digestible starch (SDS) and resistant starch (RS) in the range of 20.50-38.40% and 1.50-27.90% respectively. In modified sweet potato starch, the SDS and RS values were in the range of 16–22.60% and 24.80–37.00%, respectively. There was a decrease in glyceamic index from 91.30 to 64.80 for cassava and 86.30 to 63.00 for sweet potato starch.

Field evaluation of starch based superabsorbent polymer showed that the total plant biomass and tuber yield increased significantly. Slow release NPK fertilizers with a range of release kinetics (5 to 40% release after 25 days in aqueous medium) were synthesized by coating with grafted cassava starch.

Slow release curcumin, incorporated in cassava starch-poly vinyl alcohol nanocomposite matrix was synthesized and characterized. *In vitro* dissolution of curcumin from the nanocomposite films was determined at simulated gastric (pH 2.1) and intestinal fluids (pH 7.4). A water soluble curcumin, loaded on a modified nanocassava starch, and with significantly higher bioavailability, anticancer properties and non-toxicity was synthesised and characterized. The study showed that compared to pure curcumin, nanocurcumin increased the curcumin bioavailability by 71.27%. Anthocyanins present in the purple-fleshed tubers and leaves of sweet potato and tubers of greater yam were structurally identified and through spray drying technique, anthocyanins from sweet potato tubers, leaves and greater yam tubers were encapsulated.

Process variations in the production of high quality cassava flour were studied at different loading densities (3, 5 and 7 kg m^{-2}) of cassava chips and gratings and at different drying sources (open yard, solar yard and mechanical tray drying). It was found that drying of chips under poly carbonated solar yard saved about 1-2 h than drying under open sun. The drying time required to dry 3 kg m^{-2} pressed gratings in the direct sun was six hours, whereas the 5 kg m^{-2} and 7 kg m^{-2} pressed gratings took 7 and 10 hours, respectively.

Electrical properties of cassava tubers were studied for the development of cassava starch indicator. Correlation coefficient between electrical and biochemical properties (starch and moisture) of cassava tubers were worked out. Hardness of the peeled and unpeeled cassava tubers were measured and correlated with electrical and biochemical properties of tuber.

In Belgaum district, five varieties of sweet potato viz., local, Kanaka, Sree Arun, ST-13 and ST-14 were planted and found that Sree Arun produced the highest yield of 20 t ha^{-1}.

Techno-incubation centre under the Division of Crop Utilization organized 20 training programmes on value addition and entrepreneurship development in tuber crops. It was attended by 336 people, including farmers and young entrepreneurs from different districts of the state. The incubation centre was used by 19 entrepreneurs for the production of snack foods like pakkavada, crisps, nutrichips, murukku, sweet fry and pasta. In-plant training was imparted to four B.Tech Food Engineering students from Kerala Agricultural Univerity. One month project work was offered to six students from College of Indigenous Food Technology, Konni.

Extension and Social Sciences

Demonstrations have been laid out in three Kunbi villages, Katel, Wagabandhe and Deriye with the planting materials of high yielding varieties of yams (Sree Roopa, Da-340, Sree Swathy, Sree Neelima, Da-178 and Dr-1047), sweet potato (Sree Arun, Sree Varun, Sree Kanaka, Gouri and Sree Bhadra) and elephant foot yam (Gajendra). The harvesting and evaluation of these trials revealed that Da-340 of greater yam produced the maximum yield of 2.72 kg per plant and Sree Neelima could give only 0.43 kg per plant. The white yam x clone Dr-1047 performed satisfactorily with an average per plant yield of 1.44 kg. Of the five sweet potato varieties evaluated for their performance in Belgaum, Sree Arun performed satisfactorily producing an average tuber yield of 19 t ha^{-1}. The nutritionally rich varieties, ST-13 and ST-14, and the local gave less than 10 t ha^{-1}. During rabi, the varieties in general yielded about 4 t ha^{-1}only mainly because of lack of moisture. Under Belgaum condition, sweet potato can be raised only with assured irrigation during rabi season to get profitable yield.

In the lexicon generation phase of the dry pasta, about 110 experts provided their responses. The results indicated that 60 per cent respondents consumed short macroni pasta once or twice a month. The pasta sensory attributes, taste (93%), aroma (82%) and chewiness (78%) were the most recommended attributes for evaluating sweet potato pasta. A consumption cohort comprising 50 farmers belonging to age group of 18-37 years was created in the Nayagarh and Khorda districts of Odisha. The baseline data indicated that the consumption of tuber crops like taro (>10 kg/ month/family) was high.

The livelihood analysis study was conducted in Thiruvananthapuram and Pathanamthitta districts of Kerala with a sample of 60 tuber crop farmers. Overall human index of tuber crops farmers was more in Pathanamthitta (0.65), when compared to Thiruvananthapuram (0.63). Equal percentage (93.33%) of tuber crop farmers from both the districts had high physical capital index. The overall social index was more for Thiruvananthapuram (0.84) than Pathanamthitta (0.73). In Pathanamthitta 33.33 per cent of the tuber crop farmers had high level of natural capital index than Thiruvananthapuram (40%). In Thiruvananthapuram 46 per cent of the tuber crop farmers were having high financial capital compared to Pathanamthitta (13.33).

E-Crop was developed by integrating various sensors. The device is installed in sweet potato field and the device has started collecting weather and soil data and these data are uploaded in the website. E-Crop scheduler was installed in the local machine, which automatically downloads the weather data from the website, run the simulation model, generates agro-advisory and sends the advisory to the mobile of the farmer as SMS. Validation of the weather data collected by the device and development of E-Crop version of sweet potato simulation model SPOTCOMS are progressing. The different hardware components of the variety identifier device were assembled into one unit.

A Macro for converting multiple comparisons output to letter groupings in PROC MIXED of SAS software was developed, which helps in getting letter displays for main plot x sub plot interaction effects. The interactive web based tool for tuber crops statistics was modified by incorporating interactive graphics. The district wise data on area, production and productivity of cassava and sweet potato has been incorporated.

Under the North Eastern Hill Regions programme a “Village Incubation Centre for Value Addition of Tuber Crops” was established at Ukhrul, Manipur. A Launching Workshop-cum-Training Programme on “Incubation Centre for Value Addition of Tuber Crops” at Riha village, Ukhrul district under ICAR-CTCRI-NEH programme was also convened. About 100 progressive farmers/SHG members/ prospective entrepreneurs from Riha village were trained in the tuber crops snack food production.

Introduction

ICAR-CTCRI (1963-2016)

The ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) was established during the Third Five Year Plan for intensification of research on tuber crops (other than potato). The Institute started functioning in July 1963 with its headquarters (HQ) at Sreekariyam, Thiruvananthapuram, Kerala in an area of 21.50 ha. Later, an area of 26.69 ha has been added. The Head quarters has completed it's golden jubilee during 2012-2013 and became the **ISO (ISO 9001:2008) certified Institute since 31 March, 2014.** ICAR-CTCRI has one Regional Centre (RC) at Bhubaneswar with a farm area of 20 ha. The All India Coordinated Research Project on Tuber Crops (AICRPTC) was started at ICAR-CTCRI in 1968 with three centres at Dholi in Bihar, Coimbatore in Tamil Nadu and Acharya N.G. Ranga Agricultural University, Hyderabad, Andhra Pradesh. The AICRP TC which was started for testing and popularizing the location specific tuber crop technologies in various parts of India has presently 20 centres including ICAR-CTCRI HQ and Regional Centre. The Institute is also one of the centres of All India Coordinated Research Project on Harvest and Post-Harvest Technology. The ICAR-CTCRI is conducting basic and applied research on various edible tropical tuber crops.

Vision

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

Mission

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

Mandate

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

- To undertake basic, strategic and applied

research to generate technologies for sustainable production of tropical tuber crops as a component of integrated farming system.

- To act as digital repository of scientific and socio-economic information on tropical tuber crops.
- To co-ordinate network research with National Agricultural Research and Education System (NARES) for generating location specific technologies.
- To develop indigenous processes and products for diversified utilization and reduction of post-harvest losses.
- To act as a centre for knowledge and skill development of various clientele systems.
- To undertake transfer of technologies through outreach programmes and consultancies.

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 more than five decades of concerted research have led to the development of several production and processing technologies for tuber crops, besides release of 53 improved varieties. The target group of most of the technologies being marginal and resource poor farmers, adequate emphasis is also given for on-farm evaluation and popularisation of the technologies. In addition, several industrial Hi-tech technologies were also developed in the recent past enabling resource generation through consultancies.

ICAR-CTCRI has a wealth of germplasm of tuber crops, totalling 5618. This has formed the basis of all the genetic improvement and variety development programme. Earlier the improvement work was exclusively based on conventional breeding programmes. Infact, the pioneering role of ICAR-CTCRI in the area of tropical tuber crops classical breeding attracted international collaboration in the breeding and genetic improvement of these crops in the past. Now, work on molecular based improvement has also been initiated.

ICAR-CTCRI has released 53 varieties in eight different tropical tuber crops. Each variety has its own unique traits and preferences. The cassava starch and sago production in the country is mostly dependent on two major industrial varieties of cassava released from ICAR-CTCRI, viz., H-165 and H-226. Two Triploid cassava varieties, viz., Sree Athulya and Sree Apoorva have been released recently, which are found to be promising and acceptable to farmers as well as industries. β carotene rich ST-14 sweet potato developed by ICAR-CTCRI was included in LANSA and FSN programme to alleviate malnutrition.

The domestic and international training received in the use of biotechnology in conservation, characterisation and genetic improvement of tuber crops has contributed to a great extent in development of facilities and formulation of programmes using this advanced technology for the improvement of tuber crops. The Institute presently has very strong programmes on biotechnology which includes the development of diagnostic tools for viral and fungal diseases and transgenic plants for conferring resistance to cassava mosaic disease and to enhance the starch content and waxy starch.

A host of tuber crops production technologies are available for monocrop, intercrop and multiple cropping systems which help in enhancing the yield, soil fertility, employment opportunities for farm families and income levels. Integrated crop protection technologies developed for cassava mosaic disease, taro leaf blight, collar rot of elephant foot yam and sweet potato weevil would help the farming community in extreme eventualities. Management of banana pseudostem weevil through cassava based biopesticides, *viz.*, *Nanma* and *Menma* was a grand success in the farmers' fields. Besides, technology has been perfected for organic production of cassava, elephant foot yam, taro and all species of yams; cropping system with rice-black gram-short duration cassava proved to be profitable with good return.

Efforts in crop utilization have paid rich dividends in terms of value addition and diversified technologies suitable for big, small and cottage industries. Many of these technologies are capable of ensuring food and nutritional security to the people of India. Technologies for the industrial sector include the latest products like superabsorbent polymers; graft copolymerized starches, cold water miscible starch, solid adhesives, bioethanol, pasta products etc. Cassava starch composite based biodegradable films and adhesive formulations for corrugation and paper industries are successfully developed recently. Development of functional food products from cassava, yam and elephant foot yam and enhancement of anthocyanin recovery from anthocyanin sweet potato is in pipeline.

Aroids especially elephant foot yam is gradually gaining importance in different areas like Odisha, Bihar, Uttar Pradesh, Gujarat and north-eastern states. Supply of quality planting material is ensured to farmers of all regions though revolving fund scheme, mega seed project and tuber crops development scheme from state department. There exists a good research base in the country to sustain root and tuber crops research for development with ICAR-CTCRI giving the leadership and ICAR-AICRPTC to plan and coordinate region specific research and testing of technologies on these crops. Technology generation and transfer are being closely interlinked with the utilization by the clientele system.

ICAR-CTCRI bagged the Sardar Patel Outstanding Institution Award for the year 2005, instituted by the ICAR for outstanding contribution made in the improvement of tropical tuber crops and development of low cost production technologies.

The Institute also bagged many national and international recognitions in the past that include J. Chinoy Gold Medal (1970), three ICAR Team Research Awards (1985, 1996, 1998, 2014), D. L. Plucknett Award for Tropical Root Crops, Hari Om Ashram Trust Award (1993), Jawaharlal Nehru Award (1975, 1995, 1998, 2000 and 2003), Young Scientist Award instituted by Deseeya Sasthra Vedi (1996), NRDC cash reward for biodegradable plastics (2000), Pat Coursey Award (2000, 2006),Vasantharao Naik Memorial Gold Medal (2002), Samantha Chandrasekhar Award (2013), International Potash Institute (IPI)-Fertilizer Association of India (FAI) Award (2014) and Shri. L.C. Sikka Endowment Award (2014). 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 best annual report award (1997-98) among the category of small institutes was conferred to ICAR-Central Tuber Crops Research Institute for succinctly presenting the research results. The Institute has conducted more than 15 national and international Symposia/Seminars/Workshops.

The infrastructural facilities of the Institute have been tremendously increased during the X and XI Plan periods. Additional laboratories like Food Extrusion Laboratory, Transgenic Glass House, Bioinformatics Laboratory, Biodiversity Sheds, Modernised Computer Cell, Seed Storage Laboratories, Net Houses etc. have been constructed. A new wing has been constructed for Division of Crop Improvement in the first floor. The Institute Headquarters has been renovated thoroughly, giving a totally new look to it, with modern laboratories, library, museum and millennium hall. Crop museum with the display of all mandatory crops is also being maintained for the visitors.

A number of new and sophisticated equipment have been added to the existing ones to raise the standard of research. These include several state-of-the-art equipments like the food extruder, texture analyzer, differential scanning calorimeter, FTIR, HPLC, HPTLC, atomic absorption spectrophotometer, auto analyser, gel documentation system, real time quantative PCR, nitrogen analyser, fibre analyser, genetic analyser etc. The infrastructural facilities of the Regional Centre have also been considerably improved through the creation of additional laboratory space, providing several new equipments.

Museum

Crop museum

Extramural support by way of research schemes from both international (like CIAT, CIP, CIRAD , European union, IFAD etc) and national agencies like DBT, DIT, DST, DRDO, DSIR, ICAR, JNU, KSCSTE, LSRB, MOEF, DoA, Kerala, KSPB, NABARD, PPIC, PVP & FRA, SHM, UGC etc., were a great boon to the Institute to upgrade the research infrastructure as well as to facilitate detailed studies on frontier areas of research. The Network projects of ICAR have helped the Institute to focus research on priority areas.

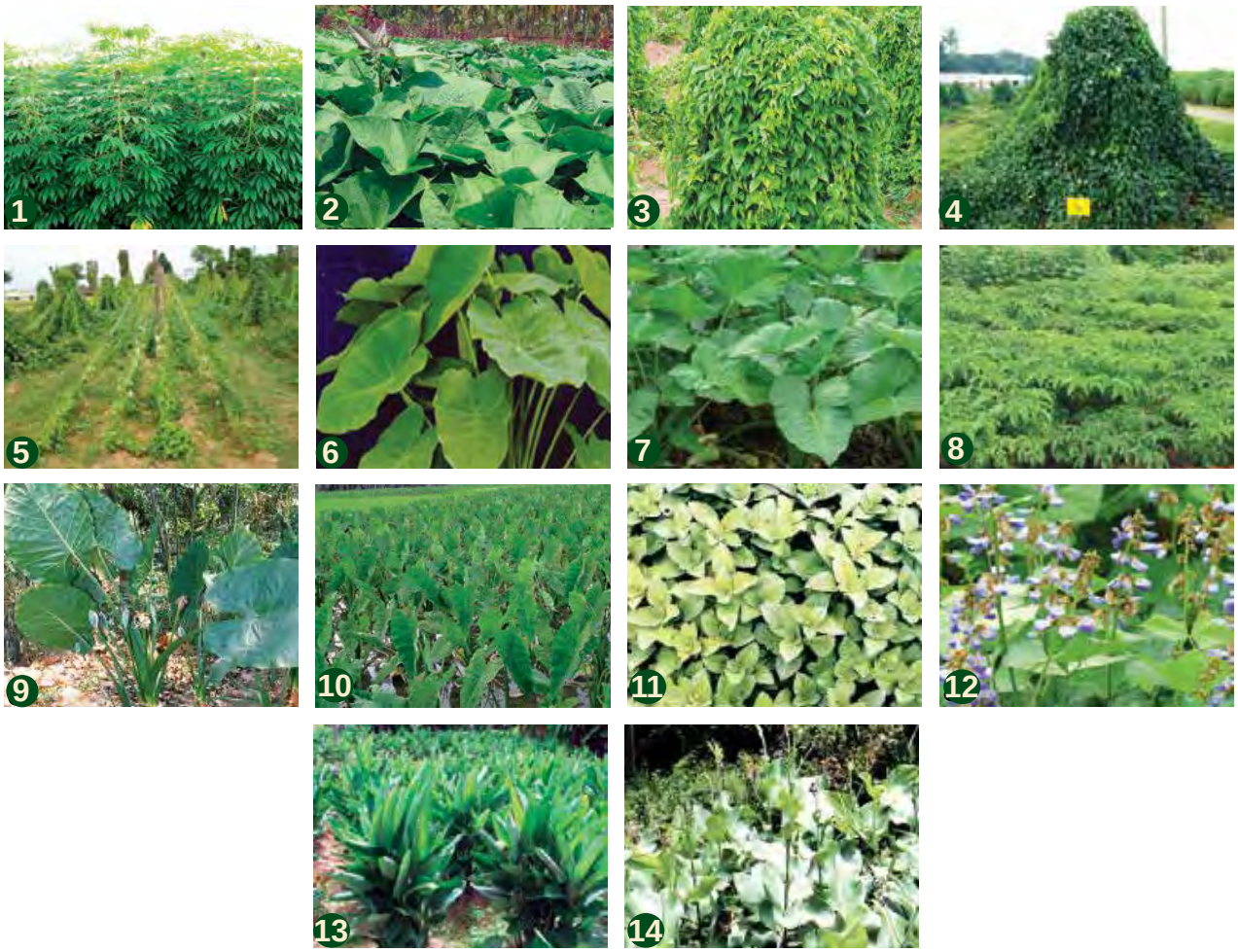
Institute Technology Management Unit (ITMU) of the Institute has been active in carrying out IP activities. The unit is engaged with public/private parties for the commercialization of technologies. The ITMU has taken initiative in filing patent applications.

Agriculture Knowledge Management Unit (AKMU) has 17 state of the art computers with centralised printing, high capacity file server with 8TB storage, 6 TB Storage server for Data Backup, proxy server with integrated Firewall, Anti Spam, IPS and Web Application Firewall, CISCO ASR 1002 Series Routers for high speed routing, connectivity with NKN, 1Gbps Powergrid fiber connectivity for Internet, 2mbps backup connectivity with BSNL for internet load balancer for peak internet traffic management, Unified Threat Management (UTM) appliance for Internet security, Internet content filtering with automatic internet access, Switchover to IPv6 in place of IPv4 being carried out step by step, Dual Layer protection against virus attack - antivirus on Internet gateway and centralized distribution on client nodes, automatic log generation, reporting and storage, Leased line video conferencing facility, VPN connectivity for global Access to the servers and touch screen information kiosk. A full fledged local area network connecting the various divisions and administration wing has also been established. The network consists of windows nt server, internet proxy server, intranet file server and email server, computers, laser printers, inkjet printers, scanners, dtp and multimedia work stations. Legal licensed versions of popular software packages like windows 98, windows, microsoft office 2000, Microsoft XP office, pagemaker 6.5, corel draw 6.0, ism multiscripts, visual studio etc. are installed for various type of applications. In addition to the supporting statistical softwares such as SAS, JMP Genetics, Genomics and R environment for statistical computing, WinBugs Visual Studio 2012, bioinformatics software DNASTAR and Laser Gene 11 Genomic Suite are installed to meet the computing requirements.

ICAR-CTCRI has set up a home page on the internet. This can be accessed at http://www.ctcri.org which provides a comprehensive picture about the various activities of the institute and various online facilities like sales counter, discussion forum etc.

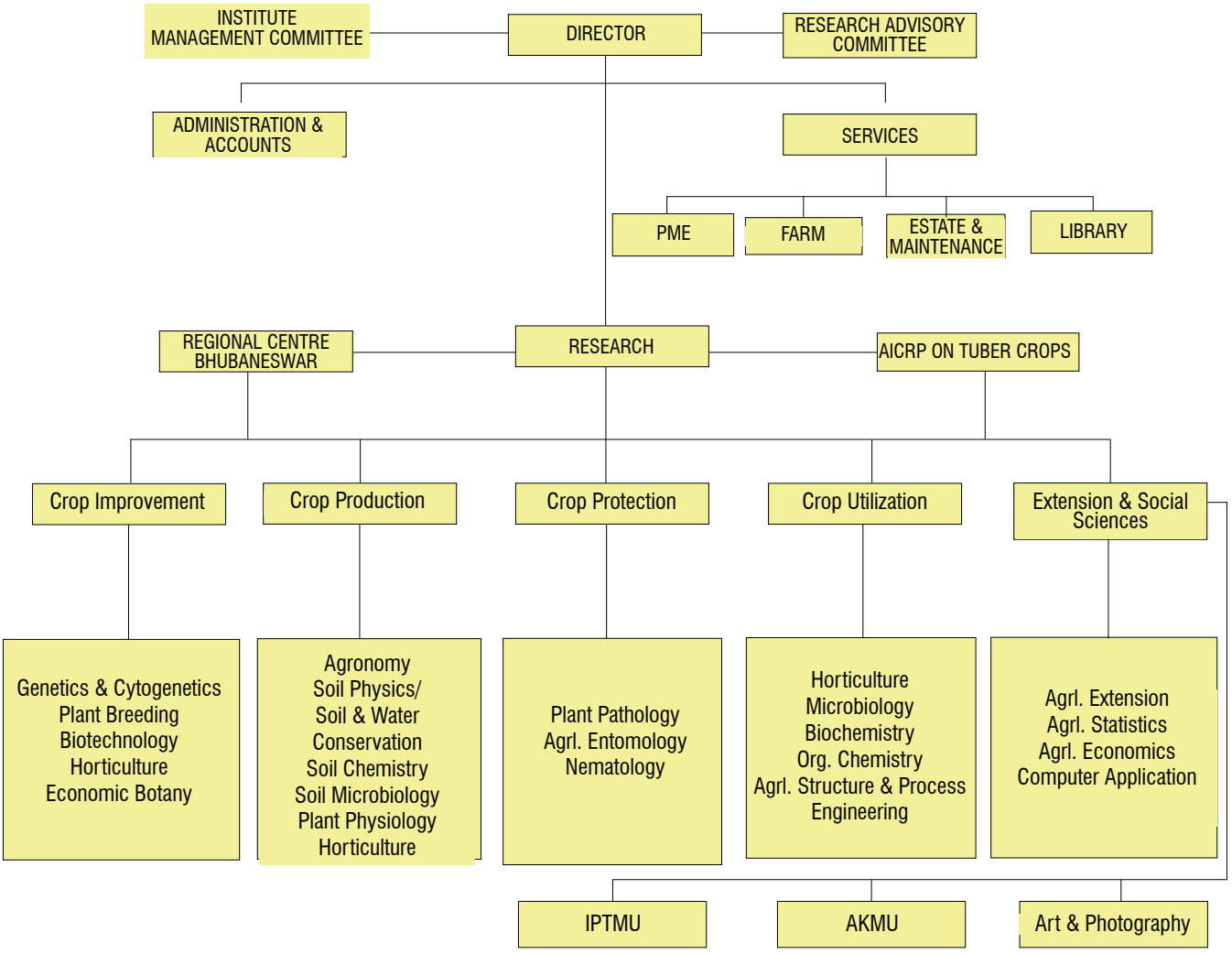
Regional Centre, ICAR-CTCRI, Bhubaneswar

Mandate Crops



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

Organisational Set up



Staff Position (2015-2016)

Category	Sanctioned	Filled	Vacant
RMP	1	1	0
Scientists	49	45	4
Technical	47	39	8
Administratiion	31	25	6
Skilled support staff	55	42	13
Total	183	152	31

Progressive Expenditure (2015-2016)

Plan

(Rupees in lakhs)

Sl. No.	Head of Accounts	RE 2015-16	Progressive Expenditure
1.	Works		
	A. Land		
	B. Building		
	i. Office building	53.07	53.07
	ii. Residential building		
	iii. Minor works		
2.	Equipments	102.90	102.91
3.	Information technology	10.99	10.98
4.	Library books & journals	10.07	10.07
5.	Vehicles & vessels		
6.	Livestock		
7.	Furniture & fixtures	27.97	27.97
8.	Establishment charges		
9.	Travelling allowances (Instt. + NEH)	32.00	32.00
10.	Research & operational expenses (Instt .+TSP + NEH)	159.00	159.00
11.	Administrative expenses	107.00	107.00
12.	Miscellaneous (Instt.+TSP+NEH)	6.00	6.00
	GRAND TOTAL (CAPITAL + REVENUE)	509.00	509.00
13.	AICRP on TC	550.00	406.01
14.	AICRP on PHT		7.75
15.	Plan Schemes		337.20

Non-plan

(Rupees in lakhs)

Sl. No.	Head of Accounts	RE 2015-16	Progressive Expenditure
1.	Works		
	A. Land		
	B. Building		
	i. Office building		
	ii. Residential building		
	iii. Minor works		
2.	Equipments	5.00	5.00
3.	Information technology		
4.	Library books & journals		
5.	Vehicles & vessels		
6.	Livestock		
7.	Furniture & fixtures	2.00	2.00
8.	A. Establishment charges	1171.00	1171.00
	B. Pension & other retirement benefits	165.12	165.12
	C. Loans & advances	10.00	3.09
9.	Travelling allowances	10.00	9.99
10.	Research & operational expenses	43.00	43.12
11.	Administrative expenses	111.50	113.74
12.	Miscellaneous	6.50	4.12
	TOTAL	**1524.12**	**1517.18**

INSTITUTE PROJECTS

CROP IMPROVEMENT

CONSERVATION AND UTILIZATION OF GERMPLASM OF TUBER CROPS FOR SUSTAINING PRODUCTION

Field gene bank

Cassava

A total of 1271 accessions of cassava comprising of the indigenous, exotic, landraces and breeding lines were planted in the field for maintenance, characterization and preliminary evaluation. These accessions were characterized for five qualitative above ground vegetative plant traits viz., early stem, leaf, petiole and lamina-petiole joint colour and cassava mosaic disease (CMD) incidence under field epiphytotic conditions (Fig. 1). The stem colour showed a wide range of variation from brownish, greyish, orange to violet. The leaf colour also showed much variation from green in 56 accessions to brownish green in 1045 accessions, while lamina-petiole joint colour varied from green in 457 accessions to purple in 714 accessions. Out of the 1271 accessions screened, 288 showed high incidence of CMD, while 513 accessions were found to be free of any symptoms in the early stages of plant growth.

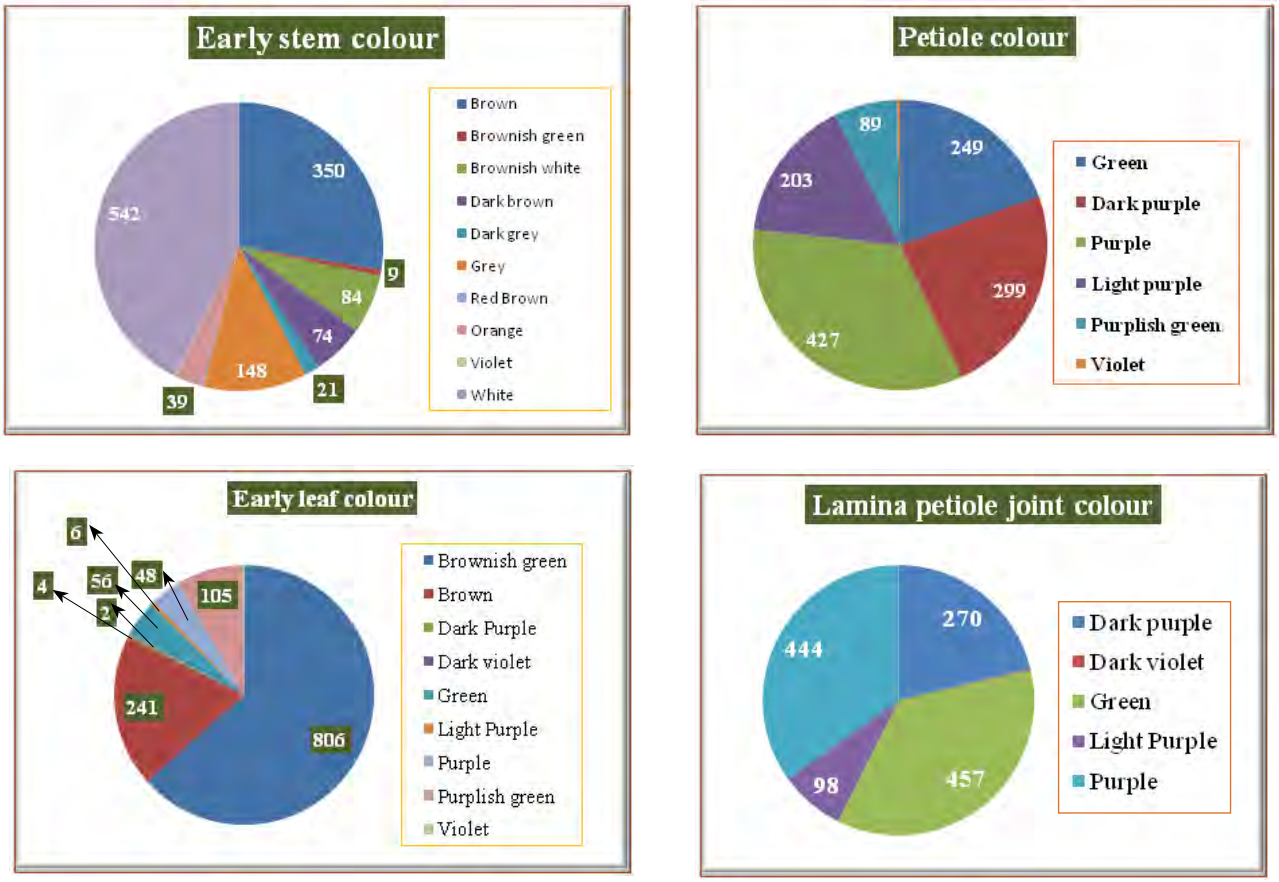
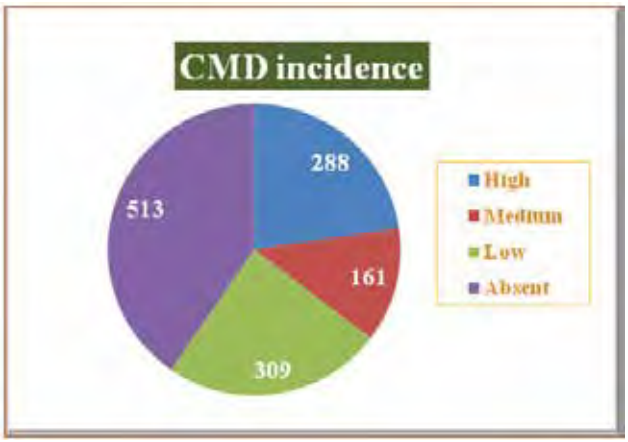


Fig. 1. Results of cassava germplasm screened for early stem, leaf, petiole and lamina-petiole joint colour and cassava mosaic disease incidence under field epiphytotic conditions



Resistant lines

Susceptible lines

Fig. 1 (contd). Results of cassava germplasm screened for early stem, leaf, petiole and lamina-petiole joint colour and cassava mosaic disease incidence under field epiphytotic conditions

DNA was isolated from 20 cassava accessions and was characterized using six SSR primers. The DNA was deposited in the DNA bank. Eighty exotic accessions of cassava were screened for cassava mosaic virus and 15 were free from symptoms.

Sweet potato

Augmentation of sweet potato germplasm was done with the addition of a total of six accessions from Joida Taluk, Uttara Kannada, Karnataka and two from Sirsi, Karnataka. A total of 1124 accessions are being maintained in the field gene bank.

During the period under report, 50 accessions were evaluated for 17 vegetative and six tuber characters based on IPGRI descriptors and yield in augmented plot design. The vine length varied from 120 cm (362-7) to 800 cm (No. 8). The high yielders were SD-11 (1.20 kg plant^{-1}), 526/7 (1.08 kg plant^{-1}), SD-55 (1.38 kg plant^{-1}), SD-24 (0.80 kg plant^{-1}), No. 8 (0.80 kg plant^{-1}), 112/6 (0.63 kg plant^{-1}) and No. 10 (0.96 kg plant^{-1}) (Fig. 2). Consistency of cooked tubers, texture and sweetness were assessed as per IPGRI descriptors. Among the orange-fleshed accessions, SD-11, SD-24, SP-10 and 148/12 were having very high starch and taste, but sweetness was high for SD-24. Among the white/yellow-fleshed, JASM5C, 526/12 and OP-S1 were tasty with medium to high starch and very high sweetness. Accessions, 112/11 and AF3 were having high starch and low sweetness. The vegetative and tuber characters were photo documented. The dendrogram based on qualitative traits revealed a wide diversity among the accessions studied (Fig. 3).

Fig. 2. A few high yielders of sweet potato

Fig. 2 (contd). A few high yielders of sweet potato

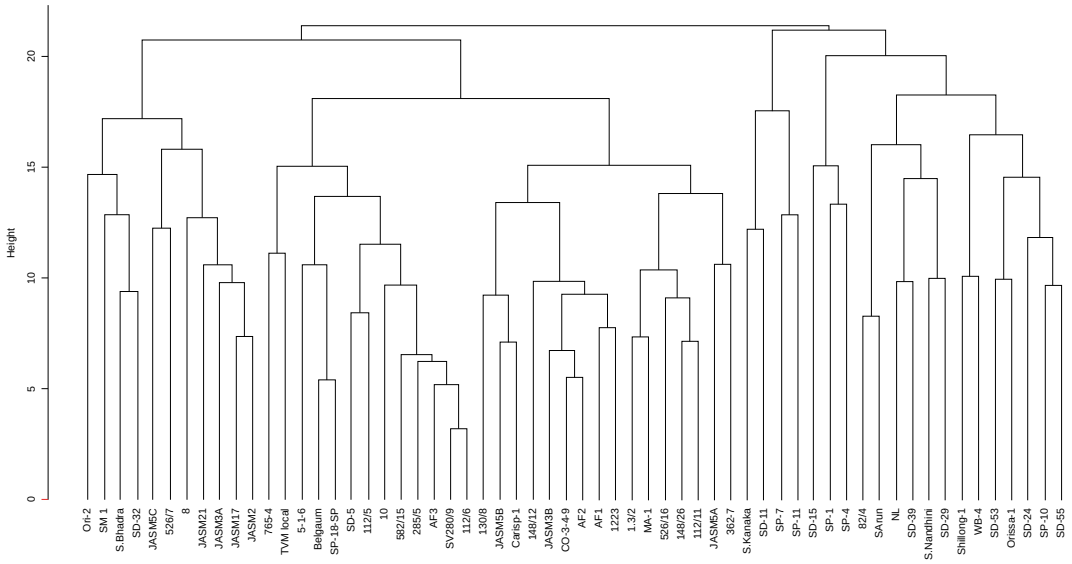


Fig. 3. Dendrogram based on morphological characters in sweet potato

Yams

Eight accessions of greater yam, three accessions of lesser yam and one accession of potato yam were added to the field gene bank. A total of 1110 accessions of yams comprising greater yam (591), white yam (158), lesser yam (220), potato yam (6) and wild yams (135) were replanted and conserved in the field gene bank. DNA gene bank was augmented with 130 accessions of yams. Morphological characterization of 100 accessions of greater yam from North Eastern states of India and Kerala was done for 30 IPGRI descriptors and the genetic diversity was analysed based on these traits. Also tuber characters of 220 accessions of lesser yam were recorded (Fig. 4). Molecular characterization of greater yam accessions (73), white yam (30) (Fig. 5), lesser yam (10) and wild yams were undertaken using 10 polymorphic SSR and 15 ISSR primers. The mantels test revealed significant correlation (0.56-0.70) among the results of different types of molecular markers (ISSR, SSR, RAPD) in white yam. Among the SSR primers screened, YM15 had the maximum number of polymorphic alleles (5) followed by Dab2D06 and YM26 with four alleles (Table 1). A high yielding, highly divergent white yam genotype, DR-17 (v 20) that could be used for the genetic improvement program in future was identified. Seven sets of duplicates were identified in greater yam.

Among 64 accessions screened for *in vitro* detached leaf assay for anthracnose resistance, 14 accessions showed high resistance to *Colletotrichum gloeosporioides* with no lesions. The promising accessions with high resistance to anthracnose disease include Da-112, TCR-36, TCR-102, TCR-246, Da-286b, Da-315 and Da-240a. Screening of lesser yam accessions (50 acc.) for yam mild mosaic virus using DAS ELISA showed the presence of virus in 60% of the samples.

Fig. 4. Variability in tuber shape in greater yam

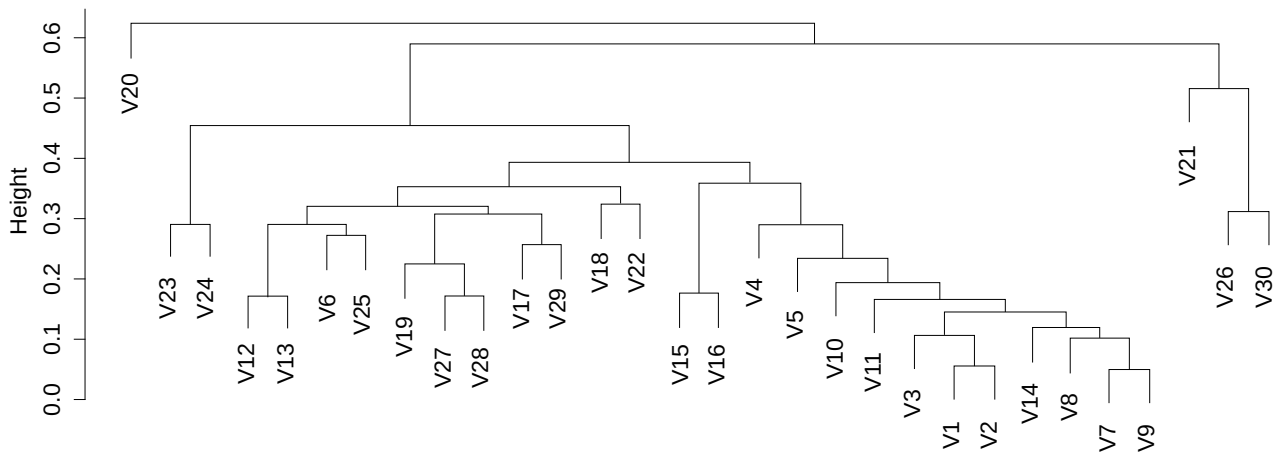


Fig. 5. Dendrogram showing diversity of white yam accessions based on ISSR markers

Table 1. Genetic characteristics of the SSR markers used for analyzing the white yam accessions

Primers	Polymorphic alleles per locus	Heterozygosity	PIC
Dab2C05	1	0.4339	0.3398
Dab2D06	4	0.7732	0.7388
Dab2E07	1	0.4444	0.3457
Da1A01	2	0.4592	0.3538
Dpr3F04	2	0.6052	0.5376
YM5	2	0.4998	0.3749
YM15	5	0.7750	0.7377
YM26	4	0.7459	0.6986
MT 13	2	0.4918	0.3709
MT 10	2	0.4872	0.3685

Edible aroids

The edible aroid germplasm was augmented with seven taro (Karnataka and Nagaland); four elephant foot yam (Joida, Karnataka; Udaipur, Rajasthan and Vizhinjam, Kerala); one tannia variety-Konkan Haritparni and two *Alocasia* (Karnataka and West Bengal) collections during the period under report.

A total of 671 edible aroid germplasm comprising 429 taro, 203 elephant foot yam and 39 tannia are being maintained in the field gene bank.

For identification of taro leaf blight resistant lines amongst the germplasm, 212 taro accessions were subjected to field screening during the rainy season, where 56 were found as highly susceptible, 18 were susceptible and 138 showed tolerance.

Nineteen taro collections from Arunachal Pradesh, Uttara Kannada and Nagaland were subjected to morphological characterization using 30 above ground traits. Nine tuber characters of 21 collections from Nagaland were completed. Molecular characterization using 10 polymorphic SSR markers were done for 30 taro accessions from Kerala. All the primers gave polymorphic bands. The PIC value ranged from 0.639 to 0.857 (Table 2). The highest heterozygosity was obtained for the primer uq 97-256 with a value of 0.871 and the lowest was obtained for the primer uq 84-207 with a value of 0.694. Number of alleles per locus ranged from 1.90-4.56 with the maximum alleles shown by uq 97-256 and the minimum showed by uq 84-207 and uq 201-302. The dendrogram showed that no correlation was seen between geographical origin of the accessions and the cluster grouping. Further, no duplicates could be identified. The DNA was deposited in the DNA bank.

Table 2. Polymorphic information content (PIC) of the ten SSR primers studied

Sl. No.	Primers	Heterozygosity	PIC	Alleles per locus
1	uq 73-164	0.833	0.814	3.57
2	Ce1 C03	0.844	0.825	2.10
3	uq 97-256	0.871	0.857	4.36
4	Ce1 B03	0.810	0.784	2.73
5	Ce1 F04	0.805	0.777	3.63
6	Ce1A06	0.803	0.774	3.73
7	Ce1 C06	0.768	0.734	1.87
8	Ce1 H12	0.805	0.777	3.60
9	uq 84-207	0.694	0.647	1.90
10	uq 201-302	0.871	0.639	1.90

Morphological characterization in 30 elephant foot yam accessions was initiated. Eighteen above ground traits and twelve tuber characters were recorded. Molecular characterization using nine ISSR markers were done for 12 elephant foot yam accessions including cultivars and wild ones. The similarity coefficient ranged from 0.62-0.93. No duplicates could be identified.

Minor tuber crops

A total of 200 accessions comprising 112 Chinese potato, 70 yam bean, 9 *Curcuma* spp., 7 *Maranta arundinacea*, one each of *Coleus aromaticus* and *Vigna* sp. were planted and maintained in the field gene bank.

Seven arrowroot germplasm collections from different states were characterized for 20 (5 quantitative and 15 qualitative) above ground vegetative plant traits (Table 3). The plant height ranged from 101.60 cm (M2) to 112.40 cm (M4) while, stem diameter ranged

from 9.00 cm (M2) to 16.60 cm (M7). The leaf lamina length and width were highest for M4 (31.60 cm) and M1 (11.98 cm) collections, respectively. The highest petiole length of 37 cm was recorded in the M4 collection. However, the stem colour, stem sheath colour, sheath margin and tip colour, stem hairiness, leaf lamina, margin, tip and vein colour, leaf hairiness, petiole colour and flower colour did not show any variation.

Table 3. Quantitative plant traits of seven *Maranta* accessions

Acc.	Plant height (cm)	Stem diameter (cm)	Leaf lamina length (cm)	Leaf lamina width (cm)	Petiole length (cm)
M1	102.80	9.70	31.40	11.98	26.30
M2	101.60	9.00	31.50	10.58	29.40
M3	101.80	10.94	29.40	11.08	30.80
M4	112.40	12.00	31.60	10.70	37.00
M5	110.60	14.60	30.10	10.70	29.40
M6	108.60	13.60	29.60	10.42	29.00
M7	108.00	16.60	29.90	10.48	30.60
Mean	106.54	12.35	30.50	10.85	30.36
SD	4.44	2.74	0.96	0.54	3.28
CV %	4.16	22.19	3.16	5.01	10.80

Among the seven accessions, the rhizome yield per plant (1.4 kg) and single rhizome weight (202 g) was highest for M1. Number of rhizomes per plant was the highest in M2 (18). Rhizome length was the highest for M7 (31.6 cm), while, the girth was highest for M1 (12 cm). The highest value of rhizome neck length (4.4 cm) was recorded in M1 and node length (1.6 cm) in M5 (Table 4).

Table 4. Quantitative traits of rhizomes in seven *Maranta* accessions

Acc.	Number of rhizomes	Rhizome length (cm)	Rhizome girth (cm)	Neck length (cm)	Node length	Tail length (cm)	Rhizome weight/ plant (g)	Single rhizome weight (g)
M1	16	30.10	12.00	4.20	1.58	1.08	1400	202.00
M2	18	22.30	10.30	4.40	1.48	0.86	900	92.30
M3	16	24.00	9.80	3.70	1.34	1.26	920	145.00
M4	18	25.40	9.70	3.70	1.24	1.90	1000	154.30
M5	15	25.30	9.70	3.20	1.60	1.28	840	197.50
M6	16	24.80	8.70	4.00	1.26	1.10	1120	128.50
M7	14	31.60	8.70	3.90	1.70	2.56	1100	142.00
Mean	16	26.21	9.83	3.87	1.46	1.43	1040	151.65
SD	2+	3.36	1.12	0.39	0.18	0.59	189.38	38.37
CV	9.35	12.83	11.37	10.08	12.37	41.30	18.21	25.30

Molecular characterization

Seven accessions of arrowroot germplasm screened using 12 ISSR markers produced 124 bands of which, 66 were polymorphic. The accessions formed two major clusters with two outliers in the grouping. Cluster I and II consisted of two and three accessions, respectively and had 72% similarity (Fig. 6). The similarity coefficient ranged from 0.61 to 0.88. The accessions from Kerala and Maharashtra remained as outliers with only 65% similarity.

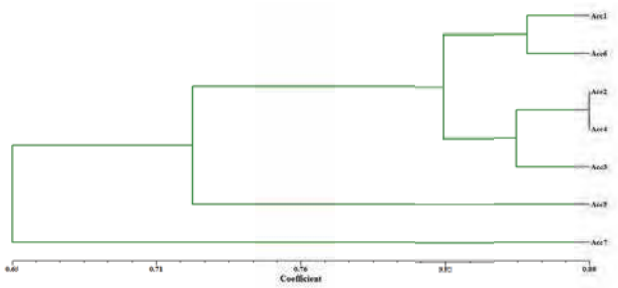


Fig. 6. Dendrogram showing the clustering pattern in seven *Maranta* accessions using 12 ISSR markers

Regional Centre

The germplasm collection at the Regional Centre was enriched with the addition of seven new accessions, which includes sweet potato (2), taro (3) and yam (2). A total of 1242 germplasm accessions are maintained in the field gene bank, which comprised, taro (506), taro breeding lines (97), sweet potato (373), yam (51), elephant foot yam (41), yam bean (146), Chinese potato (5), arrowroot (2), tannia (1) and *Alocasia* (3). Edibility test for leaves and petioles of 250 taro accessions were done.

In vitro conservation of tuber crops germplasm

Under *in vitro* conservation of germplasm, 211 accessions of sweet potato including 65 accessions from NBPGR and accessions from pre-identified core collections and released varieties of tuber crops like cassava (two breeding lines, 13 varieties, three landraces and 18 accessions); sweet potato (nine varieties); yams (seven accessions and 10 breeding lines) are being maintained *in vitro*.

Apart from these, 38 sweet potato, 21 taro, 12 cassava, five yam, five Chinese potato, two elephant foot yam and five yam bean varieties and pre-release varieties as well as elite lines are being maintained *in vitro* at Regional Centre. A total of 875 cultures of released and exotic lines are maintained under *in vitro* conditions at Regional Centre.

GENETIC IMPROVEMENT OF TUBER CROPS THROUGH CONVENTIONAL BREEDING AND MOLECULAR APPROACHES

Cassava

Two thousand four hundred and fifty hybrid seedlings of cassava were planted for evaluation. It included 572 hybrid seedlings produced by crossing early bulking clones *viz*., Vellayani Hrazwa, 9S-127, CI-889, 9S-132 and CR-54A-3. The hybrids with starch >30% were 9S-73, 11S-30, 8S-501-2, 9S-164, 9S-174, 11S-7, 11S-33, 11S-4, 8W-5 and 9S-127. Six new hybrid seedlings had dark yellow flesh colour (15S-82, 15S-91, 15S-171, 15S-172, 15S-173, 15S-210). The dry matter content of the hybrid seedlings ranged from 13.90% (15S-122) to 52.56% (15S-285) and 100 seedlings had dry matter >40% (Fig. 7). The clones with higher dry matter contents (50-52%) were 15S-183, 15S-300, 15S-298, 15S-333 and 15S-285.

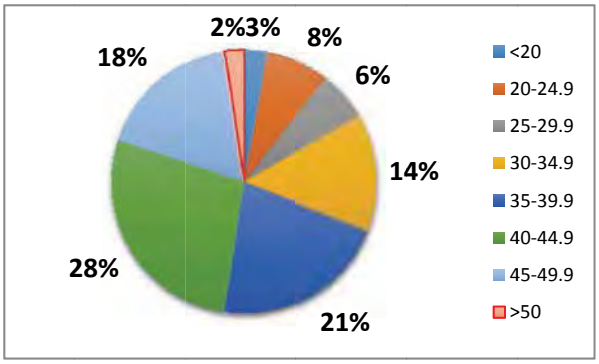


Fig. 7. Variation in dry matter content among CMD resistant F_1 hybrids of cassava

Thirty CMD resistant genotypes identified through screening were evaluated for 14 desirable traits at five months after planting to identify early bulking clones. The plant height of the genotypes ranged from 100 cm (S-1284) to 250 cm (15S-135). The stem girth ranged from 11cm (AR-1) to 16 cm (15S-288). The leaf retention was found to be very high in 8W-5, 15S-255, 15S-432, 15S-240 and 15S-436 indicating drought tolerance of these clones. The harvest index ranged from 0.04 (15S-430) to 0.59 (15S-66). Eight genotypes had high harvest index (>0.5), an important trait linked to productivity. Number of tubers per plant ranged from 1 (15S-426) to 20 (15S-433). Weight of tubers/plant ranged from 0 (15S-426) to 2.80 kg (15S-57) per plant at five months after planting. Dry matter ranged from 22% (CR-24-4) to 58% (15S-130). Among the CMD resistant hybrids identified and evaluated, 15S-57, 15S-66, 15S-135, 15S-130 and 15S-67 were found to be promising with CMD resistance (Fig. 8) coupled with earliness, high tuber yield and dry matter content.

Among the CMD resistant hybrids evaluated in advanced yield trial, 8S-532, 9S-125, 9S-736, 11S-4 and 11S-33 showed good culinary quality coupled with CMD resistance.

Fig. 8. Field screening of cassava hybrids for resistance to CMD

An experiment was carried out to develop tetraploids in CMD resistant clones with good flowering viz., 9S-127 using four levels of colchicines (10, 20, 30, 40 µM). The regenerated plants are being hardened for further screening (Fig. 9).

The CMR-100 cassava line with good fried chip and cooking quality was evaluated for agronomic performance and to standadize spacing and fertilizer dosage. The yield level of CMR-100 in different treatments were not up to the expected level, which may be due to the late planting since the variety is not suitable for dry condition. To assess fried chip quality, seven lines (CMR-100, 11S-33, CR-20A-2,

8W-5, CR-21-10, CR-24-4, 9S-165) along with one standard check (Sree Vijaya) were planted to evaluate yield and quality of chips.

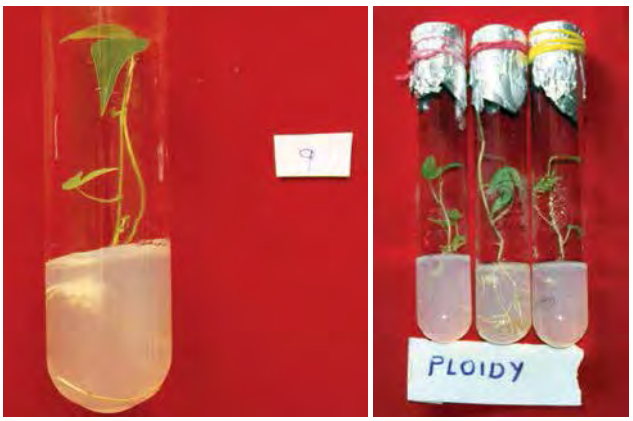


Fig. 9. *In vitro* ploidy manipulation in cassava

Sweet potato

To address the national and international gaps of sweet potato breeding and to satisfy the consumer demands, breeding programmes, aimed at achieving the following targets, were carried out: yield of >17 t ha^{-1}, higher starch of >18%, β-carotene (>14 mg $100g^{-1}$) and anthocyanin (>1g $100g^{-1}$) contents with reduced crop growth cycle (75-90 days) and weevil resistance (infestation less than 8%). A thorough study of germplasm collections, OP generated breeding lines and diallel bred lines enriched the programme with the following results towards the achievable targets.

A stock of 265 genotypes was evaluated, of which 22 were observed to be promising (orange-3, rest 19-white). Out of those evaluated in the succeeding year, 75 days maturity was observed only in seven lines (1-orange and 6–white fleshed lines) (Fig. 10).

OP generated breeding lines

Open pollination generated 29 breeding lines, of which 9-purple, 9-white, 11–orange fleshed were evaluated consecutively for the 4th clonal generation, 90 days maturity was observed in 5-purple and 2-white fleshed lines (Fig. 11).

Diallel crosses

A total of 266 crosses were made among the 20 promising parental combinations such as 6 white, 7 purple, 7 orange-fleshed lines maintained in pollination block. About 995 seeds were collected, out of which 50% germinated. Of the 500 seedlings, clonal generation were raised from 325 seedlings. Progressive evaluation of clonal generations of F1 hybrids of those revealed 75 days maturity in 12 lines with an yield of 20.40 to 25.60 t ha^{-1}. Flesh colour observed were orange-4, light purple-1, light orange-1 and white-6 (Fig. 12). Of the 12 lines, 4 lines (orange-2, white-1, light purple-1) had no weevil attack even under dry spell. All these when harvested after 110 days of planting showed less than 10% infestation.

Overall assessment

All the improved lines evaluated from germplasm collections, OP or diallel bred gave yield more than 17 t ha^{-1}, starch (>16%), β-carotene (>10 mg $100g^{-1}$) and anthocyanin contents (>75mg $100g^{-1}$). Few such lines (Fig. 13a & b) had starch >18%, β-carotene (>14 mg $100g^{-1}$) and anthocyanin (>1g 100 mg^{-1}). All these lines were also observed with less (<8%) weevil infestation. Of the 619 genotypes (265 germplasm + 29 OP lines + 325 diallele bred hybrids) evaluated for early maturity, with other valued traits, 26 were observed to be of early maturing types. 19 matured by 75 days including C_1 of F_1 hybrids (Figs. 14 & 15) and 7 had 90 days maturity including germplasm and OP lines.

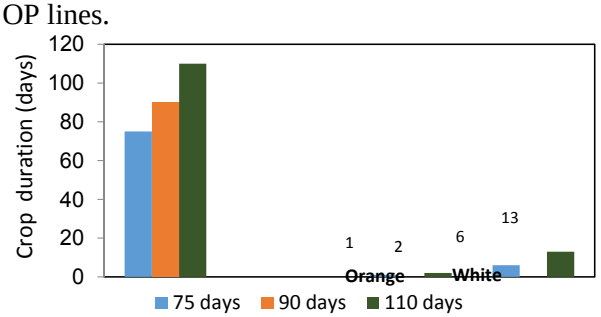


Fig. 10. Crop duration of germplasm lines with different flesh colour

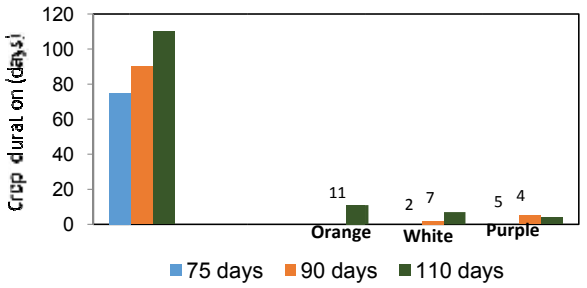


Fig. 11. Crop duration of open pollinated lines with different flesh colour

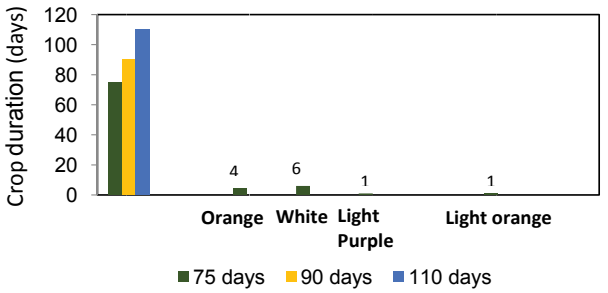


Fig. 12. Crop duration of diallel bred lines with different flesh colour

Fig. 13. Improved sweet potato (BL-Breeding line) with higher starch and β-carotene (>14 mg/100 g) [a]; with higher starch and anthocyanin (>1g/100g) [b]

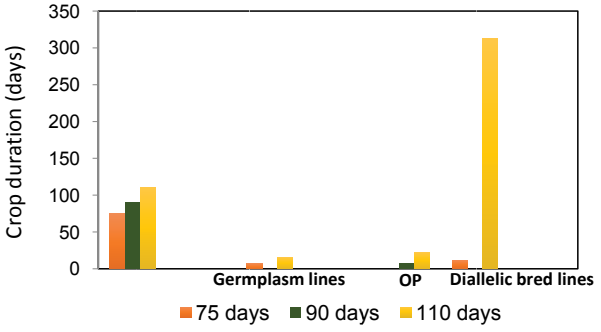


Fig. 14. Overall assessment for early maturity of sweet potato genotypes

Fig. 15. Clonal generation of F1 hybrids with 75 days maturity sweet potato

Yams

In the advanced yield trial of greater yam clones, Dah-9/196 produced the highest yield (30.20 t ha^{-1}) followed by Da-293 (Fig. 16) under non-trailing conditions. Seven hybrids of greater yam (Da H-22-2-3, DaH-10-54, DaH-58F x 967, DaH-58FG, DaH-9-155, DaH-18-227 and DaH-5) showed high resistance to *Colletotrichum gloeosporioides* causing anthracnose, with no lesions.

Fig. 16. Da-293, a promising pre-release clone suited to non trailing condition

Two white yam hybrids with high tuber yield (Fig. 17) and cooking quality viz., Drh-657 (58.60 t ha^{-1}) and Drh-1047 (50.66 t ha^{-1}) were identified for release. Among the eighth clonal white yam hybrids evaluated, Drh-1150 yielded the highest (61.70 t ha^{-1}) followed by Drh-1125 (59.70 t ha^{-1}). Among the dwarf white yam hybrids (eighth clonal) evaluated, Drd-1038, Drd-1110, Drd-1835, Drd-920, Drd-1089 and Drd-1078 had excellent cooking quality and were found to be superior to the released dwarf variety,

Sree Dhanya. Among the semi-dwarf varieties of white yam, Drd-1110, was the highest yielder (35.80 t ha^{-1}). Among the semi- dwarf varieties of white yam, SD-15 produced high yield (43.20 t ha^{-1}) coupled with excellent culinary quality.

Fig. 17. Pre-release white yam hybrid, Drh-1047

Taro

For identification of taro leaf blight resistance, 19 taro accessions were screened artificially of which six (IC087153, IC012601, IC012294, IC310104, TCR 267 and TCR 326) showed moderate resistance. Further, for the identification of molecular markers associated with taro leaf blight, 13 ISSR and 10 SSR markers were screened. Five ISSR markers showed promise as it gave an extra band in five of the six resistant lines studied. UBC 825 (Fig.18) and $(AG)_9AC$ gave an extra band in all the six accessions selected in 685 bp and 808 bp regions, respectively and can be used for further studies.

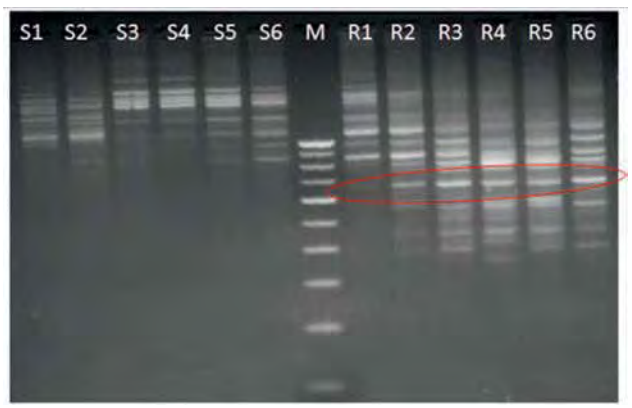


Fig. 18. ISSR marker UBC 825 showing an extra band in all the six resistant accessions (R1 to R6) of taro

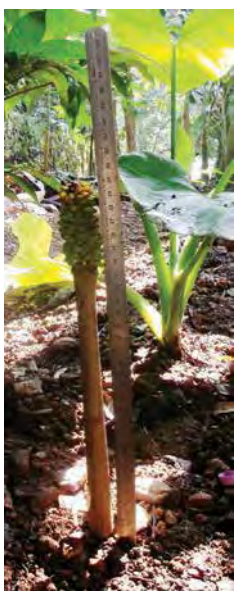
Fifteen flowering lines of taro including two TLB tolerant lines (C-565 and C-450) were planted in a breeding block. However, flowering was not obtained this season. This year, it will be replanted for flowering along with more TLB resistant lines available and high yielding non acrid lines with good cooking quality.

Preliminary Yield Trial (PYT) II for taro was harvested and evaluated. During the second season, only IC211587 outperformed Sree Rashmi (Check) having an average yield of 11.62 t ha^{-1}. The selected seven lines were planted for advanced yield trial. The percentage oxalate content ranged between 0.19 to 0.31% on dry wt. basis and all had good cooking quality.

Elephant foot yam

In elephant foot yam, during 2015-16, the F1 progeny (from the cross between two high yielding elephant foot yam lines crossed during 2014-15) and the F1C1 progeny (from the cross between Am 159 (F) x Am 158 (M) crossed during 2013-14) were harvested and the weight and shape of corms and presence of cormels were recorded. These will be planted in the field to obtain big sized corms for recording yield and acridity. The corm weight was recorded in the F1C1

Am 156 x Gajendra



Am157 x Gajendra

Fig. 19. Elephant foot yam infructescences obtained from different crosses

(Family 1) and F1 (Family 2) progeny. The corm weight ranged from 0.20 to 100 g in the former and in the latter it ranged from 0.40 to 93.68 g.

During 2015-2016, seven crosses were made. Of these, four crosses were successful. Gajendra was the male parent in three crosses. The female parents were Am 158, Am 157 and Am 156 (Fig. 19). More than 1000 seeds were obtained from these crosses which will be sown this year.

Tannia

In tannia, a PYT was initiated with seven accessions. The average cormel yield per plant ranged from 14.40 g (Xa-12) to 85.80 g (Xa-MNS/14-1). The harvested cormels were planted for PYT II in RBD with three replications.

Arrowroot

To develop high yielding arrowroot varieties with high starch, low fibre content and good culinary quality through clonal selection, rhizome multiplication of seven arrowroot genotypes was done during the period 2015-16. The harvested rhizomes were kept for planting in RBD for Advanced Yield Trial during the next year (2016-17).

Analysis of the biochemical parameters in the rhizomes of seven arrowroot genotype on fresh weight basis showed that the total starch content ranged from 15.61% in the accession M5 to the highest value of 20.21% in the accession M1, while the total sugars ranged from 0.11% in M5 and M7 to 0.12% in the others. The total crude fibre content was lowest for the accession M1 (0.52%) and highest for the accession M6 (1.36%). The crude protein content was highest for M1 (6.95%) and the lowest for M2 (4.25%). The total ash content was the highest in M2 (4.10%) and the lowest in M1 (3.30%) (Table 5).

Yam bean

To develop high yielding yam bean variety with other nutritional traits, 45 F_1 hybrids along with check variety (RM-1) were planted in 2015 for evaluation of yield and other yield contributing traits. Another

Table 5. Biochemical evaluation of rhizomes of arrowroot (on fresh weight basis)

Sample No.	Total starch (%)	Total sugar (%)	Total crude fibre (%)	Total ash (%)	Crude protein (%)
M1	20.21	0.12	0.52	3.30	6.95
M2	20.17	0.12	0.78	4.15	4.25
M3	18.16	0.12	0.61	3.90	6.10
M4	20.16	0.12	0.82	3.90	6.05
M5	15.61	0.11	0.86	4.00	5.95
M6	18.68	0.12	1.36	3.60	5.95
M7	19.56	0.11	1.02	4.00	6.05
CV	8.82	4.18	32.51	7.56	13.69

set of 45 F_1 seeds were raised for production of F_2 generation for evaluation of successive generation. Among all the F_1 hybrids, five best hybrids were identified and selected based on yield evaluation (3 x 10, 9 x 10, 3 x 5, 3 x 8 and 3 x 9) (Fig. 20). Tuber yield ranged from 43.33 t ha^{-1} (3 x 9) to 46.66 t ha^{-1} (3 x 10) as compared to 27.77 t ha^{-1} in RM-1 as a check variety. Analysis of biochemical parameter showed that starch content ranged from 11.12 to 17.33% and sugar content ranged from 5.88 to 8.06%.

Fig. 20. Promising F1 hybrids of yam bean

Gene for pyramiding for CMD resistance

In this experiment, for pyramiding of genes for CMD resistance, a total of 325 hybrid seeds from TMS-96/1089A x CR-43-11, TMS-30572 x CR-43-11 and reciprocal crosses were made and the seeds were raised in a nursery and planted in the main field for

evaluation of CMD resistance and for the presence of both *cmd*-1 and *cmd*-2 genes in the progenies. A total of 150 seedlings were identified as true hybrid seedling and having *cmd*-1 and *cmd*-2 genes using CMD associated SSR markers.

Identification of marker linked to high starch in cassava

An experiment was initiated to identify markers linked to high starch content in cassava where, two high starch (CR-43-2, 9S-127) and two low starch lines (CR-43-7, 9S-174) were selected for developing hybrid seedlings. The clones of these lines were already planted in the main field for pollination purpose.

Genetic modifications for quality improvement in cassava

To develop genetically modified cassava varieties with high starch content and also modified starch, i.e. waxy starch, CMD resistant cassava accessions 9S-127 and CR-4311, selected for genetic modification were multiplied under *in vitro* condition. Friable embryogenic callus (FEC) was initiated in CMD resistant cassava 9S-127 (Fig. 21).

The *Agrobacterium* EHA105 having *glgC* gene was confirmed for the presence of *glgC* gene and the revived colony was confirmed as *Agrobacterium* through molecular and biochemical methods; i.e. PCR with *Agrobacterium* specific primers and 3-ketolactose test. The TMS60444 cassava FEC was transformed with *Agrobacterium* EHA105 having *glgC* gene, the gene responsible for enhancing starch content in cassava. The transformed colonies were maintained in maturation media.

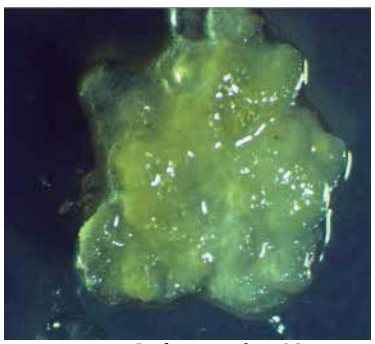


Fig. 21. FEC of cassava line 9S-127

Molecular marker development in CMD resistance using bioinformatics tools and its validation

The preliminary data set for the identification of SSR/SNP markers was obtained from the EST section of NCBI (http://www.ncbi.nlm.nih.gov/nucest) and the cassava transcript sequences (variety AM560-2, JGI annotation v4.1) from the Phytozome website (http://phytozome.jgi.doe.gov/pz/portal.html). A total of 120461 sequences belong to 20 cultivars (Table 6)

Table 6. Classification of the sequences based on the cultivars

Sl. No.	Cultivars	No. of sequences in NCBI
1	arg7	2924
2	Cas36.04	488
3	Cm523-7	3608
4	cm21772	95
5	crantz	4764
6	Iac 12.829	63
7	ku50	172
8	mper183	3391
9	mbra685	2506
10	mcol1522	1979
11	h226	21
12	mirassol	210
13	mnga2	40
14	mtai16	35400
15	sauti	5046
16	Sg107-35	720
17	w14	2089
18	Cas36.01	254
19	Others	22540
	TOTAL	86310
1	Am560-2	34151

After pre-processing and screening, the dataset was reduced to 14336 sequences. Since our aim was to predict SSRs and SNPs related to cassava mosaic disease resistance, the sequences were compared with virus resistant genes under the screening stage and significant reduction in time taken for the identification of SSRs and SNPs could be achieved (Table 7). The resulting sequences were assembled and aligned using CAP3 and 2088 contigs were obtained. These

contigs were used in Quality SNP and 56 SNPs were identified. In that 30 SNPs were nonsynonymous and 26 SNPs were synonymous SNPs. From that five sequences were selected for primer designing. From the 2088 contigs using MISA, about 537 SSRs were identified. In that 217 were mono, 132 were di, 139 were tri, 3 were tetra, 1 was penta 3 was hexa and 42 complex SSRs (Table 8). Five sequences, which had high hit percentage were selected for validation and primer designing. Among the 10 primers, after validation, one SNP (SNP 896) and one SSR (SSR 2063) primer was able to clearly differentiate between the resistant and susceptible varieties (Tables 9 and 10; Figs. 22-24).

Table 7. Characterization of the SNPs

Characterization	Type of single nucleotide change	No: of SNPs	Total
Transition	C/T	33	67
	G/A	34	
Transversion	A/C	14	54
	A/T	11	
	C/G	17	
	T/G	12	

Table 8. Distribution of the SSRs

Type of SSR	No: of SSR
Mono	217
Di	132
Tri	139
Tetra	3
Penta	1
Hexa	3
Poly	42
Total	537

Table 9. The list of SSR and SNP primers that were designed for validation of SNP and SSR markers for CMD resistance genes

SSR PRIMER LIST

Sl. No.	Primer No.	Forward primer (5′-3′)	Reverse primer (5′-3′)
1.	Contig254	CAGCCACATCAGAATCAGCG	GCATCAGTCACATCTGCAGC
2.	Contig1362	ACTGCATCGCAACTTTCAGC	TGGGTAAGCTTTCCTGCTAGC
3.	Contig1053	CTATGGTCCATCGGCCTGTC	ACCCAACACTCACAACCTGG
4.	Contig2063	TAGAGGAGTGGGAGCTTGGT	CCTGGAAAGCACAGTTGTTGG
5.	Contig414	CAACCAAAGAAAGCGGAGGC	ACATGCAGATCTGTGATCTTCT

SNP PRIMER LIST

SI. No.	Primer No.	Forward primer (5′-3′)	Reverse primer (5′-3′)
1.	Contig896	CACTGTGTGTGCATGGAAGC	GGAACCCAGTAAGCAGGCAT
2.	Contig1043	CAATTCCGGCGTCAACCATG	CGCTCAAATGGTCCACTGGT
3.	Contig361	CCGTTAATCAGGCAGGTGGT	GGATCGCACTCATGGTCACA
4.	Contig463	GCCTGCTGTCTTCGACAAGT	GGTGGCATCCATCTTGTTGC
5.	Contig1136	GCGACTGCCCTTTAACCTCT	GGTCAAGAAAGCCTGCTCCA

Table 10. The list of resistant and susceptible cultivars used for validation

Sl. No.	Resistant	Susceptible
1	TME3	Co-2
2	MNga	Co-3
3	1089A	Ambakkadan
4	Albert	Sree Apoorva
5	0304	Sree Athulya

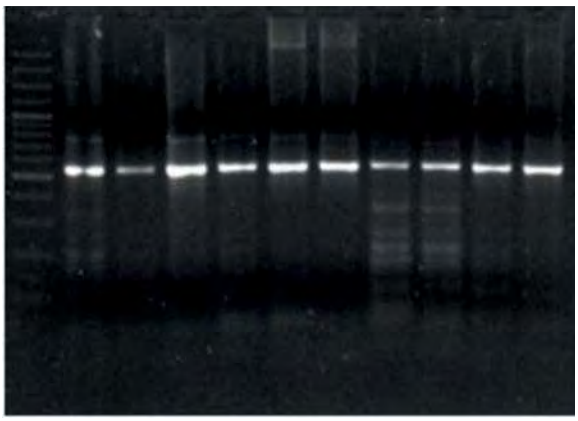


Fig. 22. Gel image of SNP 896

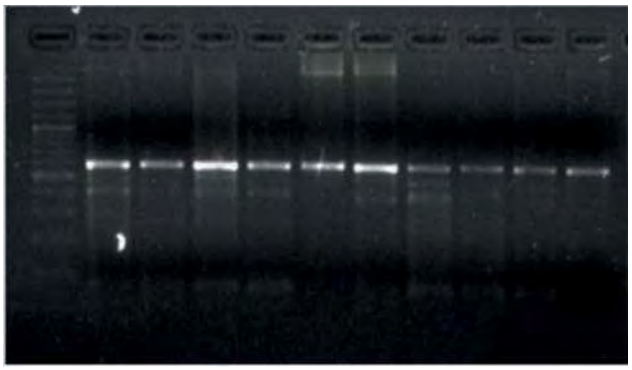


Fig. 23. Gel image of SNP 1136

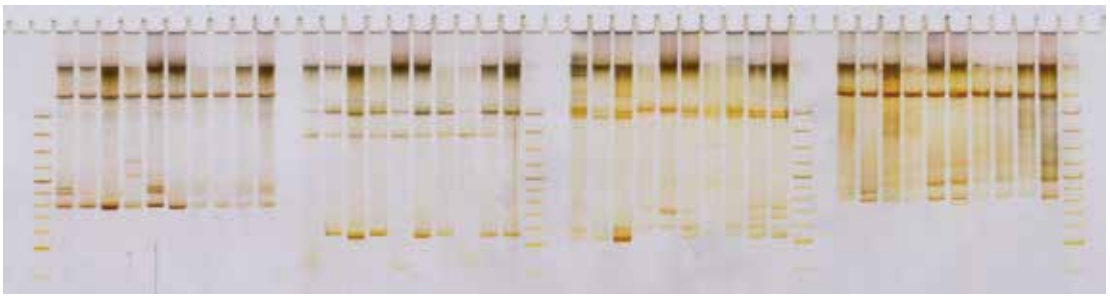


Fig. 24. Gel image of SSR 1362, SSR 1053, SSR 2063 and SSR 414

The SNP 896 in MNga showed SNP at the 1493th position as designed, but with a variation in the base.

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Contig896       CTCGCTGTGAAGCATCCAGATGGGTATATAGAAATCAAGGATAGAAGCAAGGACATTAGC 1440
2R              CCCACT--CAGGCTTCCA------------------------------------------ 490
                * *.**   *.**:****

Contig896       ATTTCAGGAGGTGAAAACATTAGTAGCTTGGAAGTAGAAAATGTGCTATATACGCACCCA 1500
2R              ----------------------------------------------------TGCACCAC 498
                                                                    *****..

Contig896       GCAGTGTATGAAGTATCTGTGGTAGCCAGAGAAGATGAGCGATGGGGAGAGTCCCCCTGT 1560
2R              ACAGTGA----------------------------------------------------- 505
                .*****:
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CROP PRODUCTION

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

Production of disease free planting materials in tropical tuber crops

Mass multiplication of virus free planting materials was done through procedures involving indexing, micropropagation, hardening and minisett multiplication under protected environment, large scale multiplication of disease free planting materials in selected areas of Kerala, Tamil Nadu, Odisha and the north-east India in a farmers' participatory mode together with farmers' training programmes for mass multiplication and popularization of disease free planting materials. During the period a total number of 145 micro plants of different cassava varieties were indexed against cassava mosaic virus through micropropagation technique in the tissue culture laboratory. A total of 50 numbers of elephant foot yam (var. Gajendra) were indexed. The micro plants were produced through micropropagation technique (indexed). Hardening of micro plants were also done in cassava. Those hardened micro plants were further multiplied in the net house at ICAR-CTCRI and in field condition. The details of quality planting material production and distribution of tuber crops at ICAR-CTCRI, Thiruvananthapuram and Regional Centre, Bhubaneswar to farmers are shown in Table 11 and field view of some of the plots are shown in Fig. 25.

Under the license agreement for quality planting material production, 60 tons of elephant foot yam and 40 tons of greater yam were also produced and distributed to farmers.

Table 11. Quality planting material production of tuber crops

Sl. No.	Crop	Variety	Quantity of planting material produced
1.	Cassava (No. of stems)	Sree Vijaya	25000
		Sree Jaya	25000
		Sree Pavithra	1000
		Sree Swarna	1000
		Vellayani Hraswa	1000
		Total	53000
2.	Elephant foot yam (ton)	Gajendra	33
3.	Greater yam (ton)	Sree Keerthi	1.5
		Sree Shilpa	1.0
		Sree Roopa	1.5
		Da-293	8.0
		Orissa Elite	2.0
		Total	14.0
4.	Taro (ton)	Telia	1.5
		Muktakeshi	0.8
		Total	2.3
5.	Sweet potato (No of vine cuttings)	ST-14	200000
		Kishan	300000
		Total	500000
6.	Yam bean (kg)	RM-1	300

Cassava

Elephant foot yam

Yams

Fig. 25. Field view of quality planting material production plots at ICAR-CTCRI farm

Taro

Fig. 25 (contd). Field view of quality planting material production plots at ICAR-CTCRI farm

Induction of early and uniform sprouting in elephant foot yam

A field experiment was conducted with eleven treatments in randomised block design (RBD) with three replications. Elephant foot yam (var. Gajendra) corms were treated with different treatments viz., GA3 200 ppm (T1), GA3 500 ppm (T2), IAA 100 ppm (T3), IAA 200 ppm (T4), thiourea 0.5% (T5), thiourea 1% (T6), potassium nitrate 0.5% (T7), potassium nitrate 1% (T8), heat treatment (T9), water treatment (T10) and control (T11). Standard recommended package of practices were followed for all the treatments. The first year results revealed that elephant foot yam corms treated with 1% potassium nitrate resulted in higher uniform sprouting (56.48 and 80.55% at 30 and 60 days after planting (DAP)) followed by 200 ppm IAA, which produced 45.37 and 78.70% sprouting at 30 and 60 DAP. Greater plant height (48 cm), stem girth (13.66 cm) and canopy spread (71.10 cm) at 60 DAP were also observed in the treatment, 200 ppm GA3. Significantly higher corm yield was obtained in the 200 ppm GA3 treatment (10.21 t ha^{-1}) followed by 100 ppm IAA (7.31 t ha^{-1}). The corm yield was very poor in the control (2.72 t ha^{-1}). The number of corms produced was significantly higher for the application of 0.5% thiourea (10059 ha^{-1}) followed by 200 ppm GA3 (9945 ha^{-1}) (Fig. 26).

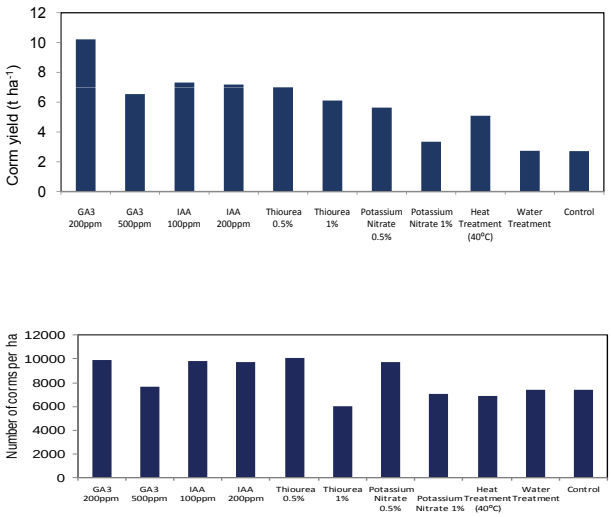


Fig. 26. Effect of growth regulators on corm yield and number of corms in elephant foot yam

Cropping systems involving short-duration cassava and legumes

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

The field experiment to evaluate the feasibility of intercropping short-duration cassava and pulse crops in rice based system was carried out for the first season. Rice var. Kanchana was taken up during the first season followed by short-duration cassava intercropped with pulse crops, green gram (var. Co-Gg-7), black gram (var. Co-6) and soybean (var. JS-95-60) (Fig. 27). Both the varieties of short-duration cassava tested, Sree Vijaya (24.18 t ha^{-1}) and Vellayani Hraswa (22.67 t ha^{-1}), were suitable for intercropping. However, there was significant yield reduction (24%) in cassava under intercropping (23.42 t ha^{-1}) over sole cassava (30.82 t ha^{-1}). All the pulse crops tested, green gram, black gram and soybean were suitable for intercropping with short-duration cassava. But intercropping short-duration cassava (either of the varieties) with black gram under reduced fertility level was preferred due to cassava tuber yield (25.86 t ha^{-1}; -16%) on par with sole cassava (30.82 t ha^{-1}) and

saving of nutrients. Also intercropping cassava (var. Sree Vijaya) with soybean under full fertility level resulted in yields on par with sole cassava. Nutrient saving to cassava to the extent of half FYM and N and full P was possible. Growth characters of cassava viz., plant height, stem girth and leaf production were significantly reduced two months after planting (MAP) due to intercrop competition, which recovered after the harvest of the pulse crop and remained on par with sole cassava by harvest. At various stages, crop growth rate and tuber bulking rate were significantly higher for sole cassava but on par with cassava at full fertility level intercropped with black gram, especially at the last phase. Harvest index was unaffected due to cropping systems. The tuber quality of cassava viz., dry matter, starch, sugar, crude protein and cyanogenic glucoside contents remained unaffected due to intercropping. The soil chemical properties, pH and available N were higher under intercropping with pulse crops, especially black gram/green gram; organic C, available P and K were not significantly affected, but higher under intercropping. The N, P and K uptake by cassava at harvest was higher for sole cassava, which was on par with cassava (either of the varieties) intercropped with black gram. Rice-

First crop of rice var. Kanchana

Short-duration cassava + green gram

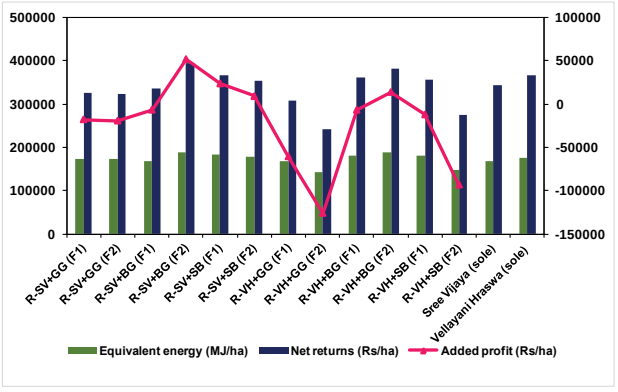
Fig. 27. Rice-short-duration cassava + pulse crops

Short-duration cassava + black gram

Short-duration cassava + soybean

Fig. 27 (contd). Rice-short-duration cassava + pulse crops

short-duration cassava + black gram resulted in higher energy equivalent (189.61x10^3 MJ ha^{-1}), tuber equivalent yield (38.86 t ha^{-1}), production efficiency (107.94 kg ha^{-1} day^{-1}) and profitability (added profit of Rs. 52107 ha^{-1} over sole cassava) besides nutrient saving (Fig. 28).



R: rice; GG: green gram; BG: black gram; SB: soybean; VH: Vellayani Hraswa; SV: Sree Vijaya; F1: Full dose of FYM, N and K; F2: Half FYM and N, full K

Fig. 28. Energy efficiency and profitability of rice-short-duration cassava + pulse cropping system

Weed management in elephant foot yam

A field experiment was conducted during 2015-16 at the Regional Centre of ICAR-CTCRI, Bhubaneswar to study the effect of weed management practices on the yield of elephant foot yam. The experiment was laid out in randomized block design with three replications. The experiment consisted of 11 treatments viz., Pendimethalin (1 day after planting (DAP)) + Glyphosate (90 DAP) (T1), Metribuzin

(1 DAP) + Glyphosate (90 DAP) (T2), Pendimethalin (1 DAP) + tank mix of Pyrithiobac sodium and Propiquizafop (90 DAP) (T3), Metribuzin (1 DAP) + tank mix of Pyrithiobac sodium and Propiquizafop (90 DAP) (T4), Pendimethalin (1 DAP) + 2 rounds of manual weeding (60 and 90 DAP) (T5), Metribuzin (1 DAP) + 2 rounds of manual weeding (60 and 90 DAP) (T6), Two rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) (T7), Two rounds of manual weeding (30 and 60 DAP) + tank mix of Pyrithiobac sodium and Propiquizafop (90 DAP) (T8), Weed control ground cover (T9), Four rounds of manual weeding (30, 60, 90 and 120 DAP) (T10) and Control (No weeding) (T11). Weed dry weight was recorded before manual weeding and herbicide applications, and at harvest. Weed control efficiency was computed by following the standard procedure. The crop was harvested at eight MAP.

Maximum dry matter was observed in the control treatment, wherein no weeding was done. Weed control ground cover (T9) resulted in lowest weed dry matter. This was due to complete suppression of weeds by the weed control ground cover. The next lower weed dry matter was observed with four rounds of manual weeding (30, 60, 90 and 120 DAP). Significantly higher corm yield was obtained with weed control ground cover treatment compared to other treatments. This was due to lower dry matter production and higher weed control efficiency (96.9%) (Fig. 29). The next best treatment was four rounds of manual weeding (30, 60, 90 and 120 DAP) (33.70 t ha^{-1}) followed by two rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) (32.90 t ha^{-1}) and Pendimethalin (1 DAP) + two rounds of manual weeding (60 and 90 DAP) (30.30 t ha^{-1}). Maximum gross return (Rs. 5,60,600 ha^{-1}) was observed in weed control ground cover treatment, however higher benefit:cost ratio (2.31) was noticed under two rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) treatment due to lower cost of cultivation.

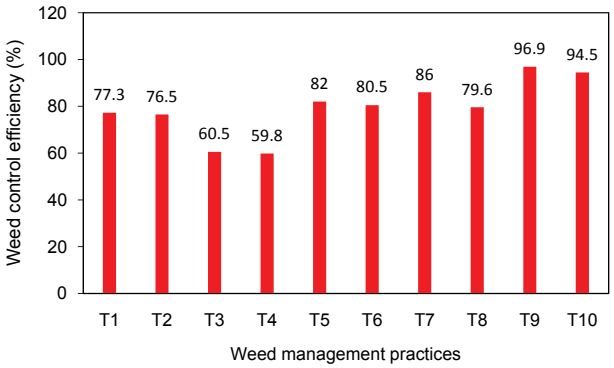


Fig. 29. Effect of weed management practices on weed control efficiency

Management of drip irrigation and fertigation in greater yam + maize intercropping system

A field experiment was conducted during 2015-16 at the Regional Centre of ICAR-CTCRI, Bhubaneswar to study the effect of levels of drip irrigation and fertigation on greater yam + maize intercropping system. The experiment was laid out in split plot design with levels of drip irrigation in main plots (I_1-80% CPE 1-260 DAP, I_2-100% CPE 1-90 DAP + 80% CPE 91-260 DAP and I_3-100% CPE 1-260 DAP) and levels of fertigation in sub plots (F_1-N:P_2O_5:K_2O @ 100:90:100 kg ha^{-1}, F_2-N:P_2O_5:K_2O @ 120:90:120 kg ha^{-1}, F_3-N:P_2O_5:K_2O @ 140:90:140 kg ha^{-1} and F_4-N:P_2O_5:K_2O @ 160:90:160 kg ha^{-1}). Two controls: control (1): (IW/CPE: 1.0 surface irrigation; soil application of N: P_2O_5: K_2O @ 120:90:120 kg ha^{-1}) and control (2): (IW/CPE: 1.0 surface irrigation; No fertilizer) were also included for comparison. The treatments were replicated thrice. In fertigation treatments, water soluble N, P and K fertilizers were applied in five splits (basal, 30, 60, 90 and 120 DAP @ 20% each). In control (1), P_2O_5 was applied at the time of last ploughing. N and K were applied in three splits at basal (40%), 45 DAP (30%) and 90 DAP (30%). Farmyard manure @ 10 t ha^{-1} was incorporated at the time of last ploughing in all the

treatments, except control (2). Greater yam cut tubers of 200 g weight 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, three maize seeds were sown on the same day at a spacing of 30 cm. Irrigation was withheld 10 days before harvesting in all the treatments. The crop was harvested 270 days after planting.

The results revealed that I_3 resulted in higher maize yield, but was on par with I_2. However, higher greater yam and tuber equivalent yields were obtained from I_2 and it was comparable with I_3. The marginal decrease of greater yam yield in I_3 may be due to higher shoot growth owing to higher level of irrigation. Drip irrigation at 80% CPE 1-260 DAP resulted in lower maize, greater yam and tuber equivalent yields. This may be due to moisture stress caused by lower level of drip irrigation. Increasing fertigation level increased the maize, greater yam and tuber equivalent yields. Fertigation at F_4 level resulted in higher maize, greater yam and tuber equivalent yields. However, greater yam and tuber equivalent yields were on a par with F_3. Interaction effect revealed that maize, greater yam and tuber equivalent yields of I_2F_3 was comparable with I_2F_4, I_3F_3 and I_3F_4. The treatment I_2F_3 resulted in 58.60, 58.00 and 58.00% higher maize, greater yam and tuber equivalent yields respectively than control (1) (IW/CPE=1 surface irrigation; no fertilizer), and 11.60, 21.40 and 20.80% higher maize, greater yam and tuber equivalent yields respectively than control (2) (IW/CPE=1 surface irrigation; soil application of fertilizer). The economics of drip irrigation and fertigation revealed that higher cost of cultivation was noticed for I_3F_4. This was due to higher water charges and fertilizer costs. Maximum gross and net returns were observed in I_2F_4. The treatment I_2F_3 resulted in higher B:C ratio (2.82). This might be due to moderate cost of cultivation and higher maize and greater yam yields.

Precision approaches in tuber crops cultivation

A field experiment to determine the optimum dose of N and K fertilizers through fertigation in cassava was carried out for the second season (Fig. 30). The experiment was laid out in 3^2 factorial design with three levels each of N and K. The three levels were 75, 100 and 125 kg ha^{-1} each of N and K_2O and full dose of P_2O_5 was applied as basal soil application. Standard NPK recommendation of 100:50:100 kg ha^{-1} was kept as control. Planting materials of cassava variety Sree Vijaya prepared through minisett technique was planted during summer season and the fertigation treatments were imposed. Biometric characters and partitioning of biomass were recorded at bimonthly intervals and tuber yield and yield parameters at harvest after 7 months. There was no significant difference in tuber yield among the three levels of N or K. Among the interaction effects, N @ 125 kg ha^{-1} and K_2O @ 75 kg ha^{-1} produced maximum tuber yield (50.30 t ha^{-1}) However, all the interaction effects, except 75 kg each of N and K_2O, were on par. Under control, the crop yielded 16.10 t ha^{-1} during summer season.

Fig. 30. A view of field experiment on fertigation in cassava

Water management in elephant foot yam

A new field experiment was initiated in elephant foot yam to assess the possibilities of water saving and to reduce the water requirement of the crop. The experiment was laid out in RBD with nine treatments

including two controls for comparison. The different water saving techniques tried were: irrigation at 100, 75 and 50% CPE through partial root zone drying (PRD) technique, irrigation at 50% CPE using residue mulching, plastic mulching, antitranspirant and super absorbent polymer along with two controls, full irrigation at 100% CPE and a rainfed crop. Drip irrigation was given once in alternate days based on the daily evaporation rate and the crop factor.

The crop took 19-22 days for initiation of sprouting and 37-40 days for achieving 50% sprouting. Full sprouting was achieved within 49-68 days under different treatments. Rainfed crop took 20 days for first sprouting, 44 days for 50% and 69 days for 100% sprouting. Morphological characters recorded at monthly intervals were more or less similar, once the canopy was established. During grand growth stage of the crop from 3-5 months after planting, girth, canopy spread, number of leaves and leaf area index under water saving treatments were on par compared to irrigation at 100% CPE. Soil samples were collected from two depths, 0-15 cm and 15-30 cm at monthly intervals and the moisture content was assessed over a period of six months from planting. All the treatments maintained 20-30% moisture in the top soil compared to less than 20% soil moisture under rainfed control.

During the first year of the trial, there was no significant difference in corm yield among the different water saving techniques compared to full irrigation at 100% CPE. Maximum corm yield was obtained with irrigation at 50% CPE along with crop residue mulching (51.15 t ha^{-1}) followed by irrigation at 50% CPE with plastic mulching (48.9 t ha^{-1}). The rainfed crop produced the lowest corm yield of 26.50 t ha^{-1}.

The root distribution pattern of elephant foot yam was studied under irrigated and rainfed conditions by planting the corms in 2 x 2 x 0.6 m cement tanks filled with soil. The plants were sampled at various stages viz., sprouting, shoot elongation, leaf emergence, full emergence and then at monthly intervals up to senescence and morphological characters of roots were recorded. The rooting pattern of elephant foot yam at different growth stages is shown in Fig. 31. Root length was more under rainfed conditions and attained maximum when the crop emerged fully, which was maintained up to 5 MAP and thereafter started declining (Fig. 32). However, root dry matter was more under irrigated conditions and reached maximum at 3 MAP and thereafter started declining (Fig. 33).

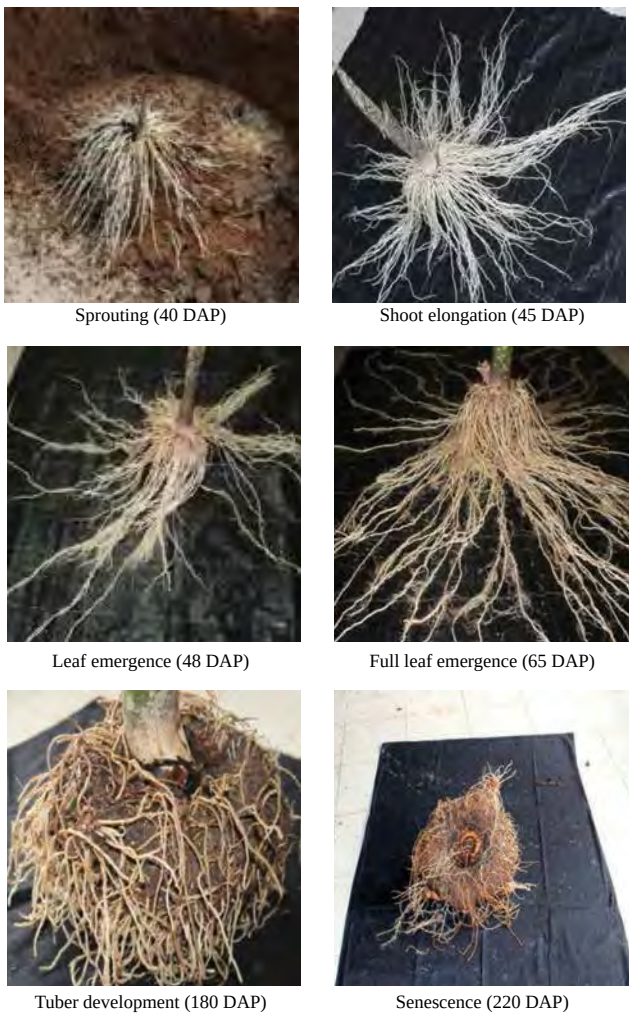


Fig. 31. Rooting pattern in elephant foot yam at different stages of growth

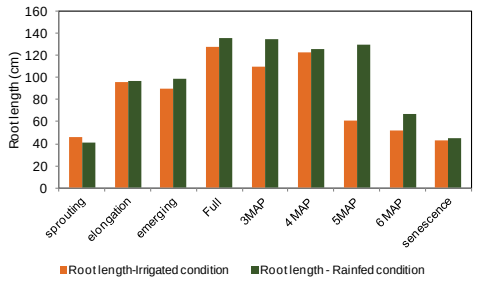


Fig. 32. Root length of elephant foot yam at different stages of growth

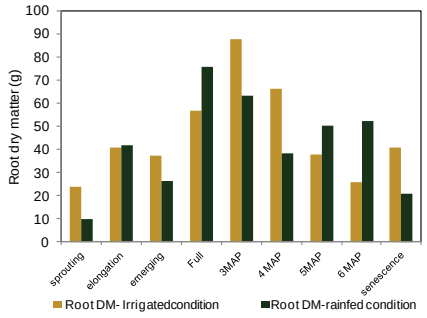


Fig. 33. Root dry matter of elephant foot yam at different stages of growth

Long term fertilizer cum manurial experiment in cassava

The result of continuous application of different levels of fertilizers, different sources of organic manures and different combinations of secondary and micronutrients on tuber yield, tuber quality, soil productivity and plant nutrient concentration for the 11th season crop of cassava is described below:

Sustainability of cassava for continuous cultivation was confirmed even after the 11th season crop with a tuber yield of 15.17 t ha^{-1}, without any manures or fertilizers. The trend in cassava productivity under package of practices (POP), soil test based fertilizer cum manurial application (STBF) and absolute control (AC) over a period of 10 years is depicted in Fig. 34.

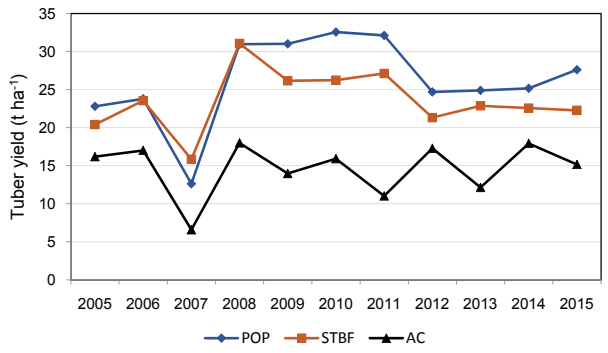


Fig. 34. Sustainable cassava tuber yield over a period of 10 years under POP, STBF and AC in the long term fertilizer experiment

Application of NPK @ 125:50:125 kg ha^{-1} resulted in significantly highest tuber yield of 32.85 t ha^{-1}. Soil test based application of NPK @ 78:0:94 kg ha^{-1} along with FYM @ 5 t ha^{-1} produced tuber yield (22.27 t ha^{-1}) on par with the recommended POP (FYM @ 12.5 t ha^{-1} + NPK @ 100:50:100 kg ha^{-1}) (27.62 t ha^{-1}). Continuous application of NPK @ 100:50:100 (27.62 t ha^{-1}), 50:25:100 (25.18 t ha^{-1}) and soil test based @ 78:0:94 (22. 27 t ha^{-1}) were on par with respect to tuber yield. Different organic manure sources viz., green manuring *in situ* with cowpea (4.87 t ha^{-1} on DW basis) (26.89 t ha^{-1}), vermicompost @ 3.91 t ha^{-1} (27.27 t ha^{-1}) and coir pith compost @ 4.6 t ha^{-1} (25.78 t ha^{-1}) were found as substitutes to FYM @ 12.5 t ha^{-1} (27.62 t ha^{-1}). Organic manures alone (crop residue as cassava leaf residue @ 3.75 t ha^{-1} (DW basis) and stem residue @ 10.43 t ha^{-1}(DW basis) + coir pith compost @ 4.6 t ha^{-1}+ vermicompost @ 3.91 t ha^{-1}and ash @ 2.7 t ha^{-1}) also resulted in an yield (23.06 t ha^{-1}) on par with the recommended POP (27.62 t ha^{-1}). Soil test based application of $MgSO_4$ @ 10 kg ha^{-1} based on the soil status of 0.508 meq 100g^{-1}, $ZnSO_4$ @ 2.5 kg ha^{-1} based on the soil status of 3.892 ppm, borax @ 5 kg ha^{-1} based on the soil status of 0.852 ppm as single nutrient (Yield under Mg-27.79 t ha^{-1}, Zn-25.50 t ha^{-1}, B-24.80 t ha^{-1}) two nutrients (Yield under Mg+Zn-25.82 t ha^{-1}, Mg + B - 27.25 t ha^{-1}, Zn + B - 28.99 t ha^{-1}) and three nutrients combination (Yield under Zn + Mg + B- 24.21 t ha^{-1}) of Mg, Zn and B did not result in significantly higher yield over POP (27.62 t ha^{-1}).

Levels of fertilizers, sources of organic manures and different combinations of secondary and micronutrients did not produce any significant effect on tuber quality attributes viz., cyanogenic glucosides and starch.

Soil samples collected before planting of 11th season crop of cassava in six selected treatments

receiving continuous organic manure applications and an absolute control were analyzed for physical parameters. Surface soil moisture and temperature observations were also taken in the field, thrice during the growth period of cassava at varied rainfall intensities. The bulk density value of the soil (sandy clay loam) was the highest (1.64 Mg m^{-3}) in absolute control, whereas significant differences and lowest value was observed in the treatment with combination of organic materials viz., vermicompost, coir pith compost, ash and crop residue treatments (1.41 Mg m^{-3}). The differences in water holding capacity was also significant and followed the above trend among the different treatments. The mean volumetric soil moisture content varied from 7.6 to 11.8% (average of three stages), whereas the soil temperature ranged from 27.4 to 32.6°C. Relationship among soil variables has shown that bulk density was significantly and negatively correlated with maximum water holding capacity (r= -0.512*).

The different levels of fertilizers did not produce significant effect on soil pH, organic C, available N, exchangeable Ca, Mg and S. But significant reduction in soil available P was seen without P under STBF (125.40 kg ha^{-1} over 255.10 kg ha^{-1} under POP) and with reduction in application of fertilizer P dose. Higher levels of NPK resulted in increased soil micronutrient status. Different organic manure sources resulted in significant effect on soil P, K, Ca, Cu, Zn, Mn, B, Fe, with FYM and green manuring on par compared to vermi compost and coirpith compost and organics alone resulted in significantly the lowest soil nutrient contents. Different combinations of secondary and micronutrients resulted in significant effect on soil P, K, Zn, B.

Leaf, stem and tuber nutrients did not differ significantly with different levels of fertilizers, except absolute control. Different organic manure sources significantly influenced the leaf Zn, stem N, Ca, Mg, Cu, Zn, tuber N, K, Ca and Cu. Different combinations of secondary and micronutrients resulted in significant effect on tuber N, K, Ca, Cu, stem N, Ca, Mg, Cu, Zn, leaf N and Zn.

Screening nutrient efficient genotypes in cassava for low input management

Preliminary screening of 83 elite accessions of cassava followed by K rate trials with six identified K efficient genotypes for three years and field level demonstration trials for two years with the selected genotypes in seven locations of three districts of Kerala since 2007 resulted in the release of the genotype 'Aniyoor', as the first K efficient variety, by name 'Sree Pavithra' during June 2015.

The third season experiment conducted during 2014-15 to test the N efficiency potential of the K efficient genotypes revealed W-19 and CR 43-8 as N efficient. The statistical analysis of the data from the third season experiment laid out with six genotypes viz., Sree Pavithra, W-19, H-1687, 6-6, CR 43-8 and 7 III E3-5 under four levels of N viz., 0, 50, 100 and 150 kg ha^{-1} indicated the following inferences:

Genotypes significantly influenced tuber yield, leaf and stem dry matter production, agro-physiological efficiency (APE), CGR and TBR at 3-6 MAP. N Levels significantly influenced the soil N and physiological efficiency (PE). Genotypes x N levels significantly influenced the stem dry matter, crop growth rate (CGR) and tuber bulking rate (TBR) at 6-9 MAP. W-19 (30.23 t ha^{-1}) and CR 43-8 (31.69 t ha^{-1}) produced the highest tuber yield and all other genotypes, except H-1687, were on par. W-19 and CR 43-8 had the highest CGR at 3-6 MAP (18.63 and 14.16 g m^{-2} day^{-1} respectively) and W-19 had the highest TBR at 3-6 MAP (9.28 g day^{-1}). W-19 and CR 43-8 showed significantly the highest TBR at 6-9 MAP as 20.25 and 22.55 g day^{-1} at N @ 50 kg ha^{-1}. CGR at 6-9 MAP was significantly highest for W-19 and CR 43-8 at N @ 50 kg ha^{-1} (30.26 and 28.37 g day^{-1}). The CGR, relative growth rate (RGR) and TBR

of the different genotypes during the crop growth period is given in Fig. 35. The crops stand and tuber yield of the promising genotypes are shown in Fig.36.

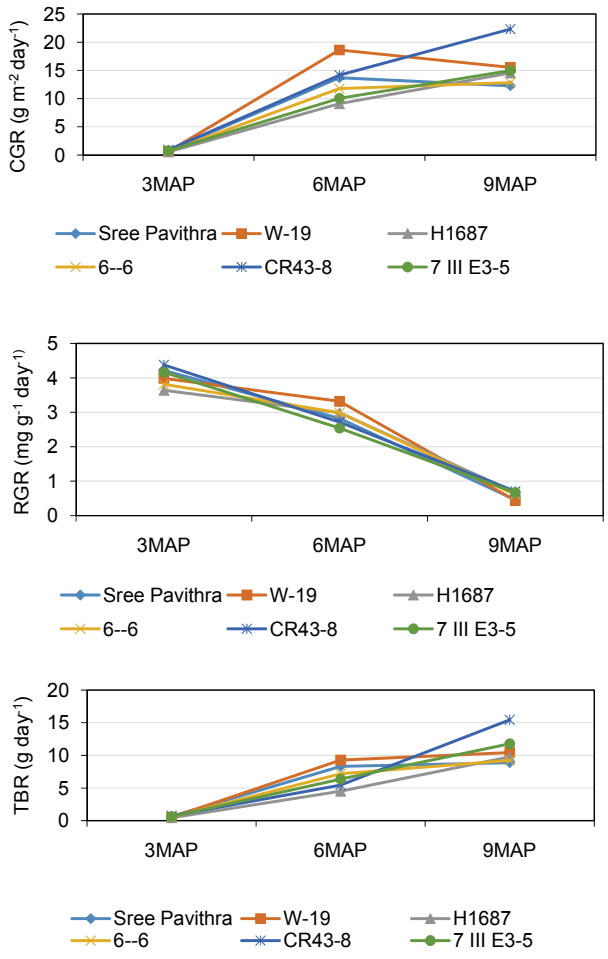


Fig. 35. The CGR, RGR and TBR of casssava genotypes during the crop growth period

A field experiment was conducted for the first season with four genotypes viz., Sree Pavithra, 7III E3-5, Acc. No. 905 and Acc. No. 906 under four levels of NPK viz., 25, 50, 75 and 100 kg ha^{-1} to study the possibility of reduction/substitution of fertilizers by using NPK efficient genotypes. Plant growth characters and plant dry matter production was studied at quarterly intervals from 3 MAP till harvest. A total of 14 NPK efficient genotypes viz., (Acc. Nos. 662, 750, 908, 905, 906, 115, 890, 896, 766, 788, 696, 130, 7 and 796) are maintained in Block I of ICAR-CTCRI farm. Planting materials of the newly released K efficient variety, 'Sree Pavithra' was multiplied in an area of one acre for distribution to farmers.

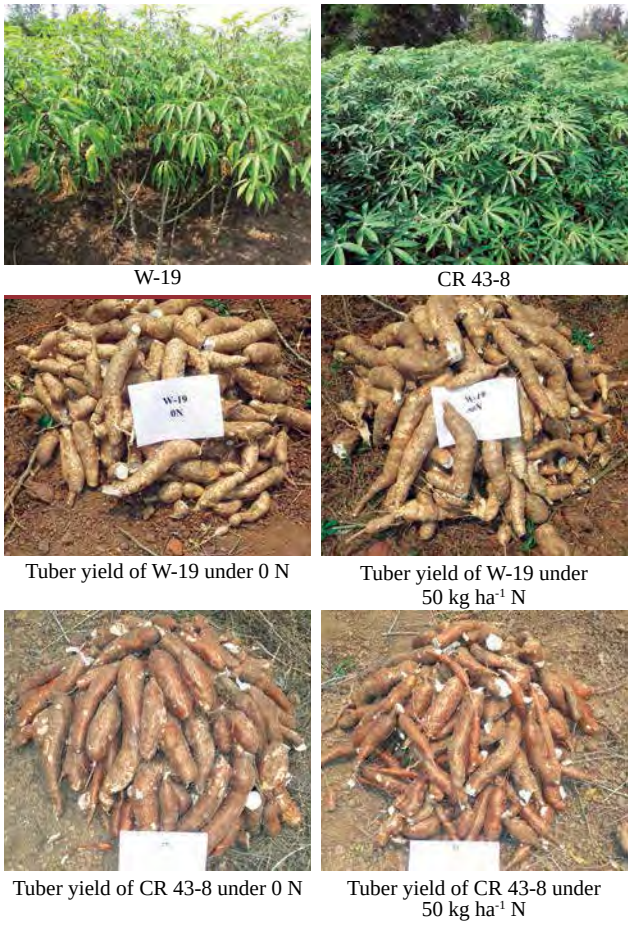


Fig. 36. The crop stature of W-19 and CR 43-8 and tuber yield of the genotypes under different N levels

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

Three field experiments on fertilizer best management practices by SSNM of cassava (crop 8), elephant foot yam (crop 5) and sweet potato (crops 2 and 3) were conducted in the farm of ICAR-CTCRI with six treatments (N-omission, P-omission, K-omission, NPK-omission, present recommendation and SSNM) and four replications in a randomized block design. The results of field experiments on cassava and elephant foot yam showed very good agreement between predicted and actual yields in SSNM treatment. In the case of cassava, the SSNM treatment resulted in a tuber yield of 28.60 t ha^{-1}, which was significantly higher than the yield obtained for the present nutrient recommendation (24.25 t ha^{-1}). The SSNM treatment of elephant foot yam resulted

in a corm yield of 27.20 t ha^{-1}, while the predicted yield was 35.00 t ha^{-1}. Further studies are needed to develop SSNM recommendation for sweet potato since reasonable yields could not be obtained during this year to validate the QUEFTS model. On-farm validations of secondary- and micronutrient- inclusive customized plant nutrient formulations developed for cassava and elephant foot yam were conducted at five farmers' fields each for cassava and elephant foot yam (Fig. 37). The results showed an average yield of 34.56 t ha^{-1} for cassava in SSNM plot, which was significantly higher than the average yield obtained in farmer fertilizer practice (FFP) plot (29.28 t ha^{-1}). For elephant foot yam, the corresponding yields were 38.85 and 32.55 t ha^{-1} respectively.

Fig. 37. On-farm validation of customized plant nutrient formulation for elephant foot yam

The results of SSNM and fertilizer best management practices developed over the past 13 years for cassava based on on-station and on-farm experiments and validated through three different centres of AICRP on Tuber Crops were used to develop zone NPK recommendations for major growing areas. Based on the calibrated and validated results of QUEFTS model, soil fertility maps (http://www.iiss.nic.in/STCR.html) and 23 agro-ecological units of Kerala state, we have categorized the major cassava growing areas and region specific NPK recommendations were developed. Table 12 shows eighteen different nutrient recommendations developed as an improvement over the existing blanket recommendation of 100:50:100 kg ha^{-1} of N, P_2O_5 and K_2O.

Table 12. SSNM recommendations for cassava in major growing areas of India

Sl. No.	State	Management zone	Rainfed / Irrigated	Target yield	FYM	N	P_2O_5	K_2O
				(t ha^{-1})	(t ha^{-1})	(kg ha^{-1})		
1	Kerala	State	Rainfed	30	12.5	100	20	100
2	Kerala	State	Irrigated	40	12.5	160	30	160
3	Tamil Nadu	State	Rainfed	30	12.5	100	50	100
4	Tamil Nadu	State	Rainfed	40	12.5	200	75	200
5	Tamil Nadu	State	Irrigated	40	12.5	160	60	160
6	Tamil Nadu	State	Irrigated	50	12.5	240	80	240
7	Andhra Pradesh	State	Rainfed	30	12.5	100	50	100
8	Maharashtra	State	Irrigated	40	12.5	160	60	160
9	Kerala	AEU* 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 20, 21, 22, 23	Rainfed	30	12.5	100	20	100
10	Kerala	AEU 17	Rainfed	30	12.5	100	20	50
11	Kerala	AEU 4, 14	Rainfed	30	12.5	50	20	100
12	Kerala	AEU 16	Rainfed	30	12.5	50	20	50
13	Kerala	AEU 18, 19	Rainfed	30	12.5	200	20	50
14	Kerala	AEU 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 20, 21, 22, 23	Irrigated	40	12.5	160	30	160
15	Kerala	AEU 17	Irrigated	40	12.5	160	30	80
16	Kerala	AEU 4, 14	Irrigated	40	12.5	80	30	160
17	Kerala	AEU 16	Irrigated	40	12.5	80	30	80
18	Kerala	AEU 18, 19	Irrigated	40	12.5	240	30	80

* AEU – Agro-ecological unit

The results of SSNM and fertilizer best management practices developed over the past five years for elephant foot yam based on on-station and on-farm experiments and data generated through five different centres of AICRP on Tuber Crops were used to develop zone NPK recommendations for major growing areas. Based on the calibrated and validated results of QUEFTS model, soil fertility maps (http://www.iiss.nic.in/STCR.html) and data obtained from the experiments conducted across India at five different centres of AICRP on Tuber Crops, we have categorized the major elephant foot yam growing areas and region specific NPK recommendations were developed. Table 13 shows nine different nutrient recommendations developed as an improvement over the existing blanket recommendation of 100:50:150 kg ha^{-1} of N, P_2O_5 and K_2O.

Table 13. SSNM recommendations for elephant foot yam in major growing areas of India

Sl. No.	State	Management zone/District	Target yield (t ha^{-1})	FYM (t ha^{-1})	N	P_2O_5	K_2O
					(kg ha^{-1})		
1	Kerala	State	40	25	80	30	120
2	West Bengal	South 24 Parganas, North 24 Parganas, Nadia	50	25	100	50	80
3	Andhra Pradesh	West Godavari, Guntur	50	25	100	75	80
4	Andhra Pradesh	Krishna	50	25	80	50	100
5	Tamil Nadu	Tirunelveli	40	25	100	50	100
6	Tamil Nadu	Erode	40	25	80	50	100
7	Bihar	Samastipur, Vaishali, Begusarai	50	25	80	50	100
8	Bihar	Muzaffarpur	50	25	80	75	100
9	Gujarat	Navsari	40	25	100	50	80

Effect of organic sources, secondary and micronutrients on soil quality, yield and proximate composition of elephant foot yam

A field experiment was conducted during kharif, 2015-16 at Regional Centre, ICAR-CTCRI, Bhubaneswar, to study the effect of integrated use of lime and inorganic and organic manures on soil quality, yield and biochemical constituents of elephant foot yam. The experimental soil is sandy loam, acidic (pH 4.67), non saline (0.24 dS m^{-1}), having 0.256% organic C, and 226, 24.64 and 189 kg ha^{-1} of available N, P and K respectively. The experiment was laid out with 14 treatments viz., Control (T1), Soil test based fertilizer (STBF) i.e. 94-30-80 kg ha^{-1} N, P_2O_5 and K_2O (T2), 150% STBF (T3), 50% STBF (T4), FYM (Eq. wt. based on N conc.) (T5), vermicompost (Eq. wt. based on N conc.) (T6), Neem cake (Eq. wt. based on N conc. (T7), Lime + STBF (T8), FYM + NPK + $ZnSO_4$ @ 10 kg ha^{-1} (T9), Lime + FYM + NPK + $ZnSO_4$ @ 10 kg ha^{-1}(T10), FYM + NPK + borax @ 5.0 kg ha^{-1} (T11), Lime + FYM + NPK + borax @ 5.0 kg ha^{-1}(T12), FYM + NPK + $MgSO_4$ @ 25 kg ha^{-1} (T13) and Lime + FYM + NPK + $MgSO_4$ @ 25 kg ha^{-1}(T14). The treatments were replicated thrice in a randomized block design. Elephant foot yam (Gajendra) corms were cut into 250 g sizes, and planted in 45 cm^3 pits at a spacing of 75 x75 cm. All the cultural practices were followed as per schedule and the crop was harvested at 6 months after planting, yield parameters were recorded and plant samples were analyzed for proximate composition and nutrient contents.

Significantly highest corm yield (19.09 t ha^{-1}) was obtained due to integrated application of lime + FYM + NPK + $MgSO_4$, with highest yield response of

113% over control. The increase in corm yields was 20, 75 and 103% due to application of 50, 100 and 150% NPK over control. Relatively lower crop yields of elephant foot yam were observed due to delayed sprouting of the corms and poor performance of the crop. Among the organic sources, incorporation of vermicompost has shown higher tuber yield (11.30 t ha^{-1}), which was on par with FYM (10.86 t ha^{-1}) and neem cake (10.47 t ha^{-1}). Integrated use of lime + FYM + NPK + $ZnSO_4$ produced a tuber yield of 17.95 t ha^{-1}. Lime addition along with organic manure showed higher yield response rather than inorganic fertilizers. Highest starch content (17.17%) was noticed due to integrated application of lime + FYM + NPK + $MgSO_4$, however, the total sugars varied from 1.32–1.88 % with the highest being due to integrated use of lime + FYM + NPK + B. The dry matter ranged from 25.32 to 27.75%. Significantly highest dry matter was observed due to integrated use of lime + FYM + NPK + B followed by lime + FYM + NPK + $MgSO_4$.

The soil pH improved progressively due to integrated application of lime, inorganic fertilizers and organic manures. Addition of lime in combination with NPK, FYM and $MgSO_4$ improved the soil pH over the initial level. Greatest increase of organic C was observed due to application of 150% NPK, which was on par with application of lime + FYM + NPK + $MgSO_4$ (0.48%) from the initial level. Total N content in the soils increased in all the treatments. Significantly highest available N (249 kg ha^{-1}) and P (39.6 kg ha^{-1}) were observed due to application of super optimal doses of NPK, however highest available K (337 kg ha^{-1}) was observed due to incorporation of vermicompost followed by lime + FYM + NPK + $ZnSO_4$ (322 kg ha^{-1}). Significantly highest exchangeable Ca and Mg (3.63 and 2.33 cmol (p^+) kg^{-1} soil, respectively) were noticed due to combined application of lime, $MgSO_4$, optimum doses of NPK and FYM. The available Fe and Mn contents decreased from the initial levels, whereas the available Cu and Zn enhanced in all the treatments. In conclusion, integrated use of balanced dose of fertilizers along with organic manure, lime and $MgSO_4$ not only improved the soil quality, but also produced highest corm yields of elephant foot yam with good quality tubers.

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

Soil samples (0-30 cm depth) were collected during 2015 from areas adjacent to mines and industrial areas of Koraput block (Bauxite mining areas) of Koraput district (2); Kashipur (1) and Rayagada (3) blocks of Rayagada district and Kujang block (industrial areas) of Jagatsinghpur district (9) of Odisha along with one sample of arable land from Kujang block of Jagatsinghpur district to assess the accumulation of heavy metals due to pollutants released from mines and industries into the arable lands. The soil samples were processed and analyzed for physico-chemical properties and the fresh soil samples were analyzed for enzyme activities.

The soils varied widely in pH (4.47 - 8.81), are non saline, low to high in organic C (0.39 - 1.59%) and with 0.018 - 0.236% total N, 110-280, 2.69-148.90, 80-893 kg ha^{-1} of available N, P, and K, respectively. The exchangeable Ca and Mg was 4.75 - 33.72 and 1.30 - 16.85 cmol (p+) kg^{-1} respectively. The soils contained 5.40 - 281.1, 11.6 - 184.4, 0.4 - 8.68 and 0.51 - 3.93 mg kg^{-1} of available Fe, Mn, Cu and Zn, respectively. The soils from Rayagada is slightly alkaline in reaction with moderate levels of available NPK, whereas the soils from Bauxite mining areas are neutral in soil reaction, deficient in available P and medium in status of available N and K. The soils from industrial areas of Paradip, Jagatsinghpur are strongly acidic to slightly alkaline, low to high in available nutrient status with toxic levels of micronutrients. However, the arable land from Jagatsinghpur district is acidic, medium in organic C, low in available N, medium in available P and high in available K with

higher toxic levels of Fe and Mn and higher than the critical limits of Cu and Zn.

Dehydrogenase activity and fluorescein diacetate activity in the soils ranged from 0.116-3.629 µg TPF $h^{-1}g^{-1}$ and 0.022-2.726 µg g^{-1} h^{-1}, respectively. The acid and alkaline phosphatase activities in the soils ranged from 2.45-30.18 and 1.31-28.61 µg PNP g^{-1} h^{-1}. The soils adjacent to industrial areas of Paradip, Jagatsinghpur contain very low biological activity (DHA and FDA) as well as phosphatase activities as influenced by various types of effluents released from the industries. Fig. 38 shows field views of some locations of the study areas.

Fig. 38. Some of the study sites in mines and industrial areas of Odisha

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

Variations in soil moisture storage, soil water transmission properties, other important soil properties and crop biometric observations in laterite soils were studied under different tillage and mulching practices in cassava (var. Sree Vijaya) during two seasons. Tuber yield and major physico-chemical properties of soils at harvest under different treatments were also estimated. During the first year, tuber yields of 30.50, 34.90 and 28.20 t ha^{-1} were obtained under conventional (CT), deep (DT) and minimum tillage (MT) practices respectively (Fig. 39). Results of the study showed that yield obtained under ground cover sheet mulch (36.70 t ha^{-1}) was significantly higher than crop residue mulch treatment (27.30 t ha^{-1}). Tillage levels were found to be non-significant, whereas some of tillage and mulch interaction treatments showed significant results. The different types of mulches influenced the yield in the order: porous ground cover (GC) > crop residue (CR) > no mulch (NM). Soil hydraulic properties viz., field saturated hydraulic conductivity (HC), matric potential (MP) and sorptivity (SS) estimated for different treatments showed that HC and SS of CT was found to be 14 and 28% higher compared to minimum tillage, whereas 18% increase in matric potential was observed under GC compared to NM.

Fig. 39. View of crop harvest during September 2015 (top) and estimation of water transmission properties in the second year experiment, 2015-2016 (bottom)

Integrated soil and water conservation strategies for rainfed hill cassava production systems

The field experiment was conducted for confirmatory results at Vengamudi, Pachamalai hills, Eastern Ghats. The aim was to study the interaction of soil

moisture and P and K using seven treatments. The treatments consisted of black porous ground cover (GC), intercropping cassava with black gram (IC) and control (C) treatments each under farmer's (FP) and scientific (SP) practices along with an absolute control (AC) in a sloping hill bottom field. The performance of above treatments in terms of variations in soil moisture, soil temperature, soil properties especially available P and K, cassava tuber yield and nutrient use efficiencies (NPK) was studied. The mean volumetric soil moisture content of GC was 30.60% higher than absolute control (AC). The sheet treated soils also recorded lower soil temperature to the extent of 9.50% as compared to control. The cassava tuber yield in FP and SP treatments were 24.40 and 28.90 t ha^{-1}, whereas sheet and no sheet (control) treated soils produced tuber yields of 32.60 and 21.60 t ha^{-1}. Moreover, it was observed that the quantity, size and shape of tubers under SP-GC were superior as compared to FP-GC and other treatments (Fig. 40). The NPK efficiencies of soils treated with GC sheets under SP was 113, 105 and 86% higher than FP plots. The NPK efficiencies of GC sheets were 74, 59 and 77% higher as compared to no sheet (control) treated soil. The benefit:cost ratio calculated for the different treatments, assuming the life of ground cover sheet as four years under the hill conditions, showed that the highest value was obtained for the GC method of soil and nutrient conservation, especially with the soil test based application of N, P and K (SP) treatments (1.78) as compared to the control (0.69).

Fig. 40. Soil moisture and temperature estimations in the field site (top left); tubers obtained in different soil moisture conservation and nutrient treatments viz., FP-GC (bottom left) and SP-GC (bottom right) as compared to absolute control (top right)

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

Performance of elephant foot yam under heat stress

The objective was to induce tolerance to high temperature stress through chemical treatments in elephant foot yam. For this purpose, variety Gajendra was planted in the farm of ICAR-CTCRI during May 2015 in RBD with four replications. Five foliar spraying treatments were given as follows (1) Control without water spray (2) Control with water spray (3) Foliar spraying of 0.2% $CaCl_2$ during 4-8th month at fortnightly intervals (4) Foliar spraying of 0.2% Salicylic acid (0.2%) during 4-8th month at fortnightly intervals (5) Foliar spraying of 1000 ppm Benzyl Adenine (BA) during 4-8th month at fortnightly intervals. Elephant foot yam plants were cultivated inside polyhouse and four treatments were given (T_2 to T_5). Prevailing weather conditions under open field and polyhouse conditions were recorded. On bright sunny day inside the polyhouse, the plants experienced high temperature stress of ~32 - ~38^{o}C with 51-54% RH and 734-1185 µmol m^{-2} s^{-1} light intensity during day time (10 am to 4 pm). Plants under open field conditions experienced ~30-32^{o}C temperature with 64-68% RH and 2059-2317 µmol $m^{-2}s^{-1}$ light intensity during day time. On cloudy day, light intensity was 250-355 µmol m^{-2} s^{-1}, 29^{o}C and 65% RH under outside conditions and light intensity was 138 µmol m^{-2} s^{-1}, 30^{o}C and 65% RH under polyhouse conditions. Plant height and leaf area were recorded from all treatments under field as well as under polyhouse conditions. The

crop was harvested at 8 MAP. The corm yield data indicated that under field conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 14.35%, 21.82% and 7.9% respectively under ~32°C day temperature. Under polyhouse conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 17.26%, 29.13% and 3.92% respectively under ~32-38°C day temperature (10 am – 4 pm).

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

A field experiment was conducted in the natural saline soil during rabi, 2015-16 in participatory mode in the field of Shri. Madan Mohan Joydhar, Chouldari Village, Chouldari Gram Panchayat, South Andaman district, Andaman & Nicobar Islands in collaboration with Central Island Agricultural Research Institute, Port Blair, Andaman, to study the response of P and K on sweet potato in saline soils under Island ecosystem of Andaman (Fig. 41). The trial was laid out with 4 levels of P i.e. 0, 20, 40, 60 kg ha^{-1} P_2O_5 and 4 levels of K i.e. 0, 25, 50, 75 kg ha^{-1} K_2O replicated thrice in a two factorial design. Uniform dose of N @ 50 kg ha^{-1} was applied in all the plots in three splits i.e. ⅓ each of N at basal, 30 days after planting and 50 DAP. Entire P was applied as basal dose and ½ K at basal and ½ K at 50 days after planting. Sweet potato (var. Samrat) vine cuttings were planted at a spacing of 60 x 20 cm during November 2015, all the cultural practices were followed as per schedule and the crop was harvested during March 2016.

It was observed that significantly highest tuber yield of sweet potato was obtained due to combined application of 40 and 75 kg ha^{-1} of P_2O_5 and K_2O, respectively. Highest tuber yield was obtained due to application of 40 kg P_2O_5 ha^{-1} (14.25 t ha^{-1}) and the yields declined at higher doses of P. However, the tuber yields increased with the application of K up to 75 kg K_2O ha^{-1} (14.43 t ha^{-1}). The vine yield showed an increasing trend with the application of graded doses of P and K, whereas the combined application of 40 and 75 kg ha^{-1} of P_2O_5 and K_2O, respectively produced significantly highest vine yield (17.87 t ha^{-1}). Among the treatment combinations, application of 60 and 50 kg ha^{-1} of P_2O_5 and K_2O, respectively resulted in highest starch (17.28%) and sugars (3.66%), whereas highest dry matter (27.70%) was recorded due to combined application of 40 and 75 kg ha^{-1} of P_2O_5 and K_2O, respectively. Thus, the results of the study emphasized that application of N, P_2O_5 and K_2O @ 50:40:75 kg ha^{-1} respectively was optimum to realize higher tuber yields with greater amounts of biochemical constituents in the natural saline soils under island ecosystem of Andaman.

Fig. 41. View of sweet potato field under Island ecosystem of Andaman

Nutrient omission trial was laid out in the field of Shri. K.C. Majumdar, Lalpahar village, Chouldari G.P., South Andaman district to study the response of NPK on sweet potato in saline soils. The experiment was laid out with nine treatments (Control, NPK, NP, NK, PK, N, P, K and FYM) replicated thrice in a RBD. A fertilizer dose of N, P_2O_5 and K_2O @ 50-25-50 kg ha^{-1} was followed. Nitrogen was applied in three splits i.e. ⅓ each of N at 0, 30 and 50 days after planting; Entire P as basal dose and ½ K at basal and ½ K at 50 days after planting as per the layout. Sweet potato (cv. Samrat) vine cuttings were planted at a spacing of 60 x 20 cm during November 2015, all the cultural practices were followed as per schedule and the crop was harvested during March 2016.

Significantly highest tuber and vine yield of sweet potato (16.13 and 17.76 t ha^{-1}, respectively) was

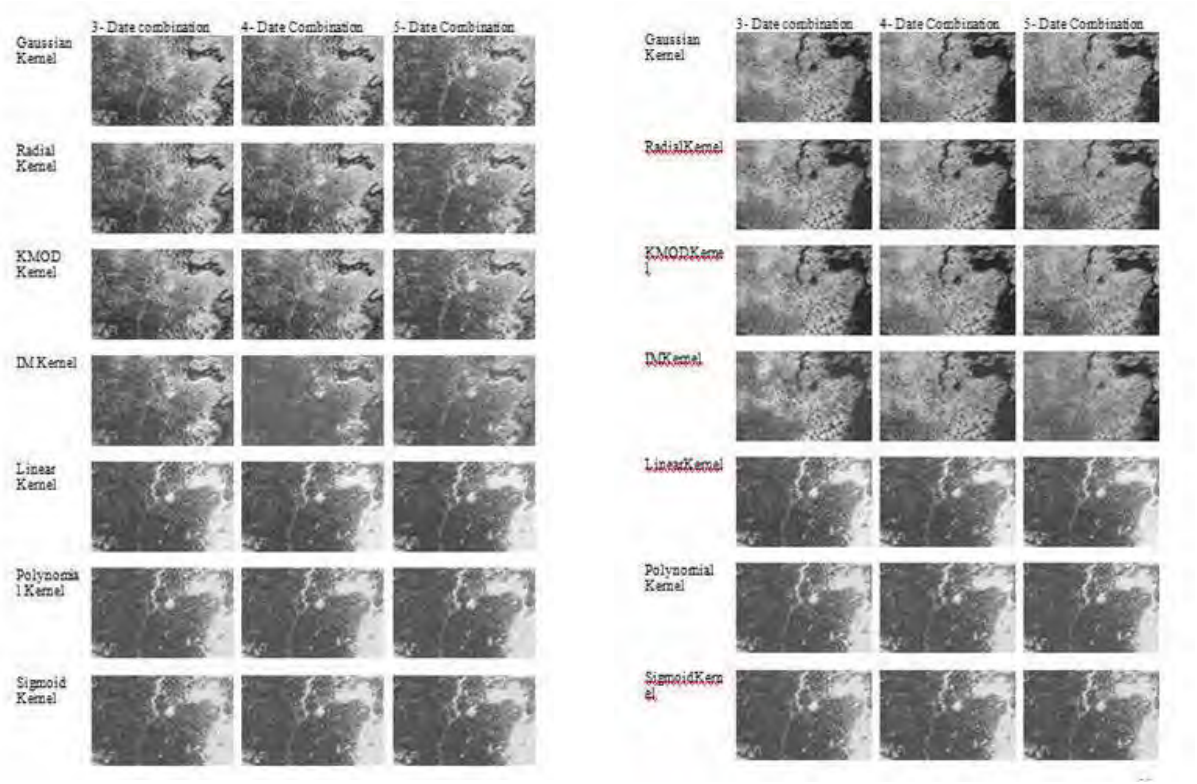
obtained due to application of N, P_2O_5 and K_2O @ 50-25-50 kg ha^{-1} with a tuber yield response of 111% over control. Among the three major nutrients, N showed higher yield response (41.80%) followed by K (36.10%) and P (24.60%). Combined application of NK showed higher yield response (79.5%) rather than NP (67.4%) and PK (66.4%). However, application of FYM @ 5.0 t ha^{-1} alone produced a tuber yield of 10.70 t ha^{-1}. Significantly highest dry matter (27.12%) was observed due to application of optimum doses of NPK followed by NK (26.93%) and FYM (26.39%). Highest starch content (16.85%) was recorded due to application of NPK followed by NP (16.67%) and FYM (16.52%). The results indicated that application of balanced doses of NPK produced sustainable crop yields of sweet potato with good quality tubers in the saline soils of Andaman.

Climate smart agriculture practices for tropical tuber crops using remote sensing and GIS

A study was conducted using satellite imagery acquired by Operational Land Imager (OLI) on-board Landsat 8 satellite to develop a methodology for acreage estimation of cassava. The study area was Salem district, Tamil Nadu. The OLI is a push-broom sensor with 12-bit quantization. Size of a scene is 185-km-cross-track-by-180-km-along-track. It collects data for visible, near infrared and short wave infrared spectral bands as well as a panchromatic band. Cloud free temporal data of path 143 and row 52 from December 2013 to January 2015 acquired by Landsat-8 were used to discriminate cassava from other crops. Since temporal data covering the complete phenological cycle of the crop has been used to identify cassava, it was essential to normalize the effects of the changes in the atmospheric conditions in the temporal images. The atmospheric conditions eg. haze, aerosol etc. changes over the time. Hence, the temporal dataset from January 2014 to January 2015 was atmospherically corrected using ATCOR-2 module of Erdas Imagine. Euclidean distance measure was used for spectral separability analysis. The best date combination for discriminating cassava was found by maximising the minimum Euclidean distance between cassava and other crops. The spectral separability analysis could not give qualitative or quantitve result for classification accuracy. Thus, fuzzy based supervised classification was carried out on the selected date combinations to find out the overall best dates combination. The unbiased sites used for generating crop growth profile of different crops were taken to train the classifier. Three classification algorithms viz., Possibilistic *c*- Means (PCM), Kernel based PCM (KPCM) and Contextual information with PCM and KPCM were implemented on the temporal spectral reflectance stack. Absence of high resolution temporal images led to usage of entropy measurement for accuracy assessment of the classified outputs. Entropy at other unbiased sites (testing sites) was calculated. Entropy at unibiased sites should have low value. Lower entropy value indicates higher certainity of presence of that particular class at the unbiased site. The dates combination corresponding to lowest entropy was considered to be the best for identifation of cassava.

The kernel based Possibilistic *c*- Means classification technique was applied to the best 3, 4 and 5 date combinations for Landsat 8 OLI temporal data for identifying cassava. The results showed that best combination and corresponding minimum Euclidean distance measure was for 4 date combination, where the minimum distance was found to be 32, which could successfully separate cassava from other crops. Fig. 42 shows the fractional images thus obtained for white Thailand and Mulluvadi. The accuracy of the classified output was carried out using entropy. Entropy assessment has been computed and the assessment for white Thailand is shown in Fig. 43. As the weighted constant value is lowered down, the entropy decreases and thus at the optimised weighted constant value, the entropy is near to minimum. At optimized weighted constant for inverse

multiquadratic based Possibilistic c-Means for 4 date combination, the total estimated area was found to be 4234.10 ha and 2175.63 ha for white Thailand and Mulluvadi respectively. The total estimated area under cassava in Salem district in 2014 is 8324.20 ha. The best suitable date combination for identification of cassava was found to be 4 dates that are 4 February, 8 April, 15 August and 22 January 2015. The results clearly indicated that inverse multiquadratic kernel at optimized m value of 1.010 outperformed rest of the six kernels. The study clearly developed a methodology using Landsat 8 OLI satellite imagery along with inverse multiquadratic based Possibilistic c-Means classifier for acreage estimation of cassava.



White Thailand Mulluvadi

Fig.42. Fractional images for white Thailand and Mulluvadi using best 3, 4 and 5 date combination

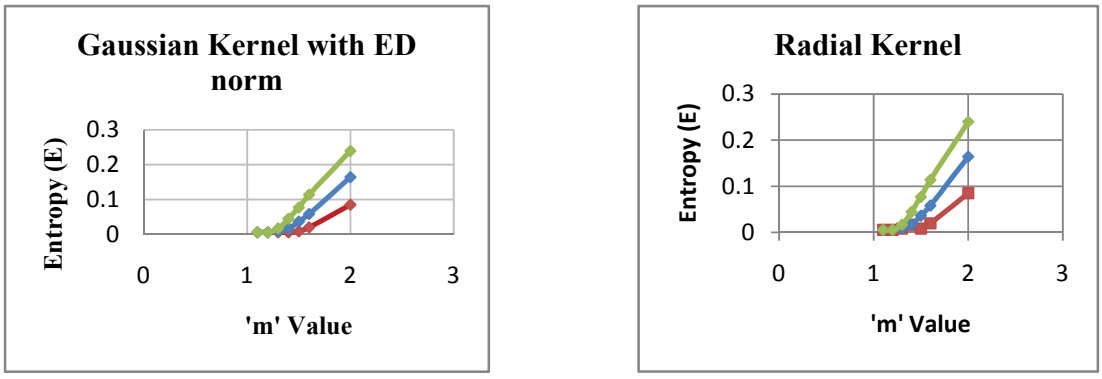
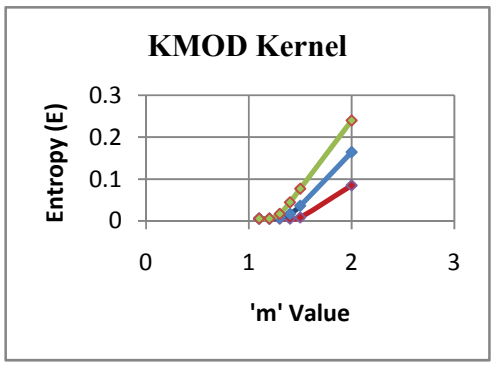
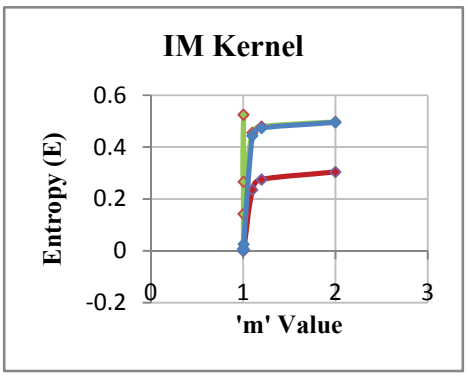
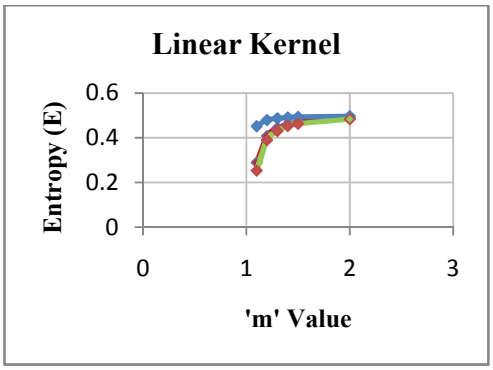
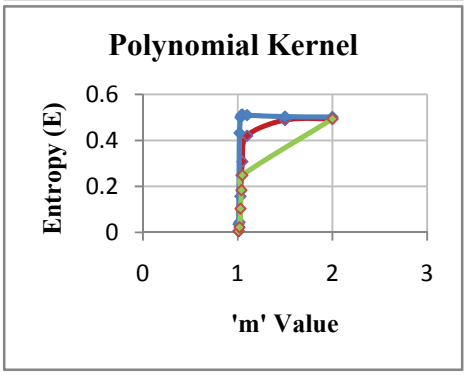


Fig. 43. Variation of entropy with 'm' for white Thailand with best 3, 4 and 5 date combination









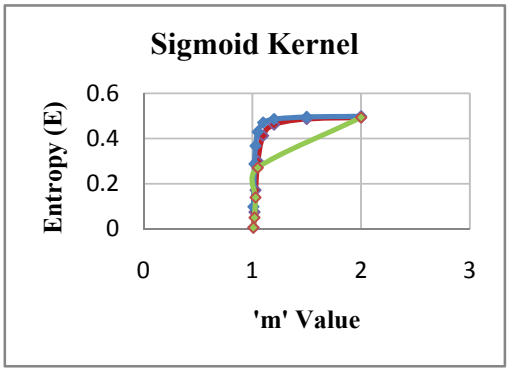


Fig. 43 (contd). Variation of entropy with 'm' for white Thailand with best 3, 4 and 5 date combination

CROP PROTECTION

ECOFRIENDLY STRATEGY FOR THE MANAGEMENT OF INSECT PESTS IN TUBER CROPS

IPM of borer pests of tropical tuber crops

Sweet potato weevil

Survey and variability studies

Borer pests of tuber crops were surveyed in Dhenkanal, Boudh, Angul, Kalahandi, Koraput, Navranpur and Bargarh districts of Odisha. Sweet potato weevil (SPW) (*Cylas formicarius*) is the major pest of sweet potato with yield losses ranging from 15 to 75%. Sweet potato weevils were collected from different States of India through ICAR-AICRP on Tuber Crops Centres. The genomic DNA was isolated and the mitochondrial cytochrome oxidase (MtCOX1) gene was amplified by PCR using universal primers LCO 5'GGTCCA CCAATCATAAAGATATTGG3'and HC O 5'TTAACTTCAGGGTGACCAAAAA ATCA3'. The samples were cloned and the sequences obtained were aligned using BIOEDIT software. All the samples were identified as *Cylas formicarius* with 98-99% similarity. The samples collected from different states showed variation within the sequences.

Sex pheromone for SPW management

Sex pheromone technology demonstration for SPW was conducted in sweet potato fields in Dhenkanal, Bargarh, Navranpur and Koraput districts of Odisha. In Dhenkanal, farmers used the sex pheromone technology in 500 ha @ 10 traps per ha, and 33 meters distance between two traps and were able to control the weevil significantly. The control plots without the technology resulted in 75% tuber damage, whereas, the pheromone technology used plots resulted in 10% tuber damage, which was seven times less damage than the control plots. The cost of pheromone traps including lures, plastic boxes etc. was only Rs. 400 per ha. Pheromone technology used plots (60 ha continuous plot) in farmers' fields in Dhenkanal resulted in 18 tonnes of healthy tubers; whereas, in control plots (50 ha), it was only two tonnes of healthy tubers per ha. These results made hundreds of farmers to adopt the technology, as it was easy to use, erect and safe to environment. Fourteen new insecticides from different chemical groups have been evaluated against SPW and other borer pests.

Safer pesticides for SPW management

The insecticides used are dimethoate, chlorpyriphos, triazophos, acephate (organophosphates), bifentrhin, cypermethrin, deltamethrin (synthetic pyrethroids), imidachloprid, thiomethoxam and acetamiprid (neonicotinoid), emamectin benzoate (avermectins), spiniosad (spinosyns), cartap hydrochloride (nereistoxin analogue), propargite (inhibitors of mitochondrial ATP synthase). Profenophos 40 EC + cypermethrin 4 EC @ 400 g ai ha^{-1}, emamectin benzoate 5SG @ 11 g ai ha^{-1}, spinosad 45 SC @ 50 g ai ha^{-1} and cartap hydrochloride 50 SP @ 500 g ai ha^{-1} resulted in very less infestation of borer pests in the order of 0, 0.20, 0.33, 0.87% respectively, whereas, control plots resulted in 42.93% infestation.

Biopesticides

The bioformulation, *Nanma*, at 0.75, 1.0 and 1.5% were treated in the sweet potato field against SPW at 30, 45, 60 and 75 days after planting (DAP), and synthetic insecticide chlorpyrifos 0.01% was kept as control. On harvest, the weevil damage was recorded in three categories as low, medium and high infestation. It was found that the treatment with *Nanma* at 1.0 and 1.5% was statistically ($P<0.001$) on par with the chemical treatment. In this treatment, 85% tubers were free from weevil infestation, 14% tubers were categorised as low infestation, only 1% tuber was medium infested, and no tubers were noticed under high-infested category. In the case of

control plot, 72% of the tubers were found highly infested.

Entomopathogenic nematodes (EPNs) in powder formulations brought from ICAR-NBAIR, Bengaluru, reduced SPW incidence in kharif season. EPNs @ 20 kg ha^{-1} resulted in 10.67% weevil damage, whereas, the highest was recorded in the control plot with 52.67% weevil damage.

Nematodes

Fifteen soil samples were collected from elephant foot yam fields of Block I of ICAR-CTCRI and analyzed for plant parasitic nematodes. Lesion nematode, *Pratylenchus* sp. was the most predominant with a density of 0.9 nematode per gram of soil. The soils collected from elephant foot yam fields of Samrajnagar, Karnataka showed the presence of 1.1 nematodes per gram of soil.

CASSAVA MOSAIC DISEASE-VARIABILITY, DIAGNOSTICS, VECTOR RELATION AND MANAGEMENT

Survey and prevalence

Leaf samples infected by cassava mosaic disease were collected (145) from Kerala and Tamil Nadu and PCR analysis revealed mixed infection (9) or single infection of *Sri Lankan cassava mosaic virus* (SLCMV) (106) and *Indian cassava mosaic virus* (ICMV) (16) and reemergence of ICMV was observed (Fig. 44). Testing of the above samples for other cassava viruses reported from other countries (ACMV, EACMV, CBSV) and DNA showed negative results. Coat protein gene of ICMV and SLCMV was cloned and confirmed by sequencing. Sequences of both ICMV-CP and SLCMV-CP were analysed, which had 99.70% similarity between them. They were recloned in bacterial expression vector (pET22a+) for protein production

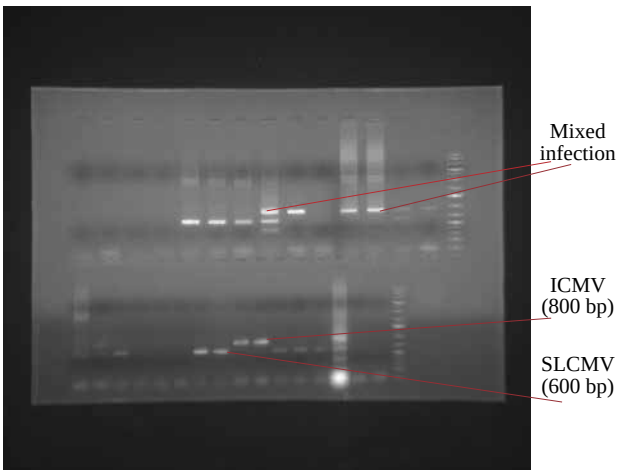


Fig. 44. PCR analysis of CMD samples collected from different cassava growing areas

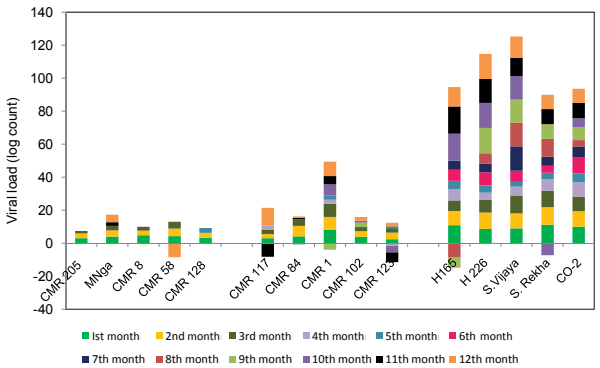


Fig. 45. Viral load in qPCR analysis of different cassava cultivars (resistant, recovery and susceptible) during the crop growth period

Molecular mechanism of the virus infection

A field experiment was laid out with susceptible, recovery and resistant lines of cassava to study the disease recovery phenomena. The disease incidence remained the same in susceptible cultivar for the entire crop growth period, recovery lines showed remission of symptoms from 5-6th month after planting and resistant lines remained symptom free. The qPCR studies showed drastic reduction in virus load during the remission of symptom and at the end of crop cycle virus load started rebuilding as low concentration in the recovery cultivars (Fig. 45). The siRNAs were isolated from these samples to understand the molecular mechanism.

Management of the disease through resistant varieties

Two thousand and five hundred cassava hybrid seedlings were developed through crossing of genotypes with resistance from different sources. Seedlings free of CMD symptoms with good plant type and tuber characters were selected (404 number) for first clonal evaluation and CMD screening. Among the hybrid seedlings, 15S-291 produced the highest tuber yield of 11.50 kg/plant followed by 15S-434 (10.60 kg), 15S-76 (10.20 kg) and 15S-178 (9.00 kg). Two hundred and ten CMD free seedlings were evaluated for dry matter content and it ranged from 13.90 (15S-122) to 52.56% (15S-285). Among these hybrids, 15S-57, 15S-66, 15S-135, 15S-130 and 15S-67 were found to be promising with CMD resistance coupled with high tuber yield and dry matter content.

Virus – vector relationship

Whiteflies were collected from different parts of Kerala in cassava growing regions and the morphological variability among the whitefly population was studied (body size, number of antennal segments, size of hind tarsus and genitalia). There was no significant variation among the collection and the molecular variation studies of whiteflies collected from ICAR-CTCRI campus using SSR markers and mtCOI gene sequencing showed that they resemble *Bemisia tabaci* with minor variations among them and belong to Aisatic biotype.

Integrated management

An experiment was conducted in lysimeter for eight months with periodic application of nutrients viz., N, P, K, Ca, Mg, Si, Zn, Mn, Cu, B, salicylic acid, as soil and foliar in alternate weeks. The observation on plant growth characters, LAI, CMD incidence at bimonthly intervals from 2 MAP to 8 MAP indicated that the order of nutrients for imparting tolerance to CMD was Zn, Si, P, B, Ca. Effect of leaf extracts of eight different plants, neem oil and a formulation D virus, which were reported to have antiviral properties was tested against CMD by sett treatment and weekly sprays up to three months in pot culture. None of them reduced the incidence. However, neem oil @ 0.2% and D virus showed maximum reduction in the intensity (30%) followed by *Bougainvillea* and *Glyricidia* (20 to 25%).

Cassava mosaic virus free planting materials of popular cassava varieties, Sree Vijaya (2000 stems) and Sree Jaya (1500 stems) were produced through meristem culture and indexed for virus. The rate of reinfection was nil up to three months and it was 16 and 18% at 4th month and 38 and 41% at 8th month of planting the virus free cassava varieties, Sree Vijaya and Sree Jaya respectively. Planting of infected material showed symptoms at first month itself and the incidence was 65 and 73% respectively in both the varieties at the 8th month.

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

Fungal diseases of aroids

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

Twenty soil samples were collected from Tamil Nadu, Odisha, Karnataka and Kerala. Sixty three isolates were made using dilution plate technique and all the isolates were purified and maintained on potato dextrose agar (PDA) or nutrient agar (NA) media. The organisms were screened against *P. colocasiae* and *S. rolfsii* using the methods, direct confrontation, production of metabolites and volatiles. Thirteen bacterial isolates and two *Trichoderma* isolates were selected for further studies based on their inhibition potential.

Seventy one bacterial isolates, which were identified for pathogen suppression in the previous years and maintained at microbial repository, ICAR-CTCRI, were screened for N fixation and P and K

solubilisation. The media used for screening were Jensen's N free agar (Jensen, 1950), Pikovskayas (Pikovskaya, 1948) and SSKM agar (Sheng and He, 2008) respectively. Seventeen isolates were identified with N fixation, P and K solubilisation (Fig.46).

Fig.46. Bacterial isolate showing P solubilising potential in Pikovskayas medium

Six *Trichoderma* isolates, which showed excellent pathogen suppression, were identified using ITS region amplification. The isolates were identified as *Trichoderma harzianum* (3 isolates), *T. erinaceum, T. virens* and *T. viride.*

Effect of bio-priming on taro leaf blight

Effect of bio-priming of taro cormels on taro leaf blight (TLB) incidence was studied in grow bags using six *Trichoderma* isolates, which showed high inhibition against the target pathogen under *in vitro* condition. *Trichoderma* @ 5g kg^{-1} of cormel was mixed with cow dung slurry and the cormels were coated with the mixture. The coated cormels were allowed to dry under shade and planted. Later, *Trichoderma* was applied twice @ 5 g $plant^{-1}$ one week after fertilizer application. The disease incidence as well as growth parameters were monitored at frequent intervals. All the six isolates could significantly reduce the TLB incidence (Fig. 47).

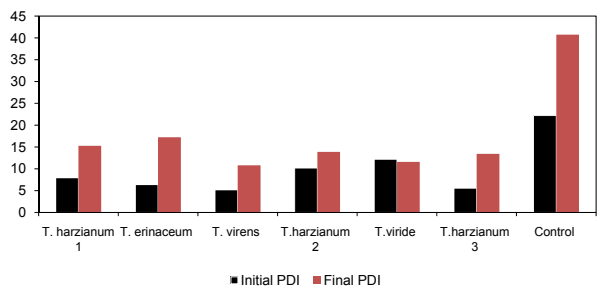


Fig. 47. Disease incidence (%) in *Trichoderma* treated taro plants

Exploitation of *Piriformospora indica* for disease suppression

Piriformospora indica is a cultivable endophyte that colonizes roots of many plant genera. The culture of *P. indica* was obtained from Amity University. The culture is being maintained on PDA medium. Six different media were tested at 28°C with 120 rpm for mycelial mass production and the media, Malt Extract Agar (MEA) and Jaggery Agar (JA) yielded maximum mycelial mass (Fig. 48).

Fig. 48. Mycelial growth of *Piriformospora indica* on different media

To confirm the root colonization of *P. indica* in taro, a pot culture experiment was conducted. Mycelial mass was mixed with sterilized soil of approximately 2.5 kg and taro tubers were planted in pots. The pots were kept in a net house under normal conditions and the growth was observed daily. After three weeks, the plants were uprooted and fungal colonization was analysed by various methods, microscopic observation (Nikon Eclipse E200, Nikon Corporation, Japan) after Trypan blue staining, Pitef amplification and confocal microscopy. In the case of amplification of Pitef, the primer pairs were successful in amplifying the *P. indica* from the colonized roots. They produced an expected amplicon size of approximately 220 bp. The sequencing of the amplified products confirmed the presence of *P. indica*. For confocal microscopy, WGA-AF 488 staining was carried out with slight modifications of the procedure of Wright 1984. Both the control and the co-cultivated plant roots

were collected, processed and viewed by confocal laser imaging on a multichannel TCS SP2 confocal system (Leica Microsystems, Bensheim, Germany). The conjugated WGA-AF 488 was excited at 488-nm wave length and detected at 500–600 nm (Fig. 49)

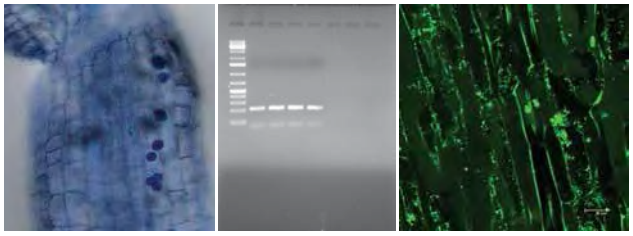


Fig. 49. Root colonization of *P. indica* in taro under microscopy, Pitef amplification and confocal microscopy

Effect of boron and silicon on taro leaf blight incidence

Effect of boron and silicon on TLB incidence was studied in pots. The variety used was Sree Kiran, a TLB susceptible variety. Boron was supplied as borax and silicon was supplied as potassium silicate. There were nine treatments, borax @ 0.75 g plant^{-1} (B1) and 1.125 g plant^{-1} (B2), potassium silicate @ 7 g plant^{-1} (Si1) and 10.5 g plant^{-1} (Si2) and their combinations. Disease incidence as well as growth parameters were monitored at frequent intervals. Disease incidence was significantly low in all borax and potassium silicate applied plants (3.13 to 16.20) compared to NPK alone applied plants (24.62) (Fig. 50). However, the growth parameters did not show significant difference by the addition of boron/silicon.

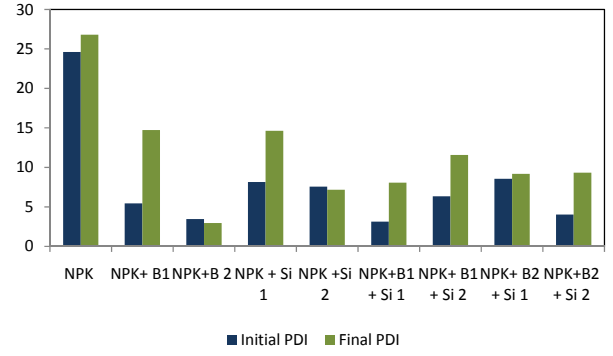
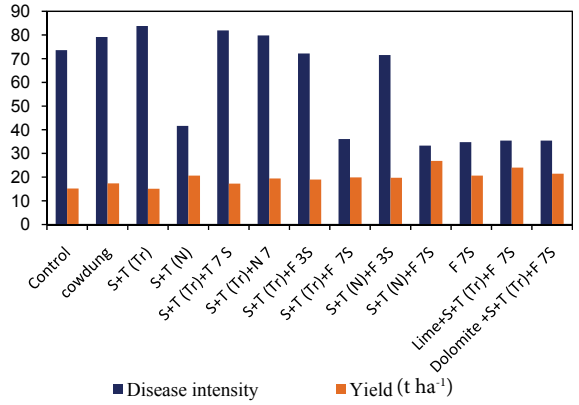


Fig. 50. Percent Disease Incidence (PDI) in boron and silicon applied taro plants

Greater yam anthracnose

Management

In a field experiment, the efficiency of different combinations of soil and tuber treatment with *Trichoderma asperellum*; ICAR-CTCRI developed biopesticide, *Nanma* and spraying of carbendazim against greater yam anthracnose caused by *Colletotrichum gloeosporioides* were tested for the second season. Lime and dolomite also were used separately. Soil treatment with *Trichoderma* was @ 50 g of 10^7 cfu g^{-1} and tuber treatment @ 5 g in fresh cow dung slurry per kg of cut tuber. The soil treatment with *Nanma* was @ 0.50% (one litre per plant). The tubers were treated with 0.50% *Nanma*. The soil and tuber treatment with *Nanma* along with spraying of carbendazim seven times showed the maximum reduction in disease intensity and increase in yield compared to control, which was on par with soil and tuber treatment with *Nanma*; soil and tuber treatment with *Trichoderma* along with spraying of carbendazim seven times; soil and tuber treatment with *Trichoderma* along with spraying of carbendazim seven times and lime application; soil and tuber treatment with *Trichoderma* along with spraying of carbendazim seven times and dolomite application and spraying of carbendazim seven times alone (Fig. 51).



C: Control; S: Soil treatment; T: Tuber treatment; Tr: *Trichoderma;* N: *Nanma*; F: Fungicide; 7S: seven sprays; 3S: three sprays

Fig. 51. Effect of bio-control agent, bio-formulation and carbendazim on the intensity of anthracnose and yield in greater yam var. Orissa Elite

Epidemiology

Three released varieties of greater yam, viz., Orissa Elite (highly susceptible), Sree Karthika and Sree Keerthi (tolerant) were planted in May 2016 and observed for disease severity at weekly intervals till 8th month of planting, December. The maximum disease intensity was observed with Orissa Elite (100%) followed by Sree Karthika (35%) and Sree Keerthi (33%). The disease started in Orissa Elite after 12 weeks of planting in the middle of July after rainfall, whereas in tolerant varieties it was delayed up to two weeks. The disease progress was high in all the varieties in the 4th month, August (17 weeks after planting). Later there was no progress of disease in tolerant varieties, which showed only leaf spot and blight symptoms, but Orissa Elite showed steady progress throughout the crop growth period till December and finally dried due to die back. The progress of the disease started from the month of August (fourth month of planting) after rainfall and reached high during October, when the rainfall and number of rainy days were high (Fig. 52).

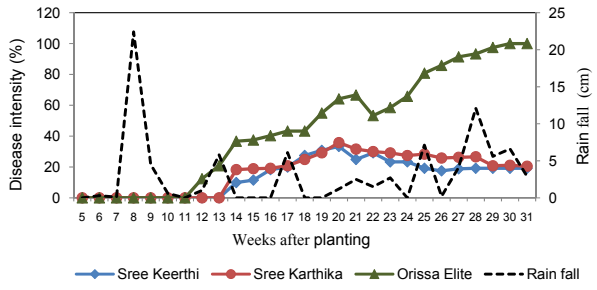


Fig. 52. Development of anthracnose in three varieties, Sree Keerthi, Sree Karthika and Orissa Elite of greater yam in relation to rainfall

Pathogenecity test

The methods of testing pathogenecity of *Colletotrichum gloeosporioides* on greater yam have been standardized by using detached leaf assay and also tissue cultured whole plant assay. Twenty microlitre of spore suspension placed on detached fully opened young leaves (5th-8th) of greater yam and incubated at 28 ± 4°C in large petri dishes on wet cotton could develop the symptom on the third day of inoculation. It was observed that the age of leaf plays a major role. The old leaves did not produce the symptoms.

For whole plant assay, the nodal culture of 10 different lines and released varieties of greater yam was developed in MS media incorporated with IAA: Kinetin (2 & 1.5 mgl^{-1}) and PVP @1 % and sub cultured in half strength MS liquid media and hardened. One month after hardening, the variety Orissa Elite, highly susceptible to anthracnose was utilized for the test with highly virulent pathogen isolate, CTCRI-Cg 7. The pathogen was inoculated in three different ways, viz., i) swabbing spore suspension with cotton ii) spraying and iii) keeping 50 micro litres of spore suspension on four different young leaves and covering with wet cotton. The whole plant was then covered with polythene cover to maintain humidity. The method (iii) mentioned was efficient and could produce the symptom after seven days of inoculation (Fig.53).

Fig. 53. Symptom in greater yam var. Orissa Elite by artificial inoculation to test the pathogenecity of *C. gloeosporioides*

Characterisation of toxic metabolite produced by *C. gloeosporioides*

Protein precipitation of the culture filtrate of a virulent *C. gloeosporioides* isolate was done using acetone and the bio-efficacy was tested in detached greater yam leaves (Fig. 54). The fraction could induce symptom within three days. The fraction was then purified using silica gel column and the fractions were UV scanned and those with distinct peaks were tested for

their bio-efficacy. The effective fractions were pooled and HRMS and HPLC of the fraction have been done (Figs. 55a & b). The analysis of the results showed that the major compound is tetrasachharides.

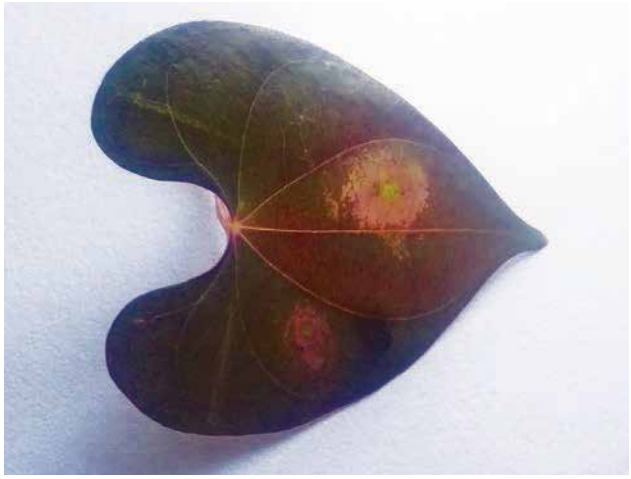


Fig. 54. Symptom induced by the purified fraction of toxic metabolite of *C. gloeosporioides*

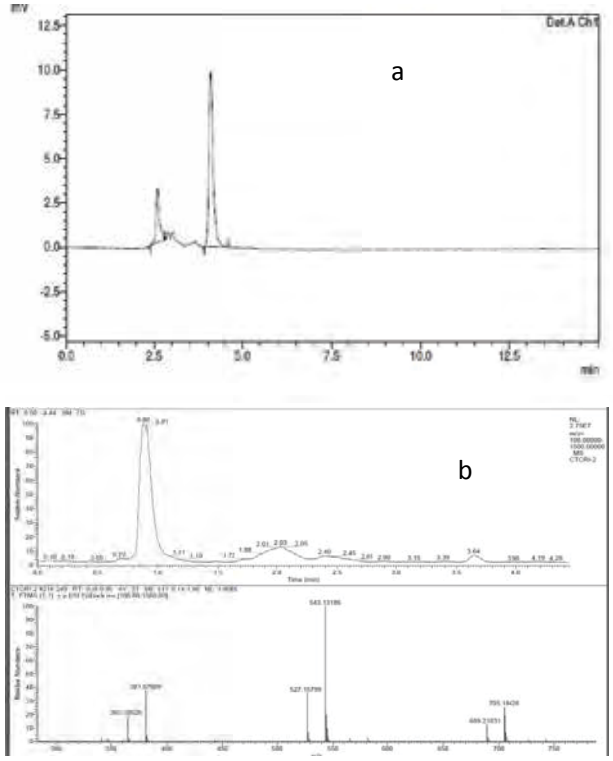


Fig. 55. a. HPLC and b. HRMS of the purified fractions of toxic metabolite of *C. gloeosporioides*

Mining of resistance genes in greater yam

With an aim to identify genes for resistance, which will be expressed during anthracnose infection, resistance gene analogues (RGAs) were amplified from healthy greater yam using degenerate primers, already reported based on the conserved domains. For this, DNA was isolated from Sree Karthika, Sree Keerthi (tolerant varieties) and Orissa elite (susceptible variety), quantified and quality of DNA was checked. PCR has been performed using the degenerate primers, viz., Forward primer-GGIGGIGTIGGIAAIACIAC and Reverse primer – ARIGCTARIGGIARICC. An expected size of ~ 500 bp amplicons was produced from all the three varieties (Fig. 56). The products were purified, cloned and sequenced. The sequence obtained showed relation to disease resistance proteins, when compared with known protein sequences in the database using blast program.

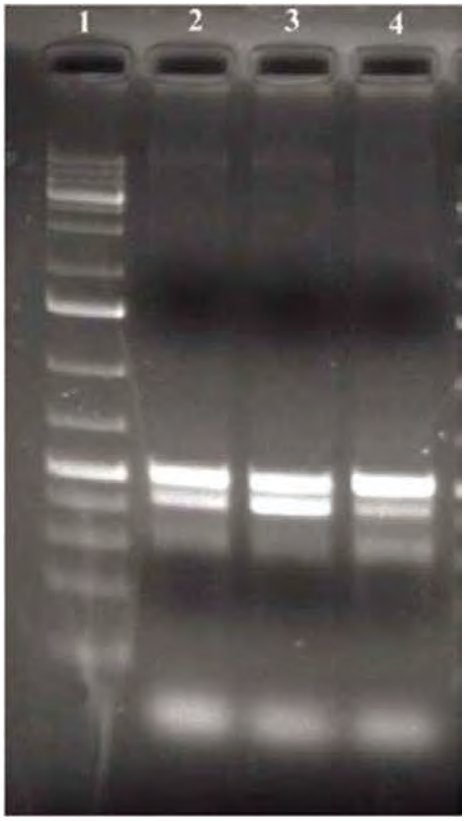


Fig. 56. Lane 1. Marker; Lane 2. Amplicons produced from Sree Karthika; Lane 3. Amplicons produced from Sree Keerthi; Lane 4. Amplicons produced from Orissa elite

Characterisation, diagnosis and management of viruses of tuber crops

The objective of this study was to identify and characterize viruses infecting lesser yam and sweet potato at molecular level to know and record the viruses infecting the crops in India.

Viruses of lesser yam

The leaf and tuber samples with various virus like symptoms, viz., chlorosis, mosaic, puckering, leaf distortion and mottling were collected from the lesser yam growing fields of ICAR-CTCRI. And the total nucleic acid (DNA and RNA) was isolated from the virus infected samples. CTAB method was effective in isolating DNA from both the leaf and tuber. The Ambion Pure Link RNA Mini kit and Lithium chloride method were found to be the most appropriate for RNA isolation from lesser yam leaf and tuber samples respectively. Serological and nucleic acid based techniques were performed to identify the presence of virus infection.

Serological based detection

DAS-ELISA and TAS–ELISA used for the detection of YMMV, *Yam macluravirus* and *Yam badnavirus* with specific antibodies obtained from DSMZ, Germany showed that out of 75 samples, 88, 36 and 40% samples were positive to YMMV, *Yam macluravirus* and *Yam badnavirus* respectively. Mixed infection of viruses were also observed (YMMV and *Yam macluravirus* (34%); YMMV and *Yam badnavirus* (31%); YMMV, *Yam macluravirus* and *Yam badnavirus* (14%); *Maclura* and *Badnavirus* (14%)).

Nucleic acid based detection

Nucleic acid based (PCR and RT-PCR) diagnostics were carried out using YMMV 1c/YMMV ls, YV1-F/YV1- R,YMac1s/YMac1c, and Badna F/Badna R, the virus specific primers. The first two sets of primers amplified YMMV with amplicon size of 500 bp and 260 bp respectively, whereas the third and fourth sets gave amplicon size of 200 bp and 579 bp respectively for *Yam macluravirus* and *Yam badnavirus*. Based on the sequence, two pairs of species specific primers viz., YMMV F1/YMMV R1 and YMac F/YMac R were designed to amplify the partial coat protein gene of the viruses of YMMV and *Yam macluravirus*. The annealing temperature was standardized and RT-PCR performed with these primers provided amplicon size of 193 bp and 237 bp respectively (Figs. 57 and 58).

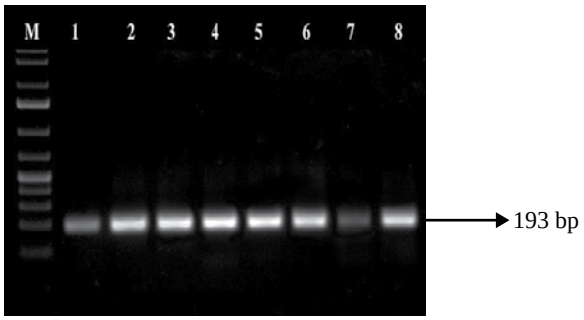


Fig. 57. YMMV amplification using YMMV F1/YMMV R1 primers

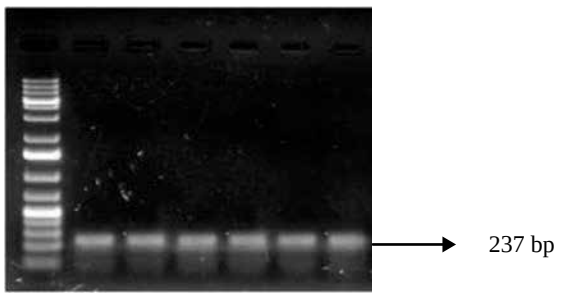


Fig. 58. *Yam macluravirus* amplification using YMac F/YMac R primers

Characterisation

The samples characterized suggest mild to severe mosaic, puckering, cupping, mottling and chlorosis as the common symptoms associated with YMMV. The samples with no prominent symptoms were also detected with YMMV. Since mixed infection of these viruses also showed similar symptoms, the specific symptoms of individual virus could not be established. The *Yam macluravirus* and *Yam badnavirus* were also detected in lesser yam, but compared with YMMV the other viruses (*Yam macluravirus* and *Yam badnavirus*) occur at lower incidence and concentration in plant tissues.

The amplified PCR sample (partial coat protein gene) of YMMV, *Yam macluravirus* and *Yam badnavirus* were cloned into *E. coli* DH5α cells. The presence of gene insert in the transformed colonies was confirmed by colony PCR. The recombinant plasmids DNA were isolated from the transformed colonies of YMMV and *Yam badnavirus* and RT-PCR was performed, which yielded amplicons of expected band size of 500 bp and 579 bp respectively. For *Yam macluravirus* the colony PCR product was gel eluted. The plasmid DNA and gel elute were sequenced.

The BLAST analysis of the partial CP coding region revealed that YMMV has maximum similarity of 86% to *Yam mild mosaic virus* isolate CN20, complete genome (Accesssion KC473517), whereas *Yam macluravirus*, 95% to YMCTCRI-01 polyprotein gene, partial cds (Accesssion KM099684) and *Dioscorea bacilliform virus*, 99% to isolate FJ65c De (Accession AM072661).The phylogenetic tree was constructed with similar sequences using mega software.

Viruses of sweet potato

Symptomatology and identification

Sweet potato samples with various virus infection symptoms were screened for *Sweet potato feathery mottle virus* (SPFMV), *Sweet potato mild mottle virus* (SPMMV), *Sweet potato leaf curl virus* (SPLCV), *Sweet potato chlorotic stunt virus* (SPCSV), *Sweet potato virus G* (SPVG), *Sweet potato virus C* (SPVC), *Sweet potato virus 2* (SPV2) using both genus and virus specific primers. Out of 32, 29 samples showed SPFMV infection in PCR with virus specific primers. While, mixed infection by SPFMV and SPLCV was found in 15 samples. One sample was infected with SPVG along with SPFMV and SPLCV. There was no infection of SPMMV as the serological and PCR screening gave negative results. SPVC, SPV2 and SPCSV screening through PCR gave negative results for all samples.

The samples characterized suggest feathery symptoms, puckering, pink colour ring spots, veinal chlorosis, faint-to-distinct chlorotic spots with or without purple margins to be the common symptoms associated with SPFMV. The samples with these prominent symptoms and samples showing no such symptoms were identified with SPFMV. Stunting, upward curling or rolling of leaves were the major symptoms shown by some plants. When these samples were subjected to characterization they were confirmed with the presence of SPLCV. Yellow netting shown by two samples seemed to be infected with SPMMV, but molecular characterization proved these samples were infected with SPFMV. The presence of SPVG, a lenient of SPFMV, which was not common in India, was identified. The symptoms shown by this sample were same as the symptoms shown by SPFMV. This showed that the RNA viruses were highly prone to variations. These samples with mixed infections showed the major symptoms of both SPFMV and SPLCV, like feathering, pink colour ring spots, upward curling of leaves. When they were subjected to PCR by virus specific primers of SPFMV and SPLCV, amplicons size of 411 bp and 446 bp were obtained respectively.

Nucleic acid based detection

PCR based diagnostics carried out using *Potyvirus* specific primer MJ1/MJ2 and SPFMV1 /SPFMV2 amplifying the WCIEN and QMKAA motif of CP and partial CP giving an amplicon of 327 bp and 411 bp respectively was found to be a robust of detecting SPFMV infections in India. Rather than the virus specific primers, the group specific primers Pot1/Hrp5 lead to the detection of SPVG. The virus specific primers LCV1/LCV2 coding for the partial CP giving an amplicon of 446 bp were efficient to detect SPLCV.

Characterisation of the viruses

The 304 nt SPFMV sequence obtained in the study showed maximum similarity of 96% to *Sweet potato feathery mottle virus* isolate Fe polyprotein gene,

partial cds (Accession EU021070). The 251 nt SPVG sequence obtained showed maximum similarity of 90% to sweet potato virus G isolate IS103, complete genome (Accession KM014815). While the 418 nt SPLCV sequence obtained showed maximum similarity of 96% to *Sweet potato leaf curl virus* DNA A, complete sequence (Accession AF104036) and *Sweet potato leaf curl* isolate CTCRI TVM M1, complete genome (Accession KM 050768). The phylogenetic tree was constructed with similar sequences using phylip. Phylogenetic analysis clearly revealed that the sequences obtained in this study belongs to SPFMV for the sample S1294, SPLCV for the sample S1294, SPLCV for the sample S684 and SPVG for the sample S270 as they grouped along with their respective virus sequences used for comparison analysis.

CROP UTILIZATION

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

Value added food products from tuber crops

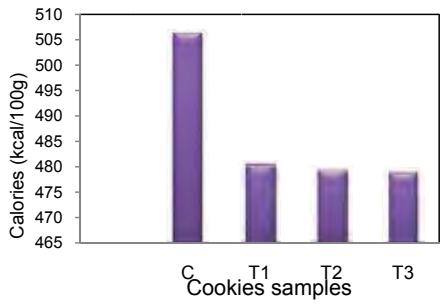
Taro flour based gluten-free cookies and bread

Taro flour based gluten free cookies and bread fortified with taro flour were developed. Initially, the procedure for development of good quality taro flour having bright colour and low acridity was standardized. The treatment of 1% citric acid followed by blanching (100°C, 5 min.) was the most effective treatment to remove acridity from taro tubers and to obtain taro flour with bright colour.

Taro flour based gluten-free cookies suitable for celiac patient was developed from blends of taro flour, rice flour, sorghum flour and cassava flour (Fig. 59). Developed cookies were evaluated for physico-textural properties, proximate composition and sensory characteristics.

Taro flour could be successfully utilized along with other flours such as rice, sorghum and cassava for the development of cookies, which could be safely consumed by celiac patients. The low calorie density in the cookies coupled with the high content of minerals such as phosphorus (167 mg $100g^{-1}$), potassium (723 mg $100g^{-1}$) and magnesium (1.59 mg $100g^{-1}$) could be an added advantage for taro flour based gluten-free cookies . Taro flour based blend containing 50% taro flour along with rice flour, sorghum flour and cassava flour was the best combination for making gluten-free cookies and it provides 3.76% protein, 3.52% crude fibre and 479.62 kcal energy (Fig. 60). Taro flour bread (Fig. 59) was prepared by replacing 30-40% wheat flour with taro flour. The properties like moisture, bulk density and colour value of bread samples were determined. The physical properties like colour value (L, a & b) and bulk density of bread with 30% taro flour was found similar to that of the wheat flour bread.

Fig. 59. Taro flour based gluten-free cookies (top) and taro flour bread (bottom)



C: Wheat based cookies;T1: Cookies with 40% taro flour; T2: Cookies with 50% taro flour; T3: Cookies with 60% taro flour

Fig. 60. Calorie content of taro flour based gluten free cookies

Refinement of machineries for cultivation and processing of tuber crops

A power weeder developed by Industrial Extension Centre of CIAE, Coimbatore was evaluated at ICAR-CTCRI farm and it was found that the weeder was suitable to address the weeding requirement of cassava planted on mounds in the hilly terrains with mean weeding index of 91.90%. Cost of weeding by machine works out to Rs.6123 ha^{-1}, while that of manual method was Rs. 25000 ha^{-1}, which denotes 75.50% of cost-saving, 90.90% of time-saving and 95.50% of energy-saving through machine-weeding compared to manual weeding. The weeding index and field efficiency of the power weeder ranged from 88.70 to 97.10% and 74.70-82.70%, respectively (Fig. 61).

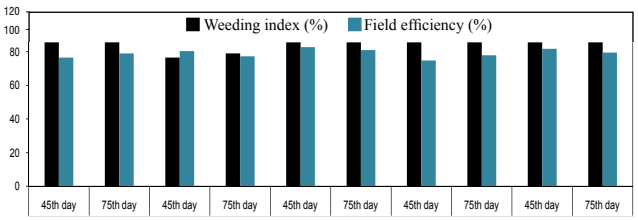


Fig. 61.Weeding index and field efficiency of power weeder

The field capacity of the power weeder ranged from 0.14 to 0.18 ha day^{-1} (Fig.62) and the fuel consumption varied from 25.70 to 29.20 l ha^{-1} (Fig. 63). Break-even point for utility of this machine was 50 ha $annum^{-1}$ and pay-back period is 0.7 year. It is also economically viable with fuel consumption limited to 27 l ha^{-1}. The machine proved its capability for weeding between the rows on both directions with acceptable weeding efficiency of 92.80% with negligible percentage

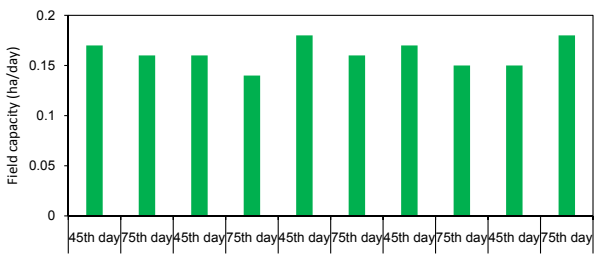


Fig. 62. Field capacity of power weeder

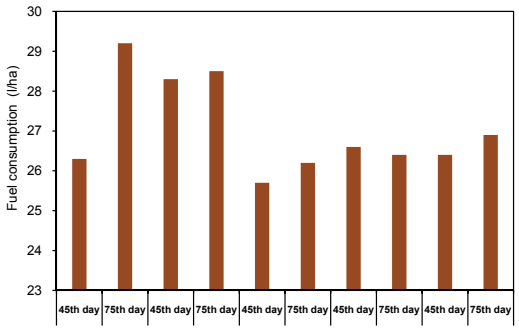


Fig. 63. Fuel consumption of power weeder

(0.70%) of damage to tubers, field capacity of 0.16 ha day^{-1} and field efficiency of 79.00%.The power-weeder was recommended as an ideal machine for medium cassava farms of India.

Particle boards and adhesives from cassava by-products and starch

Particle board from cassava stems using synthetic resins

Particle boards were developed from dried and powdered cassava stems added with different types of binding materials viz., urea formaldehyde, phenol formaldehyde, melamine urea formaldehyde and gelatinized starch by varying the concentration of resin from 30 to 50%, pressure from 20 to 60 kg cm^{-2} and time of pressing from 5 to 10 min. The boards were tested for its thickness, density, water absorption after 2 and 24 h and modulus of rupture.

Density was found to increase with increase in concentration of the resins, compression pressure and time. Maximum density of 1167 kg m^{-3} was obtained for the urea formaldehyde incorporated board made at 60 kg cm^{-2} and minimum of 845 kg m^{-3} for the phenol formaldehyde mixed board at 20 kg cm^{-2}. Maximum moisture content of 13.81% was obtained for the phenol formaldehyde incorporated board made at 60 kg cm^{-2} and minimum of 5.87% for the urea formaldehyde mixed board at 60 kg cm^{-2}. Maximum rupture force of 27.58 M Pa was obtained for the urea formaldehyde incorporated board made at 60 kg cm^{-2} and minimum of 4.56M Pa for the phenol formaldehyde mixed board at 20 kg cm^{-2} (Fig.64).

Water absorption and thickness swelling after 2 and 24 h of soaking in water decreased with increasing amount of the resins, pressure and times. Maximum thickness swelling was 6.94% for the phenol formaldehyde incorporated board made at 60 kg cm^{-2} and minimum of 2.46% for the urea formaldehyde mixed board at 20 kg cm^{-2}. It was found that maximum water absorption after 2 h soaking was 10.32% for the phenol formaldehyde incorporated board made at 20 kg cm^{-2} and minimum of 0.59% for the melamine urea formaldehyde mixed board at 60 kg cm^{-2}. Maximum water absorption after 24 h soaking was 34.76% for the phenol formaldehyde incorporated board made at 20 kg cm^{-2} and minimum of 4.70% for the melamine urea formaldehyde mixed board at 60 kg cm^{-2} (Fig. 65).

Starch was added as a binding material to partially replace the synthetic resins. By adding cassava starch at 20, 30 and 40% with the raw materials by changing the resin:urea formaldehyde content as 10, 20 and 30, the density varied from 867 to 1097 kg m^{-3} showing only minor variation in density due to the addition of starch in the mixture, whereas amount of resin content in the mixture had great influence on the density. Moisture content varied from 10.35 to 10.87% showing only minor variation in moisture content due to the addition of starch in the mixture. By adding cassava starch, there was a reduction in the modulus of rupture of the particle boards i.e., 0.91 to 16.56 M Pa. Thickness of swelling was higher for the particle boards incorporated with cassava starch and it had gone up 20.03%. Water absorption after 2 and 24 h soaking was 33.28 and 42.90%, respectively.

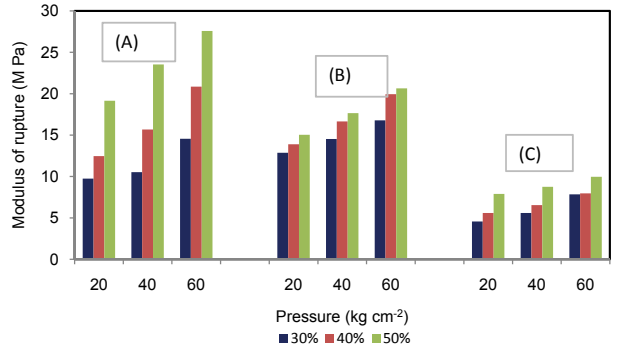


Fig. 64. Mechanical properties of the cassava stem based particle board prepared with various levels of synthetic resins (A) Urea formaldehyde (B) Melamine urea formaldehyde (C) Phenol formaldehyde

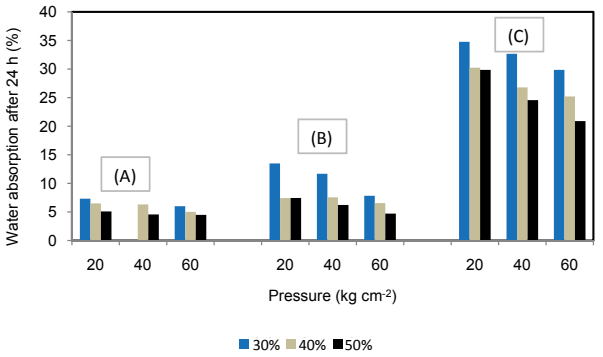


Fig.65. Water absorption of the cassava stem based particle board prepared with various levels of synthetic resins (A) Urea formaldehyde (B) Melamine urea formaldehyde (C) Phenol formaldehyde

Adhesive with poly vinyl alcohol as moisture resistant additive

Cassava starch was modified by oxidation using sodium hypochlorite to obtain starch with the required viscosity. Two phase corrugating adhesive has been prepared. Native cassava starch was mixed thoroughly with powdered borax under stirring (Component I). Oxidized cassava starch was cooked in water under thorough mixing and then mixed with sodium hydroxide under stirring. Water was added to cool the system and then poly vinyl alcohol was added under stirring (Component II). The two components were mixed together to prepare corrugating adhesives. Adhesive was applied on paper boards at 71°C and evaluated for adhesive tack, energy and time for fibre tear. The tack of the adhesive bond varied from 0.60-0.75 kg for various formulations and the drying time of the adhesive on paper board (WCPM MG PB 300 GSM/17.2 kg) was about 45-56 sec. Tack was slightly higher for formulations with lower content of poly vinyl alcohol (PVA). Water soaking test showed that the formulations with PVA could resist the moisture entry into the bond on corrugated surfaces up to 30-45 min.

Adhesive with urea-formaldehyde resin as moisture resistant additive

In the second set of experiment, urea-formaldehyde resin was used as the moisture resistant component in the adhesive formulation. Two different concentrations of resin (12 g and 15 g for 260 g of the adhesive) were used and the solid content of these formulations were 28.60 and 29.20 respectively. Both the formulations were found to be moisture resistant and could keep the bonds on corrugated paper boards intact for more than 1h, when soaked in water.

Alkali free corrugating adhesive mix

Oxidized cassava starch was mixed with a phosphate salt and two were mixed together in a Waring blender (Component I). Native cassava starch was mixed with borax (Component II). Component I was added to hot water at 85°C and admixed under continuous agitation. Component II was added to 12 ml water and agitated for 5 min. Component I was then added to Component II under vigorous agitation and stirred for 1h. The adhesive was applied on paper boards at 71°C and tested. The solid content was found to be 29.20%, gel point was 68°C and tack was 0.75 kg.

Extrusion of curcuma starch : cassava flour composites

Curcuma is an under-expoited minor tuber crop valued for its high medicinally important starch content. An attempt was made to produce ready to eat expanded extruded products from curcuma starch. Curcuma starch added with 25 and 50% cassava flour was extruded at 80, 100 and 120°C by adjusting the feed moisture content at 10, 12 and 14%. The moisture content of the extrudates ranged from 2.42 to 5.97%. The total starch content of the extrudate varied from 80 to 88%, having minimum values for the combination 75 (curcuma starch):25 (cassava flour) extruded at 80°C with 10% moisture content. Total sugar content was not detected for the samples containing curcuma starch alone, whereas the composites have values about 1.00-1.60%. Total protein content of the extruded samples ranged from 0.50-1.30%. The crude fat and ash contents have only minor difference in values. Water absorption index was found to be the highest (11.40%) for the composites having 75:25% extruded at 100°C with 12% moisture in it and the lowest value of 5.95% was obtained for the curcuma starch alone extruded at 100°C with 10% moisture. However, water solubility index was lowest (23.90%) for 50:50 combination extruded at 80°C with 12% moisture content and higher (35.8%) for 50:50 extruded at 100°C with 14% moisture content. Expansion ratio of the extrudate did not have much variation, the values were 3.2-3.8. The bulk density values ranged from 0.71-0.78 g cm^{-3}. Hardness was highest (120.74N) for the curcuma starch alone extruded at 80°C with 12% moisture content and lowest (32.12N) for 75:25 extruded at 100°C with 12% moisture .

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

Evaluation of post-harvest physiological deterioration (PPD) of cassava

Based on the visual scoring of roots, 61 cassava genotypes were grouped and segregated into different PPD category. Most of the genotypes studied were susceptible to early PPD and were either in the high or extreme category symptom groups. The moderate group also showed strong PPD symptoms with vascular streaking after a week and hence these genotypes will also show PPD symptoms at an early stage when the wounds are deep and storage conditions are favourable for deterioration. Genotypes such as 9S-7, 9S-98, 11S-31, 11S-86, 11S-14, CE-63-3, CI-43-2, CR-43-2, CR-54-A5, CR-59-8R, Sree Athulya and Kalpaka showed low PPD scores with lower discoloration and streaking compared to the rest of the genotypes. Roots of these genotypes were intact even at tenth day of storage and free from any foul smell, which normally develops in cassava when PPD intensity is high. The progress of PPD in genotypes such as 11S-4, 7 IV-D7, CI-896, CO-2, CR-43-7, CR-54-A19, CR-24-4, IMS 2-8, S-1284 and Sree

Vijaya was moderate. These genotypes were lesser susceptible to microbial deterioration compared to genotypes with high and extreme PPD. Genotypes such as CR43-11, CR59-4, CR-775, IH 5/15, IRS 2-1, Sree Harsha and Sree Padmanabha had high scores of 3 and 4 even at fifth day of storage and rapidly deteriorated with increased susceptibility to microbial attack.

Assessment of quality changes in stored cassava roots with near infra-red (NIR) spectroscopy

NIR techniques are suitable to determine simultaneously several components in a food sample within a short time. The NIR spectroscopic analysis was done for cassava roots of field grown 20 genotypes. One set of plants were pruned one week before harvest and the other set was kept as control. Both pruned and control plant roots were scored for PPD and respective category of roots were used for NIR analysis. The NIR absorbance spectra for cassava root slices for wave number 6,000 – 4,000 cm^{-1}, is presented in Fig. 66A. The NIR spectra showed a number of features, which corresponds to various biochemical constituents like starch, moisture and protein and other minor constituents present in the root tissue. Cassava root slices showed strong absorbance at 5180 cm^{-1} and a shoulder around 4716 cm^{-1}, which can be attributed to the C–H and C=O stretching vibrations of -HC=CH-.

The PCA analysis was conducted for the spectra obtained from various samples of fresh cassava roots and roots with typical PPD symptoms. The results of PCA are presented in Fig.66. The scores plots depicted in Fig. 66B. shows the distribution of various samples in principal components (PCs) 1 and 2. The first four principal components (PC) explained over 99% of the variance in the NIR spectrum. Partial Least Square can be used to build prediction correlation model between spectral data and the property of sample matrices. The loadings plot (Fig. 66C) showed clearly the influencing wave numbers for differentiating the samples in various principal components such as 1st component wave numbers (1/cm) 5300, 5200-5100, 4600-4400, 4240-4150, which are important for the variations in the first component. The second component had 5450, 5250, 4700 and 4400 cm^{-1}. The third component belonged to 4800 cm^{-1}.

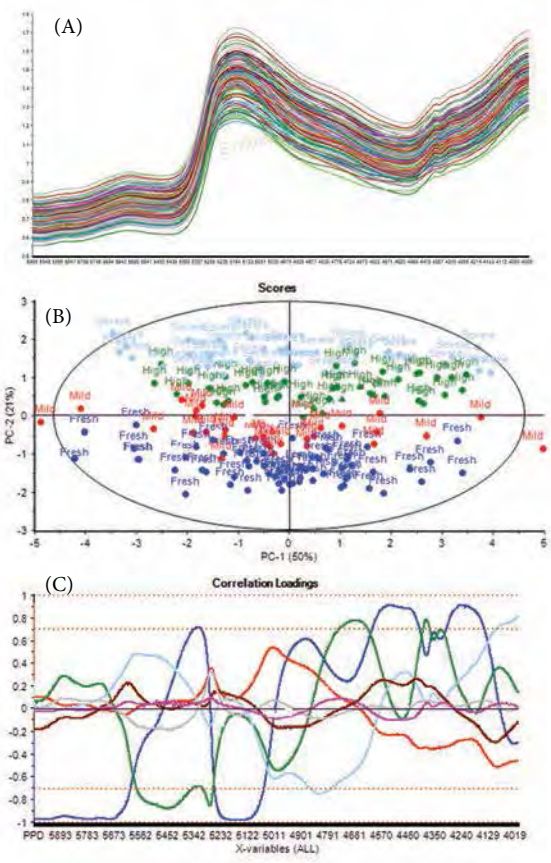


Fig. 66. NIR spectral data of cassava plants and principal component analysis (A) NIR spectra of cassava root (B) Scores plot (C) Correlation loadings plot

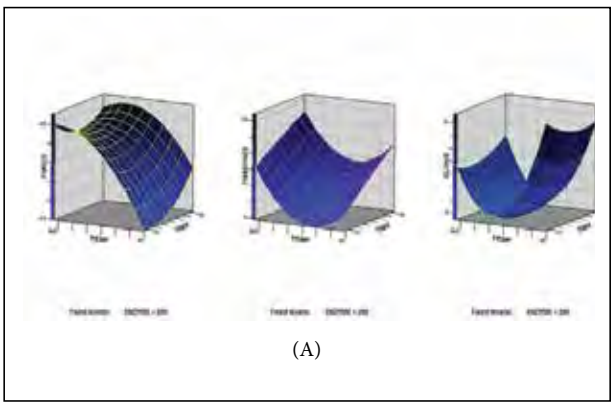
DEVELOPMENT OF CASSAVA STARCH BASED NOVEL PRODUCTS AND FUNCTIONAL FOODS FROM OTHER TUBER CROPS

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

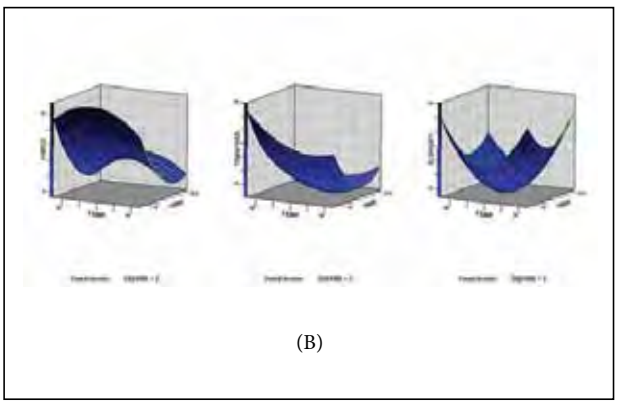
Cassava starch and starch derivatives form an important constituent in biodegradable film preparation due to its renewability, availability, low cost, film forming

properties, high oxygen barriers, odourless, tasteless, colourless, nontoxic, low solubility, biodegradability etc. But films from the native cassava starch often possess poor physico-mechanical and hydrophobic properties. Hence modified starches by chemical, physical and enzymatic methods offer better scope for the production of biodegradable films, which has got wide applications in the food packaging industry. The objectives of the present study were to find out the film forming properties of enzymatically modified cassava starch viz., liquefaction by α-amylase and debranching by pullulanase enzymes added with glycerol as plasticiser. 100, 200 and 300 µl of the stock solution of α-amylase (0.1 ml in 100 ml distilled water) were added with 5% starch solution added with 20% glycerol and gelatinized at 80, 85 and 90°C for 20, 30 and 40 min. With pullulalanase enzyme, biodegradable films were prepared with an enzyme concentration of 2, 3 and 4 units by varying temperature of incubation as 45, 50 and 55°C and time of incubation as 8, 16 and 24 h. The experiments were designed using response surface methodology using Box-Behnken design. Rheological properties were measured in terms of the dynamic mechanical spectra of the film forming solutions. Films were developed by casting method and their physico-mechanical, functional, hygroscopic, biodegradation and storage studies were carried out.

The dextrose equivalent (DE) of the filmogenic solutions varied between 1.60-8.40 with the amylase and 2.20-16.00 with the pullulanase treated starch. The higher values of storage modulus, complex viscosity and low phase angle of the solution containing pullulanase treated starch compared to α-amylase treated solutions showed that the gel formed during gelatinization of the solution is having more solid nature in their visco-elastic character. The films containing α-amylase treated cassava starch showed better whiteness character. Thickness, moisture content, tensile force, elongation at break and swelling capacity of the films containing pullulanase treated starch was higher than that of the films with α-amylase treated starch (Fig. 67). The higher solubility of the α-amylase based starch films helps easy degradation of the films in the soil, whereas offers poor packing ability, whereas the packing ability of pullulanase film is better owing to low permeability and solubility. Though the films with both the modified starch is easily biodegradable, pullulanase took four weeks to completely degrade into the soil as evidenced from the soil burial test. The microbial analysis studies showed that the soil in which α-amylase treated film buried for degradation had highest bacterial, fungal and actinomycetes population than that of the soils with pululanase treated films. Considering various physico-mechanical and functional properties, the pullulanase modified starch offers better scope for the production of biodegradable packing materials.



(A)



(B)

Fig. 67. Mechanical properties of the films made from enzymatically modified cassava starch (A) α-amylase (B) Pullulanase

Protein enriched pasta from sweet potato flour with legumes

Protein enriched pasta was developed from sweet potato flour (40, 50 and 60%) with various leguminous flours viz., lentil, red gram, rajma (kidney bean) (10, 20 and 30%) along with 5% gelatinized cassava starch and 25% maida. The nutritional, cooking, functional and textural characteristics of the protein enriched pasta were analysed and compared with the properties of the pasta made with sweet potato-maida or maida alone. Sensory analysis was also done on 9 point hedonic scale.

Addition of the flour of legumes with sweet potato decreases the starch content in the pasta, the values ranged from 54.80% for 30% red gram incorporated pasta to 62.90% for 10% rajma based pasta, whereas pasta from maida alone had a starch content of 64.04%. It was observed that as the legume content increases, the protein content also increased in the pasta and maximum protein content was noticed for 30% lentil flour mixed with sweet potato. When comparing with the control samples, addition of legumes increased the sugar content in the product, however, as the legume percentage increases in the composite flours, the fat content of the resulting pasta was found to decrease. As the legume content in the composite flour increases, the crude fibre content also increases, the highest of 1.97% with 30% lentil incorporated pasta.

Swelling index increased with increase in legume proportions in the pasta having highest for 30% red gram pasta (1.99). It was observed that the optimal cooking time was 2-5 min for the protein enriched pasta, which was less than the reported values of 7-9 min for the traditional durum wheat pasta. It was found that the developed pasta samples had higher cooking loss ranging from 13.76 to 20.12%.

On the basis of physico-chemical, nutritional, cooking and sensory qualities, the composite flour containing 40% sweet potato flour, 30% lentil, 25% refined wheat flour (maida) and 5% gelatinised starch resulted in better quality pasta product.

Development of starch based functional biopolymers, eco-friendly composites and hydrogels for food, pharmaceutical and agricultural applications

Field evaluation of starch based superabsorbent polymer

Cassava starch based superabsorbent polymer was evaluated in a field experiment, with sweet potato as test crop. The results showed that the treatments with superabsorbent polymer could save 25-50% irrigation. The total plant biomass increased significantly (54.70% for 75% irrigation with SAP and 13.30% for 50% irrigation with SAP) over the control (100% irrigation without SAP). Tuber yield was significantly higher for the treatment, 75% irrigation with SAP. The treatments 50% irrigation with SAP and the control were on par. The water holding capacity was significantly higher for the hydrogel treated soils (15-30% increase) than the initial soil. The treatment 25% irrigation with SAP was inferior to the other treatments in all aspects. There was no significant difference among the treatments for available N, P and K status in soil, organic C content and pH.

Synthesis and characterization of resistant starch from cassava and sweet potato

The RS4 type resistant starch (starch which is resistant to digestive enzymes in the small intestine but undergoes fermentation in the large intestine) has been made by octenyl succinylation of cassava and sweet potato starches. The cooked starches of octenyl succinylated cassava starch showed slowly digestible starch (SDS) and RS in the range of 20.50-38.40% and 1.50-27.90% respectively, whereas these were in the range of 16.00–22.60% and 24.80–37.00% respectively, for modified sweet potato starch. In both cases, RS and SDS increased significantly in comparison to corresponding native starches, whereas there was a decrease in glyceamic index.

RS3 type resistant starch was made by retrogradation of cassava and sweet potato starches. The RS content increased from 1.90% to 12.20% for cassava starch and 3.30% to 18.00% for sweet potato starch. Four cycles of retrogradation resulted in an increase in RS to 18.60% for cassava and 19.60% for sweet potato starch. The SDS also increased significantly. There was a decrease in glyceamic index from 91.30 to 64.80 for cassava and 86.30 to 63.00 for sweet potato starch.

Preparation and characterization of slow release curcumin incorporated in cassava starch-PVA nanocomposite matrix

Cassava starch nanoparticles were prepared in suspension form by acid hydrolysis and incorporated with curcumin to prepare curcumin loaded nanostarch. Curcumin incorporated nanostarch was then added to PVA-cassava starch composites. Curcumin incorporated nanocomposite films were analysed by scanning electron microscopy (SEM), transmission electron microscopy (TEM) (Figs. 68 & 69), i*n vitro* dissolution study at simulated gastric (pH 2.1) and intestinal fluids (pH 7.4), storage stability of the sustained release curcumin and cytotoxicity to normal cells and cancer cells. The ultra structure of curcumin resembles cylindrical rods with uniform size and shape. In nanocomposite film, needle shaped particles in very small sizes were visible, which corresponds to

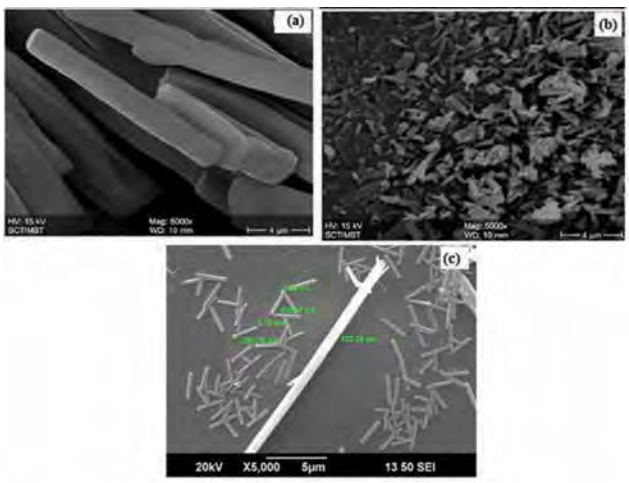


Fig. 68. SEM images of (a) curcumin (b) curcumin incorporated starch nanoparticles and (c) starch-PVA-nanocurcumin composite

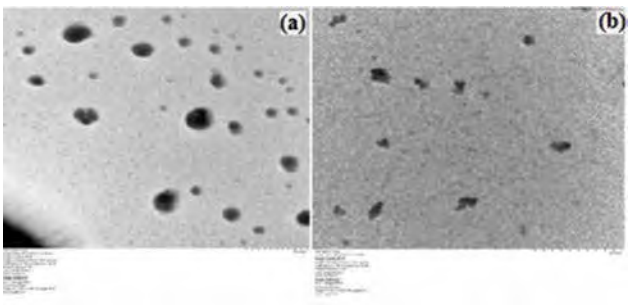


Fig. 69. TEM images of (a) curcumin incorporated starch nanoparticles and (b) starch-PVA-nanocurcumin composite

the curcumin particles loaded on nanostarch. Most of the starch nanoparticles had a size range of 20-50 nm and were spherical in shape. Curcumin incorporated nanostarch particles also appeared spherical in shape. The size was slightly higher and was in the range of 50-200 nm.

The curcumin dissolution was controlled from the starch matrix, which results in more bioavailability. The per cent cumulative release of curcumin after 10 h was only 50.75% and 61.23% at pH 7.4 and pH 2.1, respectively (Fig. 70). Sustained release property was not significantly changed even after storage for 6 months showing its storage stability.

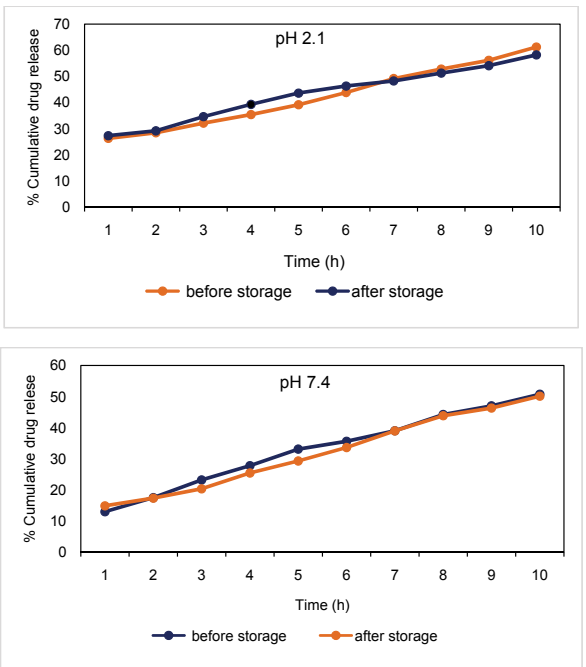


Fig. 70. *In vitro* release of curcumin from ST-PVA matrix before and after storage for 6 months at (a) stimulated gastric fluid (pH 2.1) and (b) stimulated intestinal fluid (pH 7.4)

Cell toxicity studies showed that the curcumin loaded on nanocomposite was nontoxic to normal cells (% cell viability was 86.50 and 85.70% respectively, for pure curcumin and nanocurcumin). Both the samples exhibited anticancer property, but it was significantly higher for the ST-PVA-curcumin composite. The cell viability was 48.40% for pure curcumin and 42.30% for nanocurcumin.

Probiotic enriched food products from elephant foot yam, yam beans and yams

Yam beans (*Pachyrrhizus erosus*) were pickled by lactic fermentation by brining the cut and blanched tubers and inoculating with a consortium of lactic acid bacteria (Fig. 71). Treatment with 8–10% brine was found to be organoleptically most acceptable. The final product with 8% and 10% brine solutions had a pH: 2.16-3.71, titratable acidity (TA): 1.80-2.50 g kg^{-1}, lactic acid [LA]: 1.70-2.80 g kg^{-1}, starch: 73.50-67.80 g kg^{-1}tuber, sugar: 1.10-1.90 g kg^{-1}tuber, reducing sugar: 2.40-2.60 g kg^{-1}tuber, phenol: 18-26 mg kg^{-1} tuber, ascorbic acid: 22-39 mg kg^{-1} tuber. The ability of scavenging free radicals was measured using 2, 2-diphenyl-1-picrylhydrazyl (DPPH), ferric reducing antioxidant assay (FRAP) and N, N-dimethyl-p-phenylendiamine (DMPD) assays. Experimental results indicated that the final fermented product was effective in DPPH radical scavenging (38 – 49%), FRAP (0.910 - 0.909, optical density value, O.D.) and DMPD (35-42%). The antioxidant protecting properties of fermented product confirmed health benefits when consumed and could become a valuable source of antioxidant rich nutraceuticals.

Fig. 71. Yam bean pickle

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

Ready-to-eat nutribar fortified with sweet potato flour and enriched with resistant starch

The nutribars are considered as a snack having good sensory and nutritional characteristics because it contain high amounts of carbohydrates, proteins, lipids and minerals. Consumers demand for healthy snacks, has motivated the food manufacturers to develop food bars that provide nutrition and convenience. The nutritious bars have gained importance and popularity in the market. Nutribars are small rectangular bars of weight 25-50 g, which takes all aspects into consideration, combining the best part of cereal with fruit and added vitamins, minerals and calcium and they can therefore prove to be a perfect health conscious food choice. Another positive aspect of nutribars is the fact that they do not require preparation or making ready to eat.

The ingredients for sweet potato based nutribar were optimised using response surface methodology. After preliminary trials, the upper and lower limits for the variables, sweet potato flour and sweeteners, were established. A central composite design was prepared and the levels of sweet potato flour and sweeteners were considered as 20–30% and 40–50% respectively.

Fig. 72. Ready-to-eat nutribar fortified with sweet potato flour

The sweet potato based nutribar containing 20% sweet potato, 40% sweeteners (honey and jaggery), along with oats, puffed rice, bengal gram, dhal and nuts was the best combination (Fig. 72). It contained 6.40% protein, 51.80% carbohydrates, 494.78 kcal, 4.52 mg $100g^{-1}$ iron, 30 mg $100g^{-1}$ calcium and 6.06 mg $100g^{-1}$magnesium (Fig. 73).

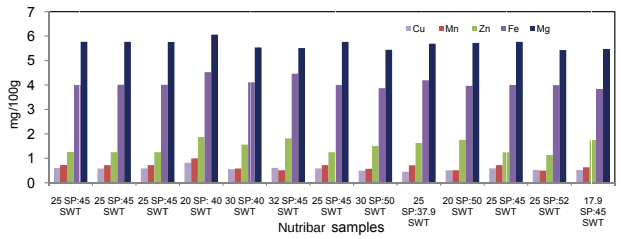


Fig.73. Mineral content of nutribar fortified with sweet potato flour

The sweet potato based functional bars enriched with enzymatically modified resistant starch were developed. The level of resistant starch was 5 – 15%. It contained moisture 5.48 - 6.52%, ash 2.17 - 2.35%, crude protein 5.37 - 6.80%, crude fat 21.68 - 28.75%, crude fiber 1.29 - 2.45%, carbohydrates 54.80 - 62.84% and energy 467.56 - 505.15 kcal $100g^{-1}$.

Sweet potato flour based gluten free cookies

The recipe for preparation of sweet potato flour based gluten free cookies were optimized using sweet potato flour blend containing sweet potato flour, rice flour, sorghum flour and cassava flour.

Fig. 74. Sweet potato based gluten free cookies

It was found that sweet potato flour based gluten free cookies for celiac patient could be prepared using flour blend containing 60% sweet potato flour along with the other ingredients like rice flour, sorghum flour and cassava flour (Fig. 74). High content of minerals such as phosphorus (88 mg $100g^{-1}$), potassium (270.33 mg $100g^{-1}$) and iron (24.60 mg $100g^{-1}$) could be an added advantage for sweet potato flour based gluten-free cookies (Fig. 75). It provides 2.53% protein, 7.44% crude fiber and 480.43 kcal.

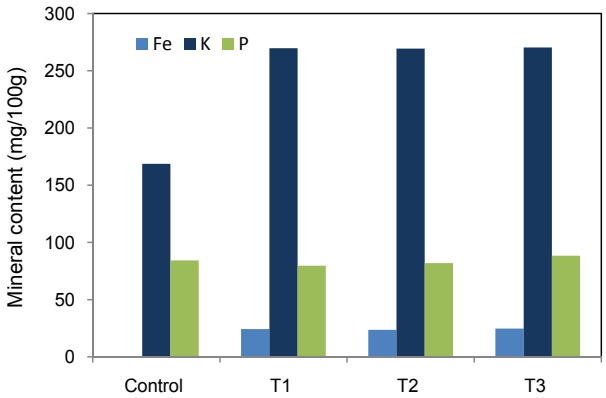


Fig. 75. Mineral content of sweet potato flour based gluten free cookies. C: control wheat based cookies, T1: cookies with 40% sweet potato flour, T2: cookies with 50% sweet potato flour, T3: cookies with 60% sweet potato flour

EXTENSION AND SOCIAL SCIENCES

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

Strategic tuber crops technology intervention and impact assessment for sustainable development

Survey and documentation of sweet potato production systems in Belgaum, Karnataka and tuber crops production systems in Joida region, Uttar Kannada district, Karnataka were undertaken during 2015-2016. In addition, participatory sweet potato varietal trials with promising clones were laid out, monitored, harvested and evaluated to identify suitable clones for processing at Belgaum. Likewise at Joida, demonstration trials with high yielding/promising varieties of tuber crops were laid out, harvested and evaluated.

In Belgaum district, Karnataka, sweet potato was raised both under reclaimed soils from mines as well as in normal soils. It was reported that sweet potato was grown in about 10,000 ha in this region spread over 40 villages (Fig. 76). Almost in the entire area, it was cultivated during kharif season under rainfed condition. Only in about 200 acres, where irrigation facility was available (on the banks of Markandeya river) two crops were taken. Using the tractor, big ridges were formed. As basal dose, 2 tonnes of FYM and 200 kg per acre of 5:5:15 NPK mixture were applied before taking ridges. Sweet potato vines measuring one foot were planted on the ridges very closely. After 15-30 days of planting, depending upon rain, 100 kg of urea per acre was top dressed. Weeding was done twice after one and two months of planting. Farmers also used herbicide to control grasses a month after planting. The harvesting started normally after 3 months and depending upon market demand it extended up to 4½ - 5 months. Harvesting was done using bullock power after removing the vines. An average tuber yield of 6-7 tonnes per acre was obtained, which were bagged in gunny bags, each weighing 55-60 kg, taken to Belgaum town and from there through commission agents using trucks were transported to far-away places like Delhi, Surat, Mumbai, Hyderabad and marketed there for human consumption. The vines were fed to the cattle and for planting during the next season were maintained in places having water sources up to June. No weevil damage was noticed, if harvested within 3-3½ month's time. If delayed by one month, 10% damage was observed. Harvesting beyond 5 months resulted in 50% damage. The farmers usually obtained a price of Rs. 15-17 kg^{-1} at the beginning of the season, which was reduced to Rs. 5-6 kg^{-1} at the fag end of the season.

Soil samples were collected from normal soil, one year after reclamation and five years after reclamation and were analyzed for major nutrient contents. It was found that all the three soils were acidic in nature (pH ranging from 6.04 to 6.13) with high organic carbon, low nitrogen and medium to high phosphorus and potash. On this basis, soil test based fertilizer recommendations were made. During kharif season, a varietal evaluation trial was laid out with four promising accessions of sweet potato viz., Sree Arun a high starch variety, Sree Kanaka and ST-14, high β carotene rich varieties and ST-13, having high content of anthocyanin. These four varieties were planted along with the local check in a replicated trial, harvested and evaluated. Since, the crop experienced prolonged drought for about 70 days, the tuber yield was considerably reduced with high incidence of weevil damage. Of the five sweet potato varieties evaluated for their performance, Sree Arun performed satisfactorily, with an average tuber yield of 19 t ha^{-1}, which was significantly higher than the other varieties (Fig. 76). In addition, 85% of the tubers were found marketable. Sree Kanaka, though yielded about 15 t ha^{-1}, majority (60%) of the tubers were severely infested by the weevil. ST-13 and ST-14, the nutritionally superior varieties and the local

gave less than 10 t ha^{-1}. In spite of low yield, 94% of ST-13 and 74% ST-14 were marketable. In the case of local, equal proportion of tubers were found to be marketable and unmarketable.

Fig. 76. Sweet potato cultivation (top) and harvested tubers at Belgaum (down)

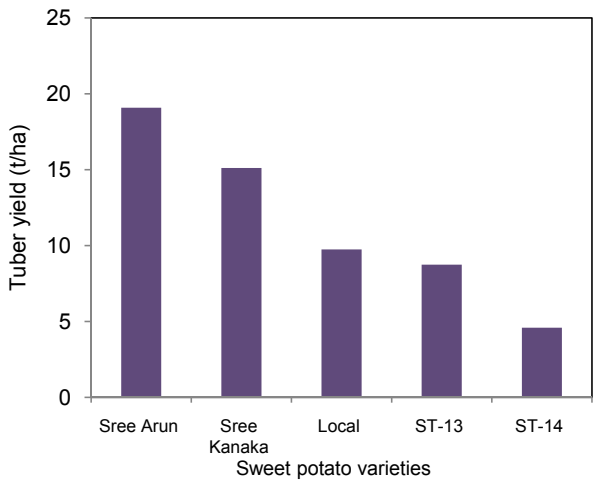


Fig. 77. Performance of sweet potato varieties in Belgaum district, Karnataka

At Joida region in Uttar Kannada the Kunbi tribe, who originally belonged to Goa state migrated to Joida Taluk in Karnataka and settled there. In fact, they are not notified as tribe in Karnataka. There were about 131 Kunbi hamlets, each having 20-25 families. The average size of each family was around 5-6. These hamlets were spread over Joida Taluk and connected by mud road. There was no transport facility connecting these hamlets and the people had to walk 15-30 km to reach the nearest bus stop. Agriculture was the main occupation of the people, with each family having 1½ - 2 acres of paddy land. Normally one crop of paddy was taken during kharif and in about 5% of the area, two crops were raised and during the remaining period it was left fallow. The Kunbi tribe practiced typical homestead farming in the land available for cultivation in and around their home. Every family had an average land holding of 0.5 to 1.0 acre and tuber crops occupied about 10-15% of this area. Greater yam, lesser yam and taro (Dasheen type) were the important tuber crops grown in this region and the farmers raised tannia, sweet potato and Chinese potato to a limited extent. These tubers formed an important source of vegetable to the Kunbi tribe. They were grown organically. Considering the importance of tuber crops in this region, demonstration trials have been laid out in three Kunbi hamlets, Katel, Wagabandhe and Deriye with high yielding varieties of tuber crops. They are yams (Sree Roopa, Da-340, Sree Swathy, Sree Neelima, Da-178 and Dr-1047), sweet potato (Sree Arun, Sree Varun, Sree Kanaka, Gouri and Sree Bhadra) and elephant foot yam (Gajendra). The harvesting and evaluation of these trials revealed that Da-340 of greater yam produced the maximum yield of 2.72 kg per plant and Sree Neelima yielded only 0.43 kg per plant (Fig. 78). The white yam clone Dr-1047 performed satisfactorily with an average per plant yield of 1.44 kg. The elephant foot yam variety, Gajendra yielded about 0.81 kg per plant. Owing to its proximity to forest, the Katel farmers experienced

attack of tubers by wild boar and monkeys. In general, the farmers opined that the tubers of the introduced varieties had very good texture and taste. Further, they expressed that the local varieties produced slender and long tubers, whereas CTCRI varieties produced very big tubers just below the soil surface facilitating easy harvest. It was also felt that the yield obtained from the new varieties was on par with that of local varieties, however, if planted early, they were likely to give very good yield. Due to this observation, the farmers have planted the introduced varieties in large area well in advance by April first week.

Fig. 78. Harvested yams at Joida

Strategic market analysis for commercializing tuber crops based food products

Lexicon generation for dry pasta sensory attributes

A lexicon online survey was conducted with 110 food science and technology scientists to identify the sensory attributes of pasta. The response rate was 60% and the coefficient of agreement among experts was 0.846 ($p<0.01$). The results revealed that taste (Mean = 4.55) and aroma (Mean = 4.21) were most preferred sensory attributes (Fig. 79).

Fig. 79. Radar chart showing mean values of sensory attribute preferences of experts

Identification of latent sensory attributes that govern consumer acceptability

To identify the latent variables among sensory attributes, which determine the consumer acceptability, exploratory factor analysis was conducted with the sensory preference data. A significant Bartlett's test ($\chi^2 = 387.03$; $p<0.01$) and a KMO value exceeding 0.5 (KMO = 0.803) indicated adequacy of the sample size for the analysis.

The factors were extracted using Maximum Likelihood Method and were rotated through promax rotation. All the factors with eigen value over one were retained for analysis. The pattern matrix along with factor loadings for each sensory attribute is presented in Table 14.

Table 14. Pattern matrix showing rotated factor loading of sensory attitudes

Sensory attributes	Factor loadings*	
	1	2
Colour	-	0.695
Surface glossiness	-	0.893
Surface smoothness	-	0.685
Firmness	-	-
Stickiness	0.770	-
Chewiness	0.803	-
Elasticity	0.703	-
Aroma	-	-
Taste	-	-
Eigen value	4.13	1.29
Variance explained (%)	40.24	9.62

*Factors loadings less than 0.50 are considered insignificant and not displayed

From Table 14, the items firmness, aroma and taste, which didn't load in any factor were removed from

the analysis. Other items like stickiness, chewiness and elasticity, which represent textural characters loaded in factor 1 and together explained 40.24% variance in the data. Therefore, the first factor can be named as "Textural properties". While the items, colour, surface glossiness and surface smoothness represented factor 2, which can be named as "Surface properties" and explained 1.29% variance in the data.

Influence of pasta consumption on sensory attribute preferences

Respondents' frequency of consumption of pasta has significant effect on their preferences for elasticity [F (4, 105) = 2.58; P=0.049)] and aroma of pasta [F (4, 105) = 2.74; P=0.032).

Table 15. ANOVA table indicating frequency of pasta consumption against the sensory attribute preferences of consumers

Frequency of pasta consumption	Elasticity	Aroma
Never or less than once a month	3.06 (1.05)^{a**}	4.16 (1.01)^{a}
One to two times a month	3.19 (1.42)^{a}	3.84 (1.05)^{a}
Two to three times a month	4.14 (0.53)^{b}	4.50 (0.94)^{b}
Once a week	3.92 (0.99)^{b}	4.58 (0.67)^{b}
Two to three times a week	3.88 (1.60)^{B}	4.88 (0.35)^{b}
F	2.58*	2.74*
P	0.049	0.032

*Figures in parentheses indicate SD

** Mean values with the same superscript letters in a column are significantly not different from each other

Posthoc analysis using LSD indicated that the consumers who consumed pasta over twice and thrice a month had significant preference ($p<0.01$; LSD) for elasticity and aroma (Table 15).

Sustainable livelihood analysis of tuber crops farmers

The study was conducted in Thiruvananthapuram and Pathanamthitta districts of Kerala with a sample of 60 tuber crops farmers. Five capitals namely human capital, financial capital, natural capital, social and physical capitals and gender index were studied. The human capital index included the parameters namely education level, trainings attended, labour availability, health facilities and knowledge possessed. It was found that health facilities ranked top in both the districts Pathanamthitta (0.95) and Thiruvananthapuram (0.88). Overall human index of tuber crops farmers was more in Pathanamthitta (0.65), when compared to Thiruvananthapuram (0.63). Physical capital index included the components such as transport facilities, type of housing, electricity, drinking water, fuel availability. All parameters were having high index value of more than 0.70 and it was more than 0.90 for drinking water availability and electricity supply. Equal percentage (93.33%) of tuber crops farmers from both the districts had high physical capital index. Social capital index has the parameters namely social relationship, membership in organisation, access to communication media, peer group communication, communication facilities. Membership in organizations was low in Pathanamthitta (0.28), whereas in Thiruvananthapuram it was 0.54. The overall index was more for Thiruvananthapuram (0.84) than Pathanamthitta (0.73). Natural capital index had the components, area of land possessed, ownership of land, crops grown, irrigation source. Ownership of land has got an index value of 1 and the overall index was more for Pathanamthitta (0.66) than Thiruvananthapuram (0.65). In Pathanamthitta, 33.33 per cent of the tuber crops farmers had high level of natural capital index than Thiruvananthapuram (40%). Financial capital index included the household income, credit availability, credit source, savings, debt. Credit availability index was more than 0.80 in both the districts. Overall index was more for Thiruvananthapuram (0.64) than Pathanamthitta (0.53). In Thiruvanathapuram, 46 per cent of the tuber crops farmers were having high financial capital compared to Pathanamthitta (13.33). In both the districts, the index was more for men than women. Only in household activities the gender index was more in Pathanamthitta (0.83) and Thiruvananthapuram (0.90). The least score of 0.18 (Thiruvananthapuram) and 0.31 (Pathanamthitta) was

scored under ownership of assets by farm women in both the districts. The rural livelihood sustainability index was 0.67 for Pathanamthitta and 0.70 for Thiruvananthapuram.

Development of ICT applications in tuber crops

Electronic device called Electronic crop (E-Crop) (Fig. 80) to simulate the crop growth real-time in the field was developed. This device collects various weather parameters from the field at 15 minutes interval and sends to the website of ICAR-CTCRI.

Fig. 80. View of E-crop installed in sweet potato field of ICAR-CTCRI

The weather parameters collected are:

1. Maximum temperature (°C)
2. Minimum temperature (°C)
3. Relative humidity (%)
4. Solar radiation (MJ m^{-2} day^{-1})
5. Wind velocity (km h^{-1})
6. Rainfall (mm)
7. Soil moisture (mm)

Geographical data about the site recorded by the device are:

1. Latitude
2. Longitude
3. Altitude

Through the web based user interface (Fig. 81), the specifications about the crops grown in the field and the input and management practices followed also can be updated in the system. A stand alone software E-Crop Scheduler (Fig. 82) was developed, which is loaded in a local machine. This scheduler gets activated at a stipulated time i.e at 7.30 pm and this scheduler downloads the day's weather parameters (Fig. 83) and the other data is updated through the interface to the local machine. In the local machine, the corresponding crop simulation model gets executed and agro-advisory is generated. This advisory is sent to the mobile of the concerned farmer in the form of SMS through the website.

Fig. 81. Web based user interface of E-crop

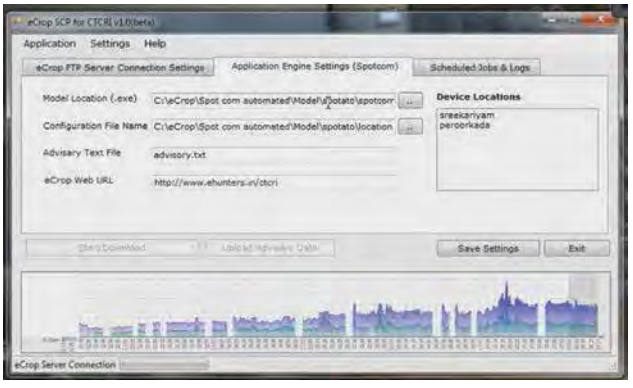


Fig. 82. E-Crop scheduler

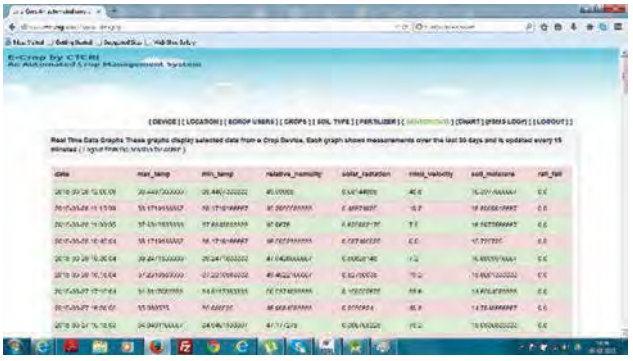


Fig. 83. Weather data collected by E-Crop

The device is developed and the sweet potato simulation model SPOTCOMS, which was developed by ICAR-CTCRI is loaded in the system. The device is installed in sweet potato field of the institute for field validation.

A lot of web based agro-advisory services are already prevailing in India in many areas and for many crops. Most of them provide advance weather information and only few of them use crop simulation models for generating agro-advisories. This device is a much more advanced automatic system, which is available at a low cost.

For a wider and better use of the software developed by ICAR-CTCRI and for identifying varieties from their morphological features, a portable electronic device (Fig. 84) was developed to implement this software. The software is also being modified by using

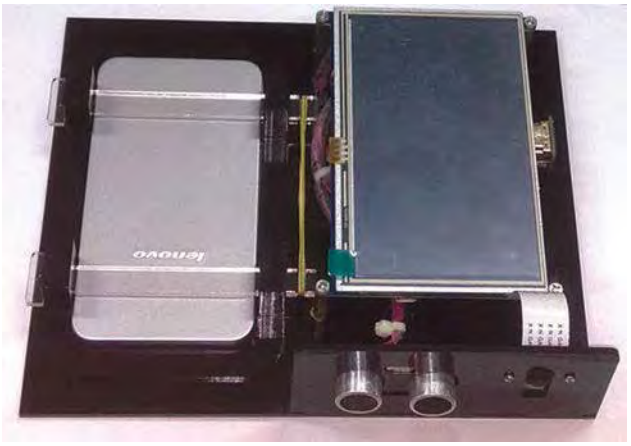


Fig. 84. Parts of variety identifier device

image analysis technique. Once the device power is on, the camera will be on and can be focused on the plant part, which is distinct for the varieties of the crop and the image can be viewed through the display unit. Ultra sound sensors detect the distance of the object from the camera and will enable capturing the image when the distance from the image is exactly 1 foot (+/-1 inches). To capture image "Capture image" button must be clicked. This image will be stored in the storage device. When "Find out variety" button is clicked, the software will be executed and will identify the variety. The result will be displayed in the display unit. If it cannot identify the variety, the picture can be stored in the device and a new name can be given, which can be entered through the key board. The approximate size of the device is slightly larger than that of a smartphone.

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

A Macro for converting multiple comparisons output to letter groupings in PROC MIXED of SAS software has been developed, which helps in getting letter displays for main plot x subplot interaction effects. R macros were developed for computing descriptive statistics, logistic and multiple regression. In order to develop an interactive user friendly tool for analysis for agricultural and plant breeding experiments in R environment for statistical computing, modules were developed for experimental design, which supports layout of lattice, Complete Block, Latin Square, augmented block, factorial, split and strip plot designs. Functions were also developed for various analysis facilities for experimental data: ANOVA, treatment comparison procedures, several non-parametric tests comparison, biodiversity indexes, mantel test, Clustering and Phylogenetic Trees.

The interactive web based tool for tuber crops statistics by incorporating interactive graphics was modified. The district wise data on area, production and productivity of cassava and sweet potato has been incorporated.

EXTERNALLY AIDED PROJECTS

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

With an objective to develop taro genotypes adapted to new environments (climate change, pest and disease outbreaks) and to satisfy market needs, hybrid taros with early maturity and blight resistance were generated through planned hybridization using cryo tools, where stored pollen was used for hybridisation to overcome asynchrony of flowering, for the first time in India. "Petiole colour" was identified as a key character to group genetic resources of taro across the globe and India was identified as the centre of origin of taro through DNA analysis of CIRAD and associated dispersal studies.

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

Established DUS facility and varietal gene bank of taro and elephant foot yam. Identified distinct, stable and uniform morphological characters for differentiating various varieties/clones of each of two aroid species, taro and elephant foot yam.

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

With the objective to develop distinct, stable and uniform morphological characters for differentiating various varieties/clones of yam bean and greater yam, to establish a 'varietal gene bank' with DUS standards of yam bean and greater yam and to develop a computerized data base, identified pre and post-harvest key characters in greater yam and yam bean. Apart from these, varietal gene banks in yam bean and greater yam were established.

4. **Tuber crops development project, Kerala** (Department of Agriculture, Govt. of Kerala; PI: Dr. James George)

The project was initiated during October 2014. The objectives of the project are large scale production of clean and disease free planting materials in cassava, yams, and elephant foot yam through micro–propagation and minisett techniques; to lay out demonstration plots of tuber crops for popularization of agro-techniques and new varieties for higher economic returns and to conduct need based and skill oriented training programmes to farmers on planting material production, agro-techniques and value addition (Figs. 85 & 86).

Fig. 85. Field visit to Elanthoor panchayat, Pathanamthitta

Fig. 86. Training to farmers at Wayanad

Physical achievements

District covered : Four (Pathanamthitta, Thrissur, Kannur, Wayanad)
Tuber crops covered : Cassava, elephant foot yam, greater yam
Total area covered : 18 ha
Cassava : 6 ha (Mattathur: 4 ha and Vellamunda: 2 ha)
Elephant foot yam : 6 ha (Elanthoor: 4 ha and Ambalavayal: 2 ha)
Greater yam : 6 ha (Ayyankunnu: 4 ha and Thavinhal: 2 ha)
No. of beneficiaries : 450

Grama panchayats covered under the project

Elanthoor (Pathanamthitta) : 100 units of 10 cents each for elephant foot yam
Mattathur (Thrissur) : 100 units of 10 cents each for cassava
Ayyankunnu (Kannur) : 100 units of 10 cents each for greater yam

Tribal belt of Wayanad district

Vellamunda : 50 units of 10 cents each for cassava
Thavinhal : 50 units of 10 cents each for greater yam
Ambalavayal : 50 units of 10 cents each for elephant foot yam

Varieties distributed

Cassava : CMR lines, CI-800 and 9S-127
Sree Jaya, Sree Vijaya
Elephant foot yam : Gajendra
Greater yam : Kovvur 1
Training programmes conducted : 12

Table 16. Quality planting material produced and projected area expansion of tuber crops

Panchayat/ District	Crop	Area covered (ha)	Total production	Projected area expansion (ha)
Mattathur (Thrissur)	Cassava	4	90,000 stems	36
Elanthoor (Pathanamthitta)	Elephant foot yam	4	120 tons	20
Ayyankunnu (Kannur)	Greater yam	4	100 tons	32
Tribal region of Wayanad district				
Vellamunda	Cassava	2	45,000 stems	18
Thavinhal	Greater yam	2	60 tons	10
Ambalavayal	Elephant foot yam	2	50 tons	16

5. Network project on organic horticulture (NPOH) (ICAR-Indian Institute of Spices Research, Kozhikode, as Lead Centre; PI: Dr. G. Suja)

Development of technology for organic production in Chinese potato

Based on two seasons' experimentation at ICAR-CTCRI in Chinese potato, organic production technologies involving FYM @ 10 t ha^{-1}, green manure, neem cake @ 1 t ha^{-1} and ash @ 2 t ha^{-1} or biofertilizers (*Azospirillum*, P solubilizer and K solubilizer @ 3 kg ha^{-1} each) were developed (Fig. 87); yield under organic management (13.94 t ha^{-1}) was 10.5% higher over conventional system (12.61 t ha^{-1}). The organic production technology for Chinese

potato developed at ICAR-CTCRI is ready for on-farm testing. At the end of first year of experimentation, the soil pH increased significantly (+0.65 unit) in the organic (biofertilizer) plots over conventional plots. Though the status of available N was in the low range in all the plots, it was significantly higher (181.50 kg ha^{-1}) under organic (biofertilizer) plots over chemical plots (78.40 kg ha^{-1}). Exchangeable Mg status was significantly higher in the integrated practice, which was on par with organic (biofertilizer) practice. Exchangeable Ca, available Fe, Mn, Zn and Cu status of the soil were unaffected by the various systems. There was slight lowering of bulk density (+6%) and particle density (+13%) and improvement in water holding capacity of the soil under organic management. The microbial population of the soil as well as soil enzyme activity were not significantly affected due to the various production systems. However, the population of bacteria and fungi and dehydrogenase enzyme activity were higher under organic practice.

Fig. 87. Field experiment on organic production of Chinese potato under NPOH

Validation of organic production technologies in yams and cassava intercropped in a coconut plantation

On-station developed (at ICAR-CTCRI) organic production technologies for yams and cassava were validated in organically raised 48 yr old coconut plantation at ICAR-CPCRI, Kasaragod (Fig. 88). Yield under organic mode (0.96 and 0.74 respectively of conventional) was on a par with chemical system in both yams (*Dioscorea* spp.) (7.18 and 7.44 t ha^{-1}) and cassava (8.06 and 10.86 t ha^{-1}) intercropped in coconut. The three species of *Dioscorea* (*D. alata*, *D. esculenta* and *D. roundata*) and three varieties of cassava responded similarly to organic and conventional management.

Fig. 88. Validation trials on organic farming of yams at ICAR-CPCRI, Kasaragod under NPOH

Development of technology for organic production in arrowroot

Field experiment on organic management of arrowroot at ICAR-CTCRI planted on 7 July 2015 was harvested during April 2016 (Fig. 89). Observations on growth and biomass were recorded at periodic intervals. Soil chemical properties were estimated at various stages of crop growth.

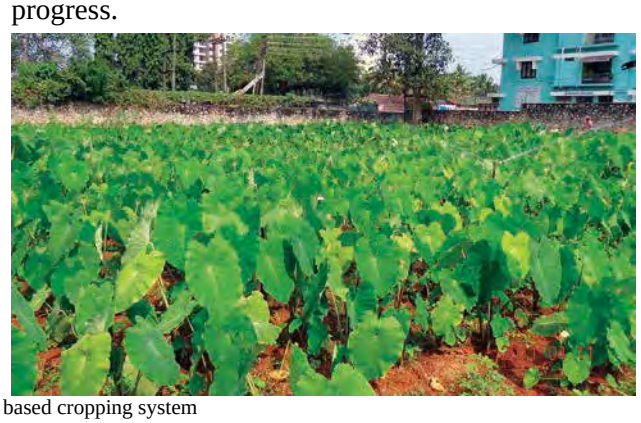
Fig. 89. Field experiment on organic production of arrowroot under NPOH

A fully equipped Agronomy Laboratory set up for a total amount of Rs. 8 lakhs is operational. Major equipments purchased were Automatic N Analyser, Flame Photometer, pH Meter, Conductivity Meter; The following minor equipments were also purchased: Hot Air Oven, Electronic Precision Balance (2 nos.), Reciprocating Shaker, Hot Plate with Magnetic Stirrer, Grinding Mill and Refrigerator.

6. Network project on organic farming (NPOF) (ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut as Lead Centre; PI: Dr. G. Suja)

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

The field experiment in non-replicated strip plot with four cropping systems involving cassava and taro in main plots and six production systems in subplots is ongoing since 27 October 2015 (Fig. 90). The experiment was laid out strictly in accordance to the layout plan stipulated by the lead centre with border rows and buffer strips. Observations on growth and biomass characters are being recorded at periodic intervals. The first crops in the systems, cassava and taro was harvested during May 2016. Geo-referenced on-farm characterization of organic growers is in progress.



Field experiment on taro based cropping system

Fig. 90. Field experiment to evaluate organic, inorganic and integrated management practices in cropping systems involving tuber crops

Field experiment on cassava based cropping system

Fig. 90 (contd). Field experiment to evaluate organic, inorganic and integrated management practices in cropping systems involving tuber crops

7. Enhancing the economic viability of coconut based cropping systems for land use planning in Kerala state (Kerala State Planning Board; PI: Dr. K. Susan John)

The aims of the project are development of best management practices (BMP) with focus on surface and subsoil acidity, soil available major, secondary and micronutrients, plant nutrient content in tuber crops viz., elephant foot yam and cassava as intercrops in coconut garden for two agro-ecological units (AEU-3, AEU-9) of Kerala; validation and demonstration of the BMP for enhancing crop production in farmer's fields in the selected agro-ecological units and development of a customized fertilizer (CF) formulation for the cultivation of elephant foot yam as intercrop in coconut garden for better profit, soil and tuber quality for the above two agro-ecological units of Kerala. View of the field experiments in the AEUs is given in Fig. 91.

The first year study indicated that BMP involving soil test based application of NPK, lime @ 1 t ha^{-1} for correcting surface acidity (based on soil pH), gypsum @ 2 t ha^{-1} for correcting subsoil acidity (based on exchange Al^{3+}), $MgSO_4$ @ 80 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1} and borax @ 10 kg ha^{-1} gave significantly higher yield for elephant foot yam in the two AEUs.

For developing CF for elephant foot yam, the rates of NPK was standardised as NPK @ 142: 12.5:160 kg ha^{-1} for AEU3 and 156:12.5:180 kg ha^{-1} for AEU 9 (based on the rate trials conducted), the rate of secondary nutrients viz., Ca, Mg and micronutrients viz., Zn and B was standardised as dolomite @ 1.5 t ha^{-1}, $MgSO_4$ @ 120 kg ha^{-1}, $ZnSO_4$ @ 30 kg ha^{-1} and borax @18.75 kg ha^{-1} for the two AEUs.

8. Assessment of soil fertility and preparation of soil fertility maps for various agro-ecosystems of Odisha (Rashtriya Krishi Vikas Yojana; PI: Dr. K. Laxminarayana)

Under the project, the Soil Science Laboratory has been strengthened by installation of instruments like digital pH meter, conductivity meter, shaker, mechanical stirrer, spectrophotometer, GPS, camera, electronic balance, double distillation unit,

Fig. 91. Field experiment of elephant foot yam on CF in AEU 9 (left) and field experiment of cassava for BMP in AEU 3 (right)

refrigerator, self racks, hydraulic bar stools, acetylene gas cylinder, etc. as well as chemicals, glassware and plasticware. A total of 6226 profile soil samples at three depths (0-30, 30-60 and 60-100 cm) were received from Gram Panchayat level representing 30 districts (Angul-209, Balasore-289, Balangir-285, Bargarh-248, Bhadrak-193, Boudh-63, Cuttack-342, Deogarh-60, Dhenkanal-199, Gajapati-129, Ganjam-474, Jagatsinghpur-194, Jajpur-280, Jharsuguda-78, Kalahandi-273, Kandhamal-154, Kendrapada-230, Keonjhar-286, Khurda-168, Koraput-226, Malkangiri-100, Mayurbhanj-382, Nawarangpur-169, Nayagarh-179, Nuapada-109, Puri-230, Rayagada-171, Sambalpur-148, Sonepur-96, Sundargarh-262) along with 10 profiles from NAC area representing Cuttack, Dhenkanal, Ganjam, Jagatsinghpur, Kalahandi, Nuapada and Rayagada districts of Odisha. Processing of the soils and analytical work are in progress. Submitted a project for additional budget of Rs. 88.53 lakhs for an extension of one year to complete the project activities.

9. Livelihood improvement of tribal farmers through tuber crops technologies

(ICAR-CTCRI - Tribal Sub Plan; PI : Dr. M. Nedunchezhiyan)

Fifty five demonstrations (0.4 ha model farming system) involving tuber crops, pulses, cereals, vegetables, poultry bird, duck and piglet were demonstrated in Jharkhand. In Kandhamal district of Odisha, 40 demonstrations (0.4 ha model farming system) involving tuber crops, pulses, cereals, vegetables and poultry bird were demonstrated. In Koraput district of Odisha, 28 demonstrations (0.4 ha model farming system) involving tuber crops, pulses, vegetables and cereals were demonstrated. A total of 123 farm families were adopted from Odisha and Jharkhand during 2015-16. Quality planting material of elephant foot yam (var. Gajendra) 6500 kg, greater yam (var. Da 293) 1000 kg, cassava (var. Sree Jaya, Sree Vijaya and Vellayani Hraswa) 6000 stems and yam bean (var. RM-1) seeds 100 kg were distributed to the farmers of Odisha and Jharkhand. Five hundred and fifty each of chicks (Divyan Red) and ducks (Kaki Cambel) were distributed to Jharkhand farmers. Eight hundred chicks (Vanaraja) were distributed to the Odisha farmers. One hundred and twenty piglets of T & D breed of 50-60 days age were distributed to the farmers of Jharkhand.

Six sprayers and small farm tools (68 nos. each of hand hoe, sickle, crow bar, pick axe, spade, garden weeder, hand trower and hand cultivator) were distributed to the farmers of Odisha. About 2160 kg of aluminium wire mesh were distributed to the Odisha farmers for fencing. Fifty five low cost poultry-cum-duck shed were constructed for Jharkhand farmers. Six on-farm trainings and two exposure visits were conducted. Each farm family received gross income of Rs. 70,000 to 90,000 depending on the components of the farming system (Figs. 92 & 93).

Fig. 92. Dr. S.K. Chakrabarti, Director, ICAR-CTCRI visiting the field

Fig. 93. Greater yam harvested by the tribal farm women

10. Establishment of techno-incubation centre at the ICAR-Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar for the commercialization of value added products from sweet potato and other tuber crops (Rashtriya Krishi Vikas Yojana; PI: Dr. M. Nedunchezhiyan)

The project was started in 2015. Setting up of a techno-incubation centre has been initiated.

11. Participatory technology transfer of cassava based biopesticides for the management of vegetable pests (Department of Agriculture, Government of Kerala; PI: Dr. C. A. Jayaprakas)

The biopesticides developed from ICAR-CTCRI viz., *Nanma*, *Menma* and *Shreya* were demonstrated in farmers' fields in two districts (Thiruvananthapuram and Kasaragod) against the major pests of vegetable crops. Farmer clusters were identified and the biopesticides were treated in each field. The pest incidence before and after treatments were recorded. A new device for the injection of the biopesticide, *Menma*, in the pseudostem was also designed and fabricated. Periodical training programmes were arranged through Krishi Bhavans, ATMA, Residential Associations etc.

12. Outreach programme on the management of sucking pests (ICAR Network Project; PI: Dr. C. A. Jayaprakas)

In order to remove the mealy substance, the bioformulation, *Shreya* was sprayed at concentrations of 0.50, 0.70, 0.90, 1.00, 1.30 and 1.50% on mealybug infested brinjal, cassava and tomato plants. It was observed that *Shreya* even at 0.50% could completely dissolve the mealy substance and the larval stages were exposed. At 5 days after treatment (DAT), in all the treated batches, complete mortality of the mealybug was observed (Fig. 94). It was also found that since eggs were resistant to the biopesticides, there was a chance of resurgence. As the incubation period was 5 days, one more spray on the 7th day would completely kill the newly emerged crawlers.

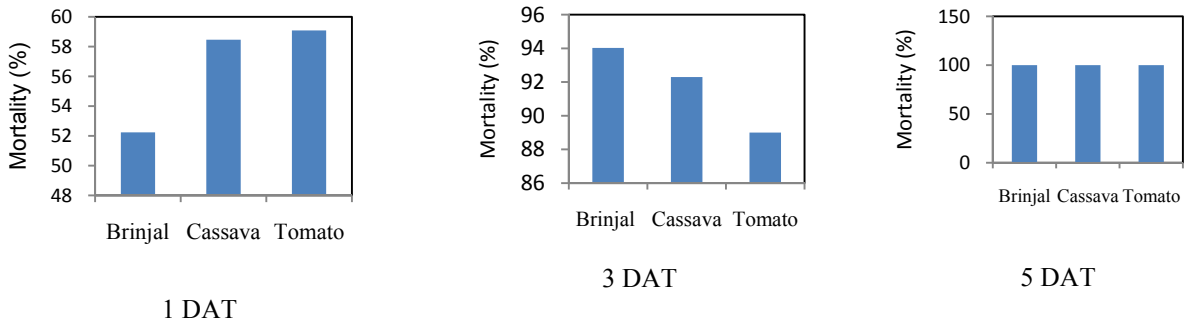


Fig. 94. Effect of *Shreya* on the mortality of mealybugs in vegetable crops

The biopesticide *Nanma* was very effective against scale insects in gooseberry, chilli and curry leaf. In curry leaf, the treatment with *Nanma* @ 5%, could reduce the population from an average of 13.6 per plant to 3.0 at 1 DAT, and complete mortality was attained at 5 DAT. Whereas, in the case of chilli, the initial population 27.1 could be brought down to 15.9 and 4.4 at 1 and 3 DAT, respectively. In gooseberry also, all the treated insects were found dead at 5 DAT. Mustard aphids were treated with different concentrations (0.01 to 3.0%) of the biopesticide *Nanma* and their mortality was recorded at 1 and 5 hours after treatment (HAT). It was observed that the mortality at 1 HAT was as low as zero in the treatment with 0.01% *Nanma*, whereas it increased proportionally to 56.0% at 1.0% *Nanma*. On 5 HAT, the mortality reached 100% due to the treatment with

2% *Nanma*, however, no mortality was observed in the control.

A launching ceremony of the ICAR-CTCRI developed biopesticides was organised at the Sangamythri Farmers Producer Company Ltd, Pallichal, Thiruvananthapuram, and it was inaugurated by Smt. K.B. Valsalakumari IAS, Executive Director, Kudumbashree State Mission, Kerala, and Prof. P. Rajendran, Vice Chancellor, Kerala Agricultural University presided over the function.

With the collaboration of ICAR-IARI Regional Station, Wellington, Nilgiri, the dose of *Menma* was standardised for the management of aphids in mustard. The impact of biopesticide, *Menma*, on the visit of honeybees was also studied. The biopesticide *Shreya* was standardized for the management of mealybugs in okra, brinjal and tomato. New formulation was prepared for the management of sucking pests in vegetables.

13. CRP on borers (ICAR, PI: Dr. Rajasekhara Rao Korada)

Sweet potato weevil repellents, humulene and gurjunene were formulated in alginate microbeads (liquid formulation). As the microbeads were not economically viable, an alternate formulation was explored. Powder formulations of weevil repellents, humulene and gurjunene, were prepared in β-cyclodextrin complexes. The formulations were evaluated in field conditions on two varieties of sweet potato. Efficacy of α-humulene in powder formulation was greater than α-gurjunene. Both the compounds have resulted in 14 to 20% weevil infestation.

14. CRP on vaccines and diagnostics (ICAR, PI: Dr. T. Makeshkumar)

The project was started in December 2015. Cassava germplasm accession (85) samples were collected and diagnosed for cassava mosaic virus infection using different virus specific primers and 15 accessions showed resistance. Sampling method for diagnosis of DSMV from tubers of elephant foot yam and YMMV from lesser yam was standardized using DAS – ELISA.

15. Indo-Swiss cassava network project ((Indo-Swiss Collaboration on Biotechnology (ISCB) and Department of Biotechnology, Govt. of India, New Delhi; PIs: Dr. M. N. Sheela and Dr. T. Makeshkumar)

Friable embryogenic callus production was optimized for three Indian cassava varieties, viz., H-165, H-226 and Sree Athulya. Complete plantlet establishment was achieved from FEC for the varieties, H-165 and Sree Athulya. Whitefly transmission was standardised. Infectious clones were revived.

ACMV resistant transgenic TMS 60444 were revived, multiplied and now hardened in ICAR-CTCRI containment facility for testing against SLCMV/ ICMV for their resistance and introgression with prominent Indian cultivars.

Imported the CMD resistant lines viz., UMUCAS-33 (EC879925), KBH18 (EC879926), KBH 26 (EC879927), TME 3 (EC879928), TME 7 (EC879929) and TME 4(EC879930) from ETH, Zurich. The cultures are being multiplied and hardened for conducting field evaluation. Also obtained permission for export of cultures of Sree Athulya, Sree Apoorva, H-226 and H-165 to ETH for the development of transgenics resistant to CMD. The transgenic clones were multiplied, hardened and planted in containment facility for the introgression of transgenes into popular varieties and also for conducting evaluation trials. Also experiments to induce flowering in cassava clones are being undertaken through pruning, grafting and hormone treatment.

On-farm trials with six CMD resistant clones viz.,

CR-24-4, 8S-501-2, 8W5, CR-43-2, CR-43-11 and 9S-127 along with Sree Athulya and Sree Apoorva have been laid out in 1.5 acres in six farmers' field in Attur, Salem, Tamil Nadu (Fig. 95). The selected CMD resistant clones had starch content >30% in evaluation trials conducted at ICAR-CTCRI. The CMD resistant hybrid, 8S-501-2 also had the highest harvest index (0.62).

Fig. 95. View of on-farm trial of CMD resistant clones of cassava in farmers field in Attur, Salem

16. IISR outreach project on PhytoFuRa: Leaf blight of taro (ICAR Network Project; Dr. M.L. Jeeva)

A field trial was performed for the management of leaf blight of taro using the identified potent biocontrol agent. There was no significant difference in disease severity between treatments. Application of *Trichoderma* in soil along with tuber treatment and spraying 0.20% of TATA Samarth (Potassium phosphonate, 16%) produced highest yield (Fig. 96). Fifteen *P. colocasiae* isolates were added to the existing collection at ICAR-CTCRI for studying yearly variation. All the isolates were confirmed to the species level using species specific PCR. Genetic diversity analysis was performed using Sequence Related Amplified Polymorphism (SRAP) markers. A reliable method for screening resistance in taro accessions against leaf blight disease using real-time PCR was standardized and identified suitable SSR markers were identified for characterizing *P. colocasiae* from reported SSR markers for *Phytophthora* spp. Resistant Gene Analogues (RGAs) from resistant (Muktakeshi) and susceptible (Sree Kiran) taro varieties were amplified, sequenced and characterized.

Fig. 96. View of PhytoFuRa field trial

17. Refinement of starch indicator developed by CTCRI and design of next generation gadget for measuring starch content of cassava (*Manihot esculenta* Crantz.) tubers (Department of Science and Technology, Govt. of India, New Delhi; PI: Dr. J.T. Sheriff)

Electrical properties of cassava tubers such as capacitance, impedance, dissipation factor and phase angle were measured using LCR meter (Agilent E4980A) for the eight varieties of cassava viz., Sree Jaya, 4-2, C-77, CMR-205, MVD-1, H-165, Co-2 and Sree Apoorva in the frequency range of 100 Hz to 2 MHz. It was found that the frequency range, 10 KHz-1MHz had significant influence on these properties. Electrical properties of H-97, Sree Prakash, Sree Visakham, Sree Rekha, Sree Sahya, Co-3 tubers were measured in the frequency range of 10 KHz to 1 MHz. Electrical properties of C-43/11, CMR-73, CMR-15, CMR-1, CMR-8, Co-1, H-226, Co-4, MNga, Sree Harsha, CMR-24-4, AVU-27, AVU-15, 9-S-125, 9-S-236, *Pulladu Kappa*, Soorna, Sree Vijaya, Vellayani Hraswa and CMR-1 were analysed in the frequency range of 700 Hz to 1 MHz and correlated with biochemical attributes. Electrical properties of AVU-27, AVU-15, 9-S-125, 9-S-236, *Pulladu Kappa* were analysed in the frequency range of 20 KHz to 40 KHz and correlated with biochemical attributes. Correlation coefficient between electrical and biochemical properties (starch and moisture) of cassava tubers were worked out.

The hardness of the peeled and unpeeled cassava tubers were measured for the proximal, middle and distal regions of 19 varieties of cassava, Sree Jaya, 4-2, H-165, Co-2, Sree Apoorva, H-97, Sree Prakash, Sree Visakham, Sree Rekha, Sree Sahya, Co-3, C-43-11, Co-1, Co-4, MNga, Sree Harsha, CR-24-4, H-226 and CR-43-7. The hardness values were correlated with electrical and biochemical properties of tuber. Starch, moisture and fibre content of cassava tubers at proximal, middle and distal regions were analysed. The starch content of the varieties, 4-2, C-77, CMR-205, CMR-22, Sree Apoorva, C 43/11, CMR-1, CMR-15, CMR-8 and CMR-73 were measured through Reimann Balance. Microwave studies were conducted in four varieties of cassava, Sree Jaya, H-226, M-4, CMR-100 using Vector Network Analyser in S-band frequency. Correlation coefficient between microwave and biochemical properties of cassava tubers were worked out.

18. Improving the livelihoods of smallholder cassava farmers through better access to growth markets (Cassava Gmarkets; PI: Dr. J.T.Sheriff)

Process production studies of high quality cassava flour (HQCF) were conducted to optimise loading density (3, 5 and 7 kg m^{-2}), type of drying (open yard, solar yard and mechanical drying) and method of processing (flour from chips, flour from crushed and pressed gratings). The chips were dried under open sun, solar yard and in tray dryer with 3, 5 and 7 kg m^{-2} loading densities and the hourly moisture contents of the products during three methods of drying were determined at different loading densities.

The initial moisture content of the tuber was 61-64% (wet basis) and 2-3 days were required for drying the chips to a final moisture of 10-11% through open sun or yard drying. Comparison of data showed that drying of chips at 3 kg m^{-2} loading density in the open sun took lesser time than 5 kg m^{-2} followed by 7 kg m^{-2} loading density. During night hours the chips were kept under air circulation to avoid mould growth.

The drying time required to dry chips at 3 kg m^{-2} loading density in the poly carbonated solar yard was six hours, whereas the chips loaded at 5 kg m^{-2} took 9 hours and 7 kg m^{-2} chips 11 hours. Comparison of data showed that drying of chips under poly carbonated solar yard saved about 1-2 h than drying under open sun. Drying time required for drying chips of 3 kg m^{-2}, 5 kg m^{-2} and 7 kg m^{-2} loading density in tray drier ranged between 23-28 h, when the tray dryer air temperature was set at 48±5°C.

The second lot of the roots were crushed using mobile rasper and the crushed contents were sacked and pressurised under a hydraulic press at different pressures and holding time and dried in the open sun, poly carbonated solar yard and tray dryer at 3, 5 and 7 kg m^{-2} loading densities.

The initial moisture content of the pressed tuber gratings was 43-48% (wet basis) and two days were required for drying to a final moisture of 10-11% through open sun or yard dryer. Comparison of data showed that drying time required for pressed gratings of 3 kg m^{-2} loading density in the open sun was lesser than 5 kg m^{-2} followed by 7 kg m^{-2}. The drying time required to dry pressed gratings in the direct sun was six hours, whereas the 5 kg m^{-2} pressed gratings took seven hours.

The loading density of 7 kg m^{-2} of pressed gratings took 10 hours in a split of 2 h in the first day from 3.00 pm to 5.00 pm and seven hours in the second day from 8.00 am to 4.00 pm. The drying time required to dry pressed gratings of 3 kg m^{-2} loading density in the poly carbonated solar yard was five hours in the first day and three hours in the second day, whereas the 5 kg m^{-2} chips took six hours in the first day and four hours in the second day. The loading density of 7 kg m^{-2} of pressed gratings took nine hours in the first day and seven hours in the second day. Comparison of data showed that drying of pressed gratings under poly carbonated solar yard saved about 1-2 h than drying under open sun. Drying time required for drying 3 kg m^{-2}, 5 kg m^{-2} and 7 kg m^{-2} pressed gratings in tray drier ranged from 15-17 h, when the tray dryer air temperature was set at 40±5°C.

The viscosities, whiteness index, starch and sugar content of the flour made from the cassava pressed gratings dried at different process conditions were measured. The viscosities of the flour were measured in a Brookefield viscometer at 60, 120 and 180 rpm and the values ranged from 7.36 to 18.03 cP. The colour values of the flour were measured using Hunter Color Lab. The 'L' values ranged from 96.18 to 98.55% and whiteness index ranged from 90.98-94.46 (Fig. 97). The whiteness index values were high for tray dried cassava pressed gratings followed by open sun dried gratings and poly carbonated yard dried products. The starch and sugar content of cassava pressed gratings ranged from 77.12-82.84% and 1.50-4.60%, respectively (Fig. 98).

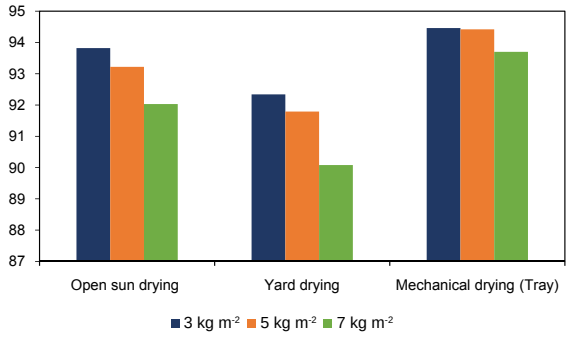


Fig. 97. Whiteness index of HQCF

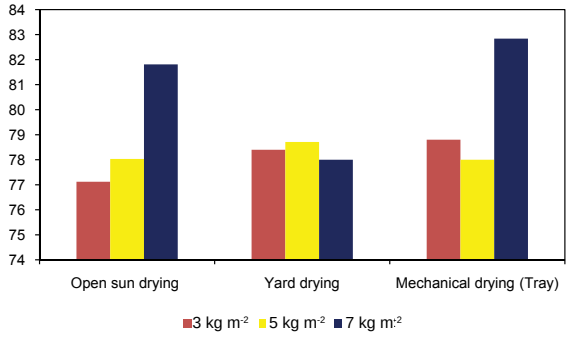


Fig. 98. Starch content of HQCF

19. Consultancy project on integration of sweet potato production and processing in Belgaum (M/S Belgaum Minerals, Belgaum, India; PI: Dr. J. T.Sheriff)

The local cultivar of sweet potato (*Chinthamani)* was harvested at Belgaum district and the biochemical properties of the tuber and flour were analysed. The moisture content, dry matter, starch, sugar, fat, protein and crude fibre content of sweet potato tuber were 67.30, 32.70, 22.03, 4.05, 1.10, 1.60 and 0.45% respectively. The energy content value of the tuber were 508.31 kJ $100g^{-1}$ and 121.4 kcal $100g^{-1}$. The micronutrient analysis showed that the phosphorous,

potassium, calcium, magnesium, iron, zinc and copper content of the tuber were 0.06, 0.19%, 173.69 ppm, 36.86 ppm, 87.62 ppm, 3.50 ppm, 7.83 ppm and 2.44 ppm. The moisture content, dry matter, starch, sugar, fat, protein and crude fibre content of sweet potato flour were 8.10, 91.90, 67.40, 12.40, 3.50 and 4.96%, respectively. The energy content value of the flour were 1562.50 kJ $100g^{-1}$ and 373.63 kcal $100g^{-1}$. The micronutrient analysis of sweet potato flour showed that the phosphorous, potassium, calcium, magnesium, iron, zinc and copper content of the tuber were 0.11%, 0.40%, 349.50 ppm, 566.70 ppm, 99.90 ppm, 12.00 ppm, 20.90 ppm and 4.50 ppm.

Protein rich sweet potato based muffins were developed using 47% sweet potato flour, 3% whey protein concentrate and 50% wheat flour and it provides 7.50% protein and 2.50% crude fiber (Fig. 99).

Sweet potato flour bread was developed using 40% sweet potato flour with 60% wheat flour. Indian flat bread (*Chapati*) was prepared by replacing wheat flour with sweet potato flour up to 50% and it was evaluated for organoleptic properties using 9-point hedonic scale. *Chapati* containing 30% sweet potato flour and 70% wheat flour was found most acceptable combination by panel members (Fig. 100).

Five varieties of sweet potato viz., local, Kanaka, Sree Arun, ST-13 and ST-14 were planted at Belgaum and it was found that Sree Arun produced the highest yield (20 t ha^{-1}). The biochemical properties of five varieties of sweet potato were analysed. The moisture content, dry matter, starch, sugar, fat, protein and crude fibre content of sweet potato tubers varied between 68.30-70.00%, 29.10-31.70%, 16.83-19.10%, 3.80-4.30%, 0.81-1.21%, 1.29-1.89% and 1.28-1.79%, respectively. The energy content value of the tuber were 102.11-107.59 kcal $100g^{-1}$. The micronutrient analysis of the five varieties of sweet potato showed that the phosphorous, potassium, calcium, magnesium, iron, manganese, zinc and copper content of the tuber ranged between 0.027-0.054%, 0.187-0.317%, 32.22-45.52 ppm, 167.25-245.6 ppm, 7.38-9.35 ppm, 0.75-1.40 ppm, 2.13-2.69 ppm and 1.83-3.06 ppm, respectively.

Fig. 99. Protein rich sweet potato based muffins

Fig. 100. Sweet potato flour based *chapati*

20. ICAR network project on high value compounds/phytochemicals

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

Anthocyanins present in the purple-fleshed tubers and leaves of sweet potato and tubers of greater yam were isolated, purified and structurally identified. In the tubers of sweet potato (ST-13), seven major anthocyanins were present, which were acylated derivatives of cyanidin and peonidin. Peonidin concentration was approximately six times than that of cyanidin. Purple leaves of sweet potato (Acc. S-1467) contained six major anthocyanins, which were also acylated derivatives of cyanidin and peonidin and in almost same concentrations. Greater yam (Acc DA-

340) tubers contained five major anthocyanins, which are acylated cyanidin derivatives.

Spray drying technique was used to encapsulate anthocyanins from sweet potato tubers, leaves and greater yam tubers (Figs. 101 & 102). This can be used as safe and stable natural colourant with added advantage of antioxidant potential. *In vitro* bioactivity studies showed potential antioxidant and anti-inflammatory activity by these anthocyanins.

Fig. 101. Encapsulated sweet potato tuber anthocyanins

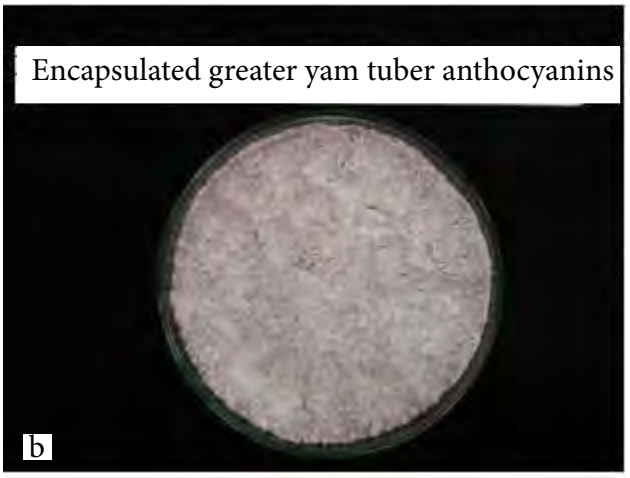


Fig. 102. Encapsulated greater yam tuber anthocyanins

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

A total of fifteen samples of cassava starch-graft copolymers were synthesized by free radical initiated polymerization reaction. The grafted starches were characterized in terms of % grafting, water and saline retention, surface morphology, X-ray diffraction analysis and thermal analysis. The O-H stretching at 3390 cm^{-1}, C-H stretching at 2932 cm^{-1}, C=O stretching at 1647.7 cm^{-1} and the triplet band for the C-O-C stretching absorption at 1159, 1084 and 1013 cm^{-1} in the FTIR spectra are characteristic bands of starch. The absorption bands at 2243 cm^{-1}, characteristic of nitrile group (–C≡N) is the evidence for grafting.

Fifteen samples each of urea, urea and potash as well as urea, potash and rock phosphate coated with the grafted starches were prepared. The % shell material as well as the water absorption capacity of the coated fertilizers was determined. The release kinetics studies with the coated fertilizers showed that the % release from various samples ranged from 5 to 40% after 25 days in aqueous medium. There was a significant negative correlation between % G and % N release. Representative samples from this set were selected and kept for soil incubation study. The soil samples are being taken for analysis of N, P, and K at monthly intervals.

22. Techno-incubation centre (Small Farmers Agribusiness Consortium, Govt. of Kerala; PI: Dr. M. S. Sajeev)

Techno-incubation centre under the Division of Crop Utilization, ICAR-CTCRI, organized 20 training programmes on value addition and entrepreneurship development in tuber crops (Fig. 103). It was attended by 336 people including farmers and young entrepreneurs from different districts of the state. The incubation centre was used by 19 entrepreneurs for the production of snack foods like pakkavada, crisps, nutrichips, murukku, sweet fry and pasta. In-plant training were imparted to four B. Tech Food

Engineering Students from Kerala Agricultural University, One month project work were offered to six students from College of Indigenous Food Technology, Konni. The centre actively participated in the Tuber Food Fest 2015 organised by the Institute at Thiruvananthapuram during 24-25 November 2015, Machinery Expo 2016, organized by Department of Industries, Govt of Kerala, Angamali, Kochi during 28-30 January 2016 and Technology and Machinery Demonstration Mela on 18 March 2016 at Changaramkulam, Malappuram, organised by AICRP on PHET Centres of Kerala. A Village Incubation Centre was established at Riha, Ukrul District, Manipur on 16 February 2016 under ICAR-CTCRI-NEH programme.

Fig. 103. Glimpses of activities of Techno-incubation centre

Technologies Assessed, Transferred, Consultancy and Patent Services

The Institute Technology Management Unit (ITMU) has been active in carrying out the following IP activities during the period 2015-2016. The unit had engaged with public/private parties for the commercialization of the following technologies:

Technologies transferred

Sl. No.	Name of technology/ know-how/ innovation	Contracting party	Mode of partnership	Revenue earned (₹)
1.	Technology for the formulation of biopesticides	KVK-Ernakulam, ICAR-CMFRI, Kochi	Licensing	25,000
		KVK-Sadanandapuram, Kottarakkara, Kollam		25,000
		KVK-Mitraniketan Vellanad, Thiruvananthapuram		25,000
		CARD-KVK, Pathanamthitta, Thiruvalla		25,000
		KVK-Alappuzha, ICAR-CPCRI		25,000
		KVK-CPCRI Kasaragod ICAR-CPCRI, Kasaragod		25,000
2.	Optimization of process for the production of quality sweet potato chips, flour and starch and product diversification	M/s Belgaum Minerals, 91 Vinaya Nagar, Hindalga Road, Belgaum-591 108	Consultancy	9,00,000
	Total Revenue			**10,50,000**

Technology for the formulation of biopesticides being transferred by Dr. Ajayaghosh, Director, CSIR-National Institute for Inter-disciplinary Science & Technology

Patent services

Sl. No.	Application/ Registration No.	Name of innovation/technology/ product/variety	Date of filing/ registration	Application in process/ granted/ registered
1.	1388/CHE/2014	Complete specification of Patent application titled 'Electronic Crop'- an electronic device for providing realistic agro-advisory to the farmers (Provisional)	April 2015	Received application number only
2.	3514/CHE/2015	A process for the production of low moist gelatinized dough for using in cassava pappad machine	July 2015	Received license

Technologies assessed (approved for including in Package of Practices Recommendations, Crops (2015), Kerala Agricultural University)

- INM for tannia.
- Technology for organic production of yams.
- Technology for organic production of taro.

Technologies developed /in pipeline

Potential tuber crop genotypes

- Released two cassava varieties viz., Sree Swarna and Sree Pavithra.
- Identified W-19 and CR 43-8 as N use efficient cassava genotypes.
- Identified breeding lines with 75 days maturity orange, white and light purple-fleshed sweet potato.
- Identified orange-fleshed sweet potato (VAO-12, VAO-33, VAO-43) of 90-100 days maturity with beta carotene >14 mg/100g, starch >18% and purple-fleshed (VAP-34, VAP-2) with anthocyanin >1g/100g, starch >18%.
- Identified six taro accessions (IC087153, IC012601, IC012294, IC310104, TCR-267 and TCR-326) moderately resistant to TLB.
- Taro hybrids of exotic and indigenous lines to adapt to climatic and commercial changes (INEA) identified.
- Two greater yam varieties viz., Sree Swathy and Sree Neelima released.
- One greater yam clone, Da-293 with high yield, good tuber shape and ccoking quality suited to non trailing condition ready for release.
- A high yielding, highly divergent white yam genotype, DR-17 developed.
- Two white yam hybrids with high tuber yield and cooking quality viz., Drh-657 (58.6 t ha^{-1}) and Drh-1047 (50.66 t ha^{-1}) ready for release.
- One dwarf hybrid of white yam viz., Drd-1110 with high tuber yield (35.8 t ha^{-1}) developed.
- Five best yam bean hybrids (3 x 10, 9 x 10, 3 x 5, 3 x 8 and 3 x 9) based on yield evaluation.

DUS guidelines

- DUS guidelines in taro.
- DUS guidelines in elephant foot yam.

In vitro cultures

- Friable embryogenic callus in CMD resistant accession 9S-127.
- Cryo-tools to store taro pollen and recover desirable hybrids for the first time (INEA).

Production technologies

- Thippi compost prepared from cassava starch factory solid waste 'Thippy' (Under Technology Transfer to Mr. Vasudevan Krishnamurthy, Chennai).
- Sustainability of cassava for continuous cultivation.
- Non response of cassava to soil application of secondary and micronutrients after attaining the soil critical level.
- Soil test based fertilizer-cum-manurial application for cassava.
- Avoidance of P application, if soil P status is high.
- Organic manures like green manuring *in situ* with cowpea, vermicompost and coir pith compost as alternate sources of organic manures to the commonly used organic manure viz., FYM, in cassava production.
- Crop intensification with rice (var. Aiswarya)-black gram (var. Co-6)-short-duration cassava (var. Sree Vijaya).
- INM strategies for yam bean in acid Alfisols.
- Usage of graded doses of NPK, organic sources, secondary and micronutrients on yield and proximate composition of yam bean.
- Soil, water and nutrient conservation method for the rainfed hill cassava production systems for the Eastern Ghats of Tamil Nadu.
- Customised plant nutrient formulations for cassava, elephant foot yam and yams in major growing areas of India.
- The customized plant nutrient formulations of cassava (NPK) in collaboration with FACT, Alwaye.
- The salt tolerant varieties of sweet potato for island ecosystem of Andaman & Nicobar Islands.
- Methodology for crop acreage estimation of

cassava using a kernel based Possibilistic *c*-means approach with remote sensing, GIS and GPS tools.

- The ECOCROP model for current and future climate suitability studies of yams in India.
- Organic production technology for Chinese potato: FYM @ 10 t ha^{-1}, green manure, neem cake @ 1 t ha^{-1}, ash @ 2 t ha^{-1} or microbial consortia comprising of biofertilizers (*Azospirillum*, P solubilizer and K solubilizer @ 3 kg ha^{-1} each).

Collaborative (contractual) / license agreement

- License agreement for quality planting material production of cassava, elephant foot yam and greater yam to Mr. Abdul Nabeel P. Natura Nursey and Agro Products, Pattorakkal House, Meppayur post, Kozhikode, Kerala.

Protection technologies

- *In vitro* protocols to test the pathogenecity of *Colletotrichum gloeosporioides* in greater yam detached leaf and tissue cultured whole plant.
- Specific primers to detect *Yam mild mosaic virus* from lesser yam.
- Diagnosis of *Yam mild mosaic virus* from lesser yam tubers.
- The dose of biopesticide to remove the waxy coating from spiralling whitefly.
- The biopesticide *Menma* against the nematode in pepper, in collaboration with ICAR-IISR, Kozhikode.
- Sweet potato weevil pheromone technology with reduced number of traps/ha (10 traps/ha).
- Biopesticides against mealy bugs in vegetable crops.
- Sweet potato weevil repellents in β-cyclodextrin.

Technologies for industrial products

- Laboratory scale technology for a moisture resistant corrugating adhesive based on cassava starch.
- Laboratory scale technology for an alkali free corrugating adhesive mix based on cassava starch.

Value added products

- Resistant starches with significantly low glyceamic index.
- Encapsulated anthocyanins with improved colour stability.
- Water soluble curcumin loaded on a modified nano cassava starch for pharmaceutical application.
- Particle board from cassava stalks.
- Protein enriched pasta from sweet potato flour with legumes.
- Electronic gadget for measuring starch content in cassava tubers.
- Gluten free cookies/biscuits/bread from taro and sweet potato flour.
- Biodegradable films from enzyme modified cassava starch.
- Sweet potato based nutribar.
- Lacto pickle from yam bean.

Post-harvest machineries

- Sold five cassava chipping machines.

User interface

- Sold five cassava chipping machines.
- Electronic Crop (E-Crop): Device for simulating crop growth real-time is installed in sweet potato field for simulating the growth of sweet potato.
- A nutrient decision support system in CD, CASSNUM version 1.1, for site specific nutrient management of cassava.

Education and Training

Education

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

Particulars of the programme	Number of students
M. Sc. project work of students	47
M. Sc. course on Integrated Biotechnology	11
Ph. D programmes	19

Trainings organized by ICAR-CTCRI

- Forty one exposure trainings were given on "Production and Processing of Tuber Crops" to 557 farmers, 799 students and 27 teachers/ extension officers. The participants were from Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Himachal Pradesh, and other parts of the country.
- A workshop was organized on "Strengthening Impact Assessment in CGIAR (SIAC)" at ICAR-CTCRI, Thiruvananthapuram on 16 April 2015.
- **Brain Storming Session:** A state level brain storming session was organized on "Extension Research in NARES of Kerala: Current Progress and Future Perspectives" on 18 April 2015 at ICAR-CTCRI, Thiruvananthapuram.
- Training programme for farmers under Tuber Crops Development Scheme was organized at Kannur and Wynad districts, Kerala, during July 2015. Training on cassava cultivation was conducted at Ayyankunnu panchayat of Kannur district and three training programmes on cultivation practices of cassava, elephant foot yam and greater yam was conducted in three tribal panchayats of Wynad district under the scheme.
- Farmers Training on "Food Processing and Value Addition", organized by Small Farmers Agri-Business Consortium and Rural Agricultural Wholesale Market, Nedumanagad, at ICAR-CTCRI, Thiruvananthapuram on 22 July 2015.
- Training on "Value Addition and Production Technology of Tuber Crops", under Project Implementation Agency, Integrated Water Shed Management, Block Development Office, Chittumala, Kollam on 5 August 2015.
- **Short Course on Business Planning:** An ICAR sponsored short course on "Business Planning for Developing New Agro-Technology Enterprises" was organized at ICAR-CTCRI, Thiruvananthapuram, during 2-11 September 2015. The course was aimed to equip the NARES professionals on critical business planning skills that are essential for developing viable agro-technology enterprises. Dr. S.K. Chakrabarti, Director, ICAR-CTCRI, inaugurated the course. During the training, the participants developed three business plans using "analytical and sequential learning approach" by employing various techniques of idea generation, product identification, market

and sales planning (segmentation, targeting, product positioning). Dr. P. Sethuraman Sivakumar, Senior Scientist, coordinated the short course. About 20 Assistant Professors/ Scientists/Subject Matter Specialists from Agricultural Universities/ICAR Institutes/

Participants of the Short Course on Business Planning

Class room session of the Short Course on Business Planning

KVKs from Haryana, Jammu & Kashmir, Gujarat, Chhattisgarh, Madhya Pradesh, Karnataka, Kerala and Tamil Nadu participated in the course.

- **ICAR Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops:** An ICAR-Short Course on "Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops" was organized at ICAR-CTCRI, Thiruvananthapuram during 14-23 September 2015. About 19 participants from different Agricultural Universities, ICAR institutes and Rubber Board attended the programme. The programme comprised of theory classes of 40 hours duration on importance of tropical tuber crops, primary and secondary processing equipments, best agronomic practices for producing quality products, nutritional and medicinal values of tuber crops, physico-chemical, thermal and viscometric properties of starches, extrusion processing of tuber crop starch/ flour, industrial products from tuber crops, functional foods, bakery and snack products from tuber crops, food safety management system, sensory evaluation, FSSAI act, rules and regulations and quality pharmaceutical applications, biodegradable packaging materials and standardization of cassava products.
- The practical session included classes for 23 hours on demonstration of equipments for the preparation of cassava flour, starch, sago and wafers, demonstration of single screw and twin screw food extruder, hands-on training on development of value added products, pasta/spaghetti/noodles type products from tuber crops and visit to edible cassava chips unit, Tierra Foods, Adoor, Pathanamthitta, Kerala. A video conferencing class on "Let them eat root and tubers crops: Is consumer

Participants of the ICAR Short Course on Processing Machineries

acceptance important?" was handled by Dr. Keith Tomlins, Natural Resources Institute, UK.

- **Science Enrichment Programme for Prathibha Scholars 2014-15:** Students Programme for Excellence in Experimental Design (SPEED) was organized under the Science Enrichment Programme for Prathibha Scholars 2014-15 by Kerala State Council for Science, Technology and Engineering (KSCST&E) for 26 UG students from Kerala and two PG students from Karnataka during 19-23 September 2015 to motivate the students to pursue science as their carrier by inculcating a scientific temper among the participating students. Dr. V. Ravi, Head, Division of Crop Production, led the program, which was co-ordinated by Dr. V. Ramesh, Senior Scientist. The programme included 16 lectures by eminent scientists, field and laboratory visits, visit to Priyadarshini Planetarium. The speakers were selected from various disciplines viz.,

Inaugural address by Dr. S. K. Chakrabarti, Director, ICAR-CTCRI during inauguration of SPEED programme on 19 September 2015

Physics, Chemistry, Biology, Mathematics, Plant Physiology, Agronomy, Soil Science, Soil Physics, Computer application, GIS,

Participants of the Speed Programme

Agricultural Engineering. All sessions were highly appreciated by the students.

- **International Training:** Eight officials from Nigeria were given three days' training during 21-23 September 2015, at ICAR-CTCRI, as a part of their "Certificate Course on Requisites of Seed Production, Processing and Quality Assurance" at MAU, Uttar Pradesh.

- "Hands on Training on SAS and R for Statistics" was conducted for the Scientists and Research Scholars of CTCRI, Thiruvananthapuram, during 15-17 October 2015.

- **Model Training Course of Tuber Crops Technology Commercialisation:** A Model Training Course on Tuber Crops Technology Commercialisation and Entrepreneurship Development" sponsored by the Directorate of Extension, Ministry of Agriculture Cooperation & Farmers Welfare, Govt. of India was organised at ICAR-CTCRI, Thiruvananthapuram, during 2-9 February 2016. This training was inaugurated by Dr. M. N. Sheela, Director (In charge). Trainings on production of commercially viable tuber crops based technologies like improved varieties, biomolecules for pest management,

value added products like pasta, alcohol, snack and savoury foods etc. were imparted. They were also equipped with practical skills on developing business plans for various tuber crops based products. Dr. P. Sethuraman Sivakumar, Senior Scientist, coordinated the training course. Twelve Horticulture/ Agriculture Officers/ADAs from Andhra Pradesh, Kerala, Maharashtra and Odisha participated in the training course.

- **Village Incubation Centre for Value Addition of Tuber Crops developed at Ukhrul, Manipur:** "Adding value to low-cost cassava tubers will double the agricultural income of the Manipur farmers" was the message delivered by Dr. S.V. Ngachan, Director of ICAR Research Complex for

Inaugural session (left) and participants of the Model Training Course on Tuber Crops Technology Commercialization

NEH Region, Umiam, Meghalaya during the Launching Workshop-cum-Training Programme on "Incubation Centre for Value Addition of Tuber Crops" at Riha village, Ukhrul district, Manipur, under ICAR-CTCRI-NEH programme on 17 February 2016. About 100 progressive farmers/SHG members prospective entrepreneurs from Riha village were trained on tuber crops snack food production. A team of scientists headed by Dr. M. S. Sajeev, Principal Scientist, Dr. P. Sethuraman Sivakumar, Senior Scientist and Mr Salimon, Senior Technical Officer, ICAR-CTCRI, Thiruvananthapuram trained

Inauguration of Incubation Centre at Riha

Farmers producing tapioca crisps at the Village Incubation Centre, Riha

the farmers. The programme was attended by Scientists from ICAR-RC-NEHR, Manipur Centre; Central Agricultural University, Imphal; KVK Ukhrul, KVK Imphal West,

KVK Chandel and officials from NABARD and line departments.

- **Entrepreneurship Orientation Programme for Agricultural Students:** One-day "Entrepreneurship Orientation Programme for Agricultural Students" was organised at ICAR-CTCRI on 21 March 2016. The objective of the programme was to create awareness among the students for setting up of new agro-technology enterprise after completion of their studies instead of searching for jobs only. About 110 students from Kerala Agricultural University, Vellayani, participated in the programme.
- **Seed Business Development Programme organised at Salem, Tamil Nadu:** An "Entrepreneurship Orientation Programme on Promoting Tuber Crops Seed Enterprises for Sustainable Seed Security" was held at the Krishi Vigyan Kendra, Sandhiyur, Salem, on 23 March 2016. The programme was inaugurated by Dr. James George, Director, ICAR-CTCRI. Dr. James George called for creating new seed oriented enterprises for multiplying and distributing several high yielding and high starch varieties like Sree Athulya, developed by ICAR-CTCRI. Dr S. Manickam, Professor and Head of Tapioca and Castor Research Station, Yethapur, spoke on the occasion. Dr. V. Ravi, Head, Division of Crop Production, ICAR-CTCRI requested tapioca farmers to avail the Soil Health Card Scheme of the Ministry of Agriculture and Farmers Welfare, Govt. of India, to profitably utilise the soil resources without leading to environmental degradation. In the concluding remarks, Dr N. Sriram, Programme Coordinator, KVK Salem, appealed to the farmers to develop expertise in the seed business. Dr. R. Muthuraj, Senior Scientist, ICAR-CTCRI explained about various high-yielding (over 30 tonnes per hectare) and high starch (>30% extractable starch) tapioca varieties released by ICAR-CTCRI and demonstrated cost-saving seed multiplication methods to the farmers. This programme was organised by the Intellectual Property and Technology Management Unit (IPTMU) of ICAR-CTCRI and Dr. P. Sethuraman Sivakumar, Scientist-In-charge of the Unit, coordinated the programme.

Dr. James George, Director, ICAR-CTCRI, distributing stems of cassava var. Sree Athulya in the Seed Business Development Programme at Salem

- **Orientation Training:** Three new Scientists posted at ICAT-CTCRI (on Probation) were given orientation training programme in the institute for a period of one month, 9 October–9 November 2015. Twelve newly recruited Skilled Support Staff were given orientation training for one month in the institute during January 2016.
- In the Techno-Incubation Centre, ICAR-CTCRI, 20 training programmes-cum-practical demonstrations on value added products from tuber crops and entrepreneurship development were organized. Thirteen entrepreneur groups utilized the incubation facility for the production of snack foods and pasta. One young entrepreneur group utilized the incubation facility for developing jack fruit seed-cassava based pasta.
- More than 135 classes on production,

- **Training Programmes under Tribal Sub Plan Scheme**

Sl. No.	Details of training programme	Name of organizers	Date & venue	Participant details
1.	Training Programme on Production and Value Addition of Tuber Crops	ICAR-CTCRI, Regional Centre, Bhubaneswar, Odisha in collaboration with the Ramakrishna Mission Ashram, Krishi Vigyan Kendra, Divyayana, Morabadi, Ranchi, Jharkhand	17 July 2015 at Barkigorang village, Angara Block, Ranchi, Jharkhand	60 farmers and farm women
2.	Exposure visit-cum-Training programme on Farming Systems Involving Tuber Crops for Livelihood Improvement	ICAR-CTCRI, Regional Centre, Bhubaneswar, Odisha	21-23 December 2015 and 4-6 January 2016 at ICAR-CTCRI, RC, Bhubaneswar	200 participants from Ranchi, Jharkhand and Koraput, Odisha
3.	One day Training Programmes (5 nos.)	ICAR-CTCRI, Regional Centre, Bhubaneswar, Odisha	11 June 2015	30 farmers from Gumagada village, Kandhamal district, Odisha
			12 September 2015	40 farmers from Badagoan village, Pottangi block, Koraput district, Odisha
			15 September 2015	40 farmers from Gumagada, Kandhamal, Odisha
			16 September 2015	30 farmers from Kuinpada, Kandhamal, Odisha
			9 October 2015	55 farmers from Barkigorang village, Angara block, Ranchi district, Jharkhand

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, soil health management INM, IPM, vermi-composting, bio-pesticides and bio-control strategies, post-harvest management and value addition.

Trainings attended by ICAR-CTCRI staff

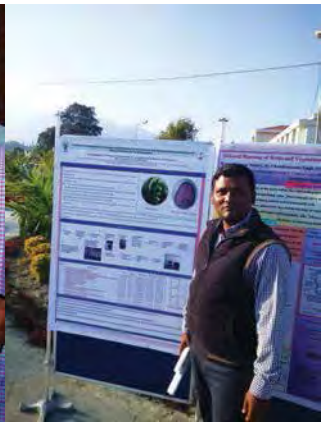
Sl. No.	Name	Particulars of the training	Period
1.	N. Krishna Radhika	ICAR sponsored Summer Training Course on RNA-interference as a Tool for Plant Functional Genomics and Crop Improvement at National Research Centre on Plant Biotechnology, New Delhi	6-26 May 2015
2.	Dr. C. A. Jayaprakas	Pre-RMP Training Programme at ICAR-NAARM, Hyderabad	16-27 June 2015
3.	Ms. Namrata Ankush Giri	Summer School Training Programme (21 days) on Post-harvest Processing and Value Addition of Millets for the Development of Functional Foods to Combat Lifestyle Disorders at TNAU, Coimbatore	1-21 July 2015
		Hands on Training in Statistical Data Analysis using SAS and R at Bioinformatics Lab, ICAR-CTCRI, Thiruvananthapuram	15-17 October 2015
4.	Ms. Sirisha Tadigiri and Ms. B. G. Sangeetha	102nd Foundation Course for Agricultural Research Service at ICAR-NAARM, Hyderabad	1 July to 30 September 2015
5.	Dr. R.Muthuraj	Business Planning for Developing New Agro-Technology Enterprises at ICAR-CTCRI, Thiruvananthapuram	2-11 September 2015
6.	Dr. V. Ramesh	Geospatial Analysis of Natural Resource Management using Statistical Tools at ICAR-NAARM, Hyderabad	2-11 September 2015
7.	Dr. Saravanan Raju Ms. Namrata Ankush Giri Ms. Pradeepika Chintha	ICAR sponsored Short Course Training Programme on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops at ICAR-CTCRI, Thiruvananthapuram	14-23 September 2015
8.	Dr. Sethuraman Sivakumar	Capacity Building Program on Methodologies in Agriculture Extension Research organized by ICAR and IFPRI	21-24 September 2015
		Training Workshop on Competency Development for HRD Nodal Officers of ICAR	10-12 February 2016
9.	Ms. Sirisha Tadigiri	Attachment Training under the guidance of Dr. Umamaheswari, Scientist, Division of Entomology and Nematology, ICAR-IIHR, Bangalore	11 November 2015 to 10 February 2016
10.	Ms. B. G. Sangeetha	Attachment Training under the guidance of Dr. R. Asokan, Division of Biotechnology, ICAR-IIHR, Bangalore	11 November 2015 to 10 February 2016

Awards and Recognitions

Awards

- Dr. C. A. Jayaprakas received the Best Scientist Award, instituted by Farm Journalist Forum, from Shri. K. P. Mohanan, Hon'ble Minister for Agriculture, Govt. of Kerala on 7 December 2015.

Dr. C. A. Jayaprakas receiving the Best Scientist Award from Shri. K. P. Mohanan, Hon'ble Minister for Agriculture, Govt. of Kerala



Dr. V. B. S. Chauhan beside the Best Poster that received the first prize

- Drs. V.B.S. Chauhan, K. Banerjee, Ahammed Shabeer, D. Oulkar, S. K. Chakrabarti, M.N. Sheela, Archana Mukherjee, K. Pati and R. C. Ray received the Best Poster Award for the work entitled "Profiling of anthocyanin in greater yam exhibited its potential for nutritional security and source of natural pigments for food industries" at the National Conference on Horticulture in North Eastern Region held at College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh, during 16-18 January 2016.
- Shri. R. Bharathan, Assistant Chief Technical Officer, bagged the gold medal in the athletic event 1500 m sprint in the ICAR–Inter Institutional Tournament (South Zone) held at Kochi during 25-29 May 2015.
- Basket Ball Team consisting of Dr. J. Sreekumar, Shri. V. R. Sasankan, Shri. P. C. Noble, Shri. R. Bharathan, Dr. S. Shanavas, Shri. C. Chandru, Shri. A. Chandran and Shri. L. Samynathan became runners up in the ICAR–Inter Institutional Tournament (South Zone) held at Kochi during 25-29 May 2015.

Award of Ph. D

- Saravanan Raju, Senior Scientist (Plant Physiology) was awarded Ph. D. in Plant Physiology from Kerala Agricultural University for the thesis titled "Biochemical and molecular studies on post-harvest physiological deterioration of cassava"(*Manihot esculenta* Crantz).
- Ms. I. P. Anjana Devi was awarded Ph. D. in Biotechnology from the University of Kerala for the thesis titled "Microbial inoculants in elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) with special emphasis on potassium solubilizers" undertaken under the guidance of Dr. R.S. Misra and co-guidance of Dr. K. Susan John.
- Ms. Neetha Soma John was awarded Ph. D. in the discipline of Biotechnology from the University of Kerala for the thesis titled "Isolation, evaluation and characterization of biocontrol agent for the control of collar rot of *Amorphophallus* under the guidance of Dr. R.S. Misra and co-guidance of Dr. K. Susan John.
- Shri. Vishnu S. Nath, was awarded Ph. D. in Biotechnology from the University of Kerala for the thesis titled "Role of avirulence gene products and biocontrol agents for the management of leaf blight disease in taro caused by *Phytophthora colocasiae*". The work was undertaken under

the guidance of Dr. Vianayaka Hegde, Principal Scientist, ICAR-CPCRI and co-guidance of Dr. M. L. Jeeva.

Award of M. Sc. (Integrated Biotechnology)

- Shri. K. S. Sudheer, was awarded B.Sc.-M.Sc. (Integrated) Biotechnology from Kerala Agricultural University on the topic "Identification and characterisation of viruses infecting lesser yam (*Dioscorea esculenta* (Lour.) Burkill)". The work was done at ICAR-CTCRI under the guidance of Dr. M. L. Jeeva. Dr. T. Makeshkumar was a member in the advisory committee.
- Ms. V. S. Jayalekshmi was awarded B.Sc.-M. Sc.(Integrated) Biotechnology from Kerala Agricultural University. Her thesis topic was "Identification and characterization of viruses in sweet potato (*Ipomoea batatas* (L.) Lam)". The work was undertaken at ICAR-CTCRI under the guidance of Dr. T. Makeshkumar Dr. M. L. Jeeva was a member in the advisory committee.
- Ms. Parvathy Harikumar was awarded B.Sc.-M.Sc. (Intergrated) Biotechnology from Kerala Agricultural University on the topic "*In vitro* propagation and identification of molecular markers linked to dwarfness in white yam (*Dioscorea rotundata* Poir.)". The work was done under the guidance of Dr. M.N. Sheela at ICAR-CTCRI.
- Mr. Ambu Vijayan was awarded B.Sc.-M.Sc. (Intergrated) Biotechnology from Kerala Agricultural University on the topic "Molecular marker development for cassava mosaic disease resistance using bioinformatics tools". The work was done under the guidance of Dr. J. Sreekumar at ICAR-CTCRI.
- Ms. A. Aswathy Anand was awarded B.Sc.-M.Sc. (Intergrated) Biotechnology from Kerala Agricultural University on the topic "Genetic diversity analysis and identification of molecular markers associated with leaf blight resistance in taro (*Colocasia esculenta* (L.) Schott.)". The work was done under the guidance of Dr. A. Asha Devi at ICAR-CTCRI.
- Ms. M. S. Amirtha was awarded B.Sc.-M.Sc. (Intergrated) Biotechnology from Kerala Agricultural University on the topic "Genetic variability analysis of sweet potato (*Ipomea batatas* (L.) Lam.) and wild relatives using SSR markers". The work was done under the guidance of Dr. C. Mohan at ICAR-CTCRI.
- Ms. O. G. Dhanya, was awarded B.Sc.-M.Sc. (Intergrated) Biotechnology from Kerala Agricultural University on the topic "Molecular characterization of cassava mosaic disease (CMD) resistant varieties and wild relatives of cassava (*Manihot esculenta* Crantz) using SSR and SNP markers". The work was done under the guidance of Dr. C. Mohan at ICAR-CTCRI.
- Mr. Edwin K. Wilson was awarded B.Sc.-M.Sc. (Intergrated) Biotechnology from Kerala Agricultural University on the topic "Development of biodegradable films from enzymatically modified cassava starch". The work was done under the guidance of Dr. M.S. Sajeev at ICAR-CTCRI.
- Mr. K.S. Sreekuttan was awarded B.Sc.-M.Sc. (Intergrated) Biotechnology from Kerala Agricultural University on the topic "Oxidative stress and protein profiling in cassava (*Manihot esculenta* Crantz) under abiotic stresses". The work was done under the guidance of Dr. V. Ravi at ICAR-CTCRI.

Recognitions

- Dr. S. K. Chakrabarti was conferred as Fellow, National Academy of Agricultural Sciences 2016.
- Dr. S. K. Chakrabarti was recognized as Chairman, Cassava Breeding Session, Nanning, Guangxi, China, in the World Congress of Root and Tubers held at Nanning, China, during 18-22 January 2016.

- Dr. James George was nominated as Councillor for South Asia of the ISTRC in the World Congress of Root and Tubers held at Nanning, China, during 18-22 January 2016.
- Dr. Archana Mukherjee was recognized as task force member to formulate DUS guidelines in tuber crops, on 7 September 2015.
- Dr. Archana Mukherjee was nominated as IMC member, ICAR-CIWARI and ICAR-CIWA.
- Dr. M. N. Sheela was inducted as member, Board of Studies, Kerala Agricultural University.
- Dr. C. A. Jayaprakas was nominated as member, expert committee, Scheme for Young Scientist & Technologist (SYST), under the Equity, Empowerment and Development (SEED) division of Department of Science and Technology, Govt. of India.
- Dr. J. T. Sheriff was nominated by DDG (Agrl. Engg.) as IMC member, ICAR-CIAE, Bhopal.
- Dr. J. T. Sheriff was nominated by DDG (Agrl. Engg.) as national expert reviewer for reviewing research project proposal for funding under Extramural Fund Scheme, ICAR.
- Dr. J. T. Sheriff was nominated as external examiner for Ph. D qualifying viva voce examination of Food Process Engineering students at Tamil Nadu Agricultural University, Coimbatore, on 14 July 2015.
- Dr. G. Byju was invited by Lakshadweep Administration to organize a workshop on cassava cultivation, during 23-29 October 2015, as well as to prepare a plan of action for introduction of cassava in the Union Territory of Lakshadweep.
- Dr. G. Byju was invited by ICAR-CPCRI for the preparation of soil fertility map of ICAR-CPCRI Regional Station, Kayamkulam using geoinformatics tools.
- Dr. G. Byju was recognized as external examiner for the conduct of qualifying examination and for evaluation of M. Sc (Ag) and Ph.D. thesis of 12 students of College of Agriculture, Vellayani and College of Horticulture, Vellanikkara, Kerala Agricultural University.
- Dr. G. Byju was invited to deliver a talk on 'Introduction to soil science and soil testing' at Christian College, Chengannur, Kerala, on 19 February 2015.
- Dr. M. L. Jeeva was recognized as external examiner to evaluate theses and conduct final viva voce of Ms. Milsha George and Ms. Saranya, M.Sc. (Ag.) (Plant Pathology), Kerala Agricultural University.
- Dr. M. L. Jeeva was recognized as external expert for project assistant selection for an external project at CSIR- NIIST, on 29 January 2016.
- Dr. G. Suja was nominated as subject expert (Agronomy), Career Advance Scheme (CAS) Promotions under UGC 2006, Kerala Agricultural University.
- Dr. G. Suja was identified as question paper setter for Research Methodology Paper I of the Ph. D. Course Work Examination July 2015, Kerala University.
- Dr. G. Suja was nominated as expert for the evaluation of extended abstracts/contest papers in the subject area of Agriculture and Food Sciences of 28th Kerala Science Congress 2016.
- Dr. G. Suja was invited as resource person to deliver a lecture titled "Climate change and food security" at the Refresher Course on Environmental Sciences at the UGC-Academic Staff College, University of Kerala, Thiruvananthapuram, on 14 January 2016.
- Dr. K. Susan John was recognized as external examiner for the conduct of the Ph. D qualifying examinations of two students of the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, on 16 September 2015.

- Dr. K. Susan John was recognised as an expert for the evaluation of an M.Sc.(Ag.) thesis in the Department of Soil Science and Agricultural Chemistry, Anbil Dharmalingam Agricultural College and Research Institute, Thiruchirappally, Tamil Nadu Agricultural University.
- Dr. K. Susan John was recognized as external examiner for the conduct of Ph.D qualifying viva voce examination of two students in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani**,** Kerala Agricultural University, on 18 March 2016.
- Dr. K. I. Asha, was recognized as external expert and conducted the Pre-submission Seminar of Smt. G. Shirmila Jose, Full-time Research Scholar, Department of Botany, University of Kerala, on 6 May 2015, at the Department of Botany, Kariavattom, University of Kerala, Thiruvananthapuram.
- Drs. K. Susan John and K. Laxminarayana were recognized as nodal officers of the Institute for the ICAR-Soil Health Card (SHC) programme at CTCRI-HQ and Regional Centre, Bhubaneswar, respectively.
- Dr. K. Laxminarayana was recognized as external examiner for the conduct of thesis viva-voce examination for four M.Sc. students of Orissa University of Agriculture and Technology, Bhubaneswar, Odisha.
- Dr. K. Laxminarayana was nominated as Executive Council Member for Indian Society of Soil Science, Bhubaneswar Chapter, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha.
- Dr. K. Laxminarayana was nominated as member of Research Council for Konark Institute of Science and Technology (KIST), Jatni, Bhubaneswar, Khurda, Odisha from December 2015 onwards.
- Dr. T. Makeshkumar was nominated as DBT nominee, Institute Biosafety Committee, ICAR-Indian Institute of Spices Research, Kozhikode (2015-2017) and external member, Institute Biosafety Committee, Kerala Agricultural University (2016-2018).
- Dr. T. Makeshkumar was recognized as the qualifying examiner of a Ph. D student, Dept. of Biotechnology, Calicut University, on 17 December 2015.
- Dr. A. Asha Devi was nominated as judge for award sessions for the best paper presentations by teaching faculty and research scholars at the Regional Seminar on Emerging Trends in Conservation Biology-Botanica-2015 held at Sree Narayana College, Chempazhanthy, on 12 February 2016.
- Dr. J. Sreekumar was recognized as a guest faculty by IISER, Thiruvananthapuram, for handling the course on Biostatistics.
- Dr. R. Muthuraj was nominated as member of the committee for National Accreditation Committee of the seed farm, nursery and tissue culture lab of the National Horticulture Board.
- Drs. C. A. Jayaprakas, M. N. Sheela, G. Byju, M. L. Jeeva, K. Susan John, G. Suja, A.N. Jyothi and T. Makeshkumar are recognized as guide for Ph.D program, University of Kerala, Kariavattom, Thiruvananthapuram.
- Drs. M. N. Sheela, V. Ravi, M. L. Jeeva, T. Makeshkumar, S. S. Veena, A. Asha Devi, K. I. Asha, Shirly Raichal Anil, A. N. Jyothi and J. Sreekumar are recognized as guide for B.Sc.-M.Sc. Integrated Biotechnology course at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala Agricultural University.

Linkages and Collaborations in India and Abroad

The Institute has international collaborations with International Potato Centre (CIP), Lima, Peru; International Centre for Tropical Agriculture (CIAT), Cali, Columbia; CIRAD, France and EMBRAPA, Brazil.

Extra mural funding is provided through 25 external aided projects including International Network Project on Edible Aroids and Cassava Gmarkets funded by European Commission and Indo-Swiss Project on cassava mosaic disease. The national and state funding agencies are: ICAR, NAIP, Government of India-DST, DBT, DIT, UGC, NABARD, KSPB, SHM, RKVY, KSCSTE etc. Linkages were established with KVK-Mithranikethan, Thiruvananthapuram, KVK-Sadanandapuram, Kottarakkara, CARD KVK-Pathanamthitta, KVK-Alapuzha, KVK-Ernakulam, KVK-CPCRI, Kasaragod, for transferring the technology for the formulation of cassava based biopesticides.

The North-Eastern Hill Region programme and Tribal Sub Plan sanctioned during 12th plan have been implemented by distributing planting materials, conducting seminars, training programmes and demonstrations in KVKs and NGOs of the implementing States as functional partners.

Under Tuber Crops Development Scheme funded by Department of Agriculture, Govt. of Kerala, the planting materials of cassava, elephant foot yam and greater yam have been distributed to the farmers by conducting training programs and exposure visits.

The Institute has established active linkage with Indian Institute of Remote Sensing (IIRS), Dehradun, Uttarakhand, for conducting a study on acreage estimation of cassava in Salem district and sweet potato in Odisha, using temporal Landsat–8 OLI images and kernel based possibilistic c-means (PCM) classification approach. Atmospherically corrected temporal images were developed (using ATCOR) that greatly reduces the influence of atmosphere and solar illumination. The NDVI images are also generated to reduce the spectral dimensionality of the data. Collaboration has been established with the Department of Agriculture, Govt. of Kerala and Kerala State Planning Board under an external funded project on "Enhancing the economic viability of coconut based cropping systems for land use planning in Kerala state". Validation trials on organic management of yams and cassava in coconut garden are being carried out in collaboration with ICAR-CPCRI, Kasaragod. MoU has been signed with Indian Institute of Crop Processing Technology (IICPT), Thanjavur for mutual utilisation of research facilities.

The Regional Centre has established active linkages with CIP, OTELP, Bhubaneswar, Directorate of Horticulture and Agriculture, Bhubaneswar, PRAVA several NGOs' and SAUs' and ICAR Institutes and other development agencies for conducting front line demonstrations, capacity building, information exchange etc. Besides the Regional Centre has collaboration with Central Rice Research Institute (ICAR-CRRI), Cuttack for isolation and identification of stink bug pheromones and plant volatiles and with Central Research Institute for Jute and Allied Fibres (ICAR-CRIJAF), Barrackpore for jute volatiles and jute pests.

ICAR - All India Coordinated Research Project on Tuber Crops, Head Quarters, ICAR - Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala

The All India Coordinated Research Project on Tuber Crops (AICRPTC), functioning since 1968, is the largest national network of tropical root and tuber crops covering 19 states and one union territory in the north-eastern, eastern, western and southern parts of India. Rajendranagar centre, previously under Dr YSRHU, Andhra Pradesh continued to be a new centre under SKLTSHU, Telengana, due to bifurcation of the erstwhile Andhra Pradesh and the Regional Station, ICAR Research Complex for NEH Region, Lembucherra was also added as a new centre during 2015-2016. Presently, the AICRPTC centres are located in 14 State Agricultural Universities, five ICAR Institutions and one Central Agricultural University. The details of the centres and their mandate crops are mentioned below:

Sl. No.	Name of the coordinating centre	Year of start	Mandate crops
1	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala	1968	Cassava, sweet potato, yams, and aroids
2	Rajendra Agricultural University, Dholi, Muzaffarpur (Dt.), Bihar	1968	Sweet potato, taro, elephant foot yam and yam bean
3	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu	1968	Cassava at Yethapur, Salem, sweet potato, taro, elephant foot yam and yams at Coimbatore
4	Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh	1969	Cassava at Venkataramannagudem, elephant foot yam and yams at Kovvur
5	Assam Agricultural University, Jorhat, Assam	1971	Cassava, sweet potato, taro, elephant foot yam and yams
6	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri (Dt.), Maharashtra	1975	Cassava, sweet potato, taro, elephant foot yam and yams
7	ICAR Research Complex for NEH Region, Barapani, Meghalaya	1975	Sweet potato and aroids
8	Bidhan Chandra Krishi Viswavidyalaya, Nadia, Kalyani, West Bengal	1976	Sweet potato, taro, yam bean, elephant foot yam and yams
9	Regional Centre of ICAR-CTCRI, Bhubaneswar, Odisha	1983	Cassava, sweet potato, aroids and yams
10	Birsa Agricultural University, Kanke, Ranchi, Jharkand	1987	Sweet potato, taro, elephant foot yam and yam bean
11	Indira Gandhi Agricultural University, Kumharwand, Jagdalpur (Baster), Chhattisgarh	1987	Cassava, yams, elephant foot yam and taro
12	Narendra Dev University of Agriculture and Technology, Faizabad, Uttar Pradesh	1987	Sweet potato, taro and elephant foot yam

13	Navsari Agricultural University, Navsari, Gujarat	1994	Cassava, sweet potato, taro and yams
14	Central Island Agricultural Research Institute, Port Blair, Andaman & Nicobar Islands	2000	Cassava, sweet potato, yams and elephant foot yam
15	Central Agricultural University, Iroisemba, Imphal, Manipur	2006	Cassava, sweet potato, aroids and yams
16	Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan	2006	Aroids and sweet potato
17	University of Horticultural Sciences, Dharwad, Karnataka	2007	Sweet potato and aroids
18	Chaudhary Sawan Kumar Himachal Pradesh Krishi Viswavidyalaya, Palampur, Himachal Pradesh	2014	Elephant foot yam and taro
19	Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, Telangana	2015	Sweet potato and taro
20	Regional Station-ICAR Research Complex for NEH Region, Lembucherra, Tripura	2015	Taro and elephant foot yam

Achievements of ICAR-AICRP on Tuber Crops during 2015-2016

The mandate of AICRPTC is generating region-specific value added varieties, agronomic interventions and production system technologies including disease and pest management of tropical tuber crops along with creating awareness among the farming community, policy makers and researchers. The salient achievements made by the centres during 2015-2016 are briefed below:

Collection and conservation of genetic resources

One of the major objectives of ICAR-AICRP on tuber crops is the collection, conservation and evaluation of the genetic stocks of tuber crops from the various agro-climatic zones for manifold purposes ranging from food production to climate change resilience. Constant efforts are therefore, being made to collect the indigenous germplasm of different tuber crops from different agro-climatic zones through coordinating centres. A total of 4574 accessions of different root and tuber crops were being maintained at different field gene banks in various AICRP Tuber Crops centres. Maximum accessions of 12 tuber crops (1324) were maintained at RAU, Dholi. Sweet potato accessions contributed a major share to the total (1926) followed by cassava (601) and taro (574). The centres were maintaining a total of 1094 accessions of taro, 452 accessions of yams, 236 collections of elephant foot yam and 153 accessions of yam bean. IC numbers were obtained for a total of 1574 germplasm collections at different centres. UHS, Dharwad collected 30 genotypes of minor tuber crops from northern dry belts and central coastal belts of Karnataka. Seventy six genotypes of taro were characterized and duplicates were found by DNA fingerprinting at BCKV, Kalyani.

Testing of genetic resources at various agro-climatic environments

Pooled data analysis of IET on K-efficient cassava lines for the last two years indicated that TCa 14-6 was superior at Yethapur, TCa 14-8 at VR Gudem (47.40 t ha^{-1}) and TCa 14-5 at Thiruvananthapuram. Under URT on cassava for culinary uses, TCa 13-1 produced maximum tuber yield (25.74 t ha^{-1}) at Imphal, TCa 13-7 at Jagdalpur (40.23 tha^{-1}) and TCa 13-3 at Thiruvananthapuram. Pooled data analysis of URT on short-duration cassava lines indicated the superiority of TCa 12-9 (46.50 t ha^{-1}) at VR Gudem, TCa 12-6 at Yethapur and TCa 12-5 at Thiruvananthapuram. Pooled data analysis of MLT on Cassava Mosaic Resistant entries showed that TCMS–7 was performing well at Dapoli and TCMS-7 and TCMS-5 at VR Gudem and TCMS – 2 at Thiruvananthapuram.

URT on sweet potato : Field view

Among the sweet potato entries evaluated in URT for weevil resistance, TSp 12-3, performed well coupled with less weevil infestation at Bhubaneswar (19.39 t ha^{-1}). At Dholi and Kalyani, TSp 12-6 produced highest marketable tuber yield and TSp 12-4 at Rajendranagar. Under URT on sweet potato, maximum tuber yield was obtained from TSp 12-10 at Kalyani (28.64 t ha^{-1}) and TSp 12-8 at Barapani. Under MLT in orange-fleshed sweet potato entries, maximum marketable tuber yield was obtained from Gouri over the years at Dharwad and Udaipur and 440127 at Navsari.

TTr12-5 was found superior in yield under URT on taro at Kalyani. The entry TTr12-2 produced maximum yield at Ranchi and TTr12- 8 at Dholi and Port Blair. The evaluation of taro against *Phytophthora* blight indicated that TCbl 12-3 and TCbl 12-4, TCbl 12-2 and TC bl 12-6 were promising against blight disease at Kalyani. The entries viz., TCbl 12-4, TCbl 12-6 and TCbl 12-7 showed lower level of disease incidence at Dholi. At Rajendranagar, TCbl 12-4 had minimum blight incidence and TCbl 12-7 at Dapoli. Under MLT on bunda, IGB-5 produced maximum yield at Jagdalpur and BCB-2 at Kalyani, based on pooled data analysis and were recommended for release in the states of Chhattisgarh and West Bengal respectively.

Under IET on greater yam, TGy 14-11 produced maximum yield at Dapoli (21.17 t ha^{-1}) and Kovvur, TGy 14-1 at Udaipur, TGy 14-9 at Jagdalpur, TGy 14-6 at Imphal, TGy 14-7 at Thiruvananthapuram and TGy 14-8 at Jorhat. Under URT, highest tuber yield was obtained in the entry TGy 12-3 at Kovvur, Bhubaneswar and at Thiruvananthapuram. The entry TGy 12-6 performed better at Jagdalpur. Under MLT, IGDa-2 gave highest yield at Jagdalpur (26.56 t ha^{-1}) and Navsari (17.14 t ha^{-1}).

In the first year of IET on swamp taro, the highest stolon yield was recorded in BCST-1 (20.10 t ha^{-1}) at Kalyani, BCST-13 at Jorhat and CAUST-1 at Imphal. Maximum number of aerial tubers per plant was noticed in the entry TDb 13-10 (21.66) at Jagdalpur, TDb 13-5 at Ranchi and TDb 13-1 at Dapoli under URT on aerial yam. Among the eight entries, TTn 14-6 performed well and produced maximum tuber yield (22.96 t ha^{-1}) at Rajendranagar and Thiruvananthapuram, TTn 14-5 at Jorhat and TTn 14-8 at Imphal. At Kalyani and Jagdalpur, TTn 14-5 performed better. In the second year of IET on yam bean, TYb 14-8 was superior at Bhubaneswar, TYb 14-7 at Dholi and TYb 14-5 at Kalyani.

Agro-techniques

Phenology studies were conducted in cassava, sweet potato, elephant foot yam, taro and greater yam at the different AICRP centres located in different agro-climatic zones. Observations recorded over the past three years were used to validate the cassava, sweet potato and elephant foot yam simulation models developed at ICAR-CTCRI, for giving agro-advisory to the farmers of the respective states.

The farming system studies involving tuber crops introduced in Gumagada (village), Chakapada (Block), Kandhamal (District), Odisha state resulted by 1303.20 kg of rice equivalent yield, net return of Rs 25,650/0.4 ha, B:C ratio of 2.91 and additional employment of 20 man days. Traditional rice cultivation alone produced 520 kg of rice, net return of Rs 6,600/0.4 ha and B:C ratio of 1.73. The gross income and net income increased at both the locations (Gumiyapal-Bastar and Tatirsh-Kondagaon districts, Chhattisgarh) after intervention of different components under tuber crops based farming system models from the year 2012-2013 to 2015-2016. Average B: C ratio increased from 1.87 to 3.36. The model developed has the potential to transform the tribal regions of Chhattisgarh, especially the Bastar and Kondabaon districts. The total income generated from the tuber crops based farming system at Harminder Bay ranged from Rs. 28180.00 to Rs. 95920.00. With the intervention of tuber crops based farming system, the employment generation among the tribals increased to 101 days/year and the net income increased to Rs 33,193 per annum as compared to their traditional system. With the success of intervention made, more tribal youths have come forward to adopt the tuber crops based farming system as their livelihood options.

Demonstration of tuber crops based farming system at Harminder Bay

Studies on micronutrient management conducted in cassava indicated positive response in terms of tuber yield with the application of micronutrients. Tuber yield was maximum with POP + $MgSO_4$ + $ZnSO_4$ + Borax + $FeSO_4$ at Yethapur, Kalyani, Dapoli and VR Gudem. In sweet potato, application of micronutrients, (Mg, B, Zn) resulted in more tuber yield at Rajendranagar, Kalyani, Ranchi and Dholi.

Greater yam + maize (1:3) additive intercropping was found to be beneficial with more yam equivalent yield

and B:C ratio, hence growing of maize as intercrop in greater yam for staking purpose will be profitable than growing of yams by staking with bamboo poles.

Pests and disease management

For integrated mangement of sweet potato weevil, the lowest vine infestation at collar region, minimum tuber infestation and maximum marketable tuber yield was obtained due to dipping the planting material in 0.02% chlorpyriphos (20 EC) for 10 min, earthing up along with weeding and fertilizer application, spraying 0.02% of chlorpyriphos (20 EC) at 30 and 60 DAP, spraying *Nanma* at 45 and 75 DAP and timely harvest.

Soil application and tuber treatment with *Trichoderma* and carbendazim spray (1%) was found effective in reducing the anthracnose incidence in greater yam and increasing the tuber yield at all the centres.

Planting material production

Planting materials of improved varieties of tuber crops were multiplied and distributed by all the centres. Kovvur centre produced 6 t of elephant foot yam, 1 t yams and 1.5 t of taro, which were made available to farmers and other agencies. ICAR-CTCRI, Regional Centre produced and distributed 20 t elephant foot yam, 10 t yams and 2 t of taro seed materials.

Tuber Food Fest-2015: Shri. K. P. Mohanan, Hon'ble Minister for Agriculture, Shri. Adoor Prakash, Hon'ble Minister for Revenue and Shri. Anoop Jacob, Hon'ble Minister for Food & Civil Supplies, Govt. of Kerala, at the stall of AICRP centre, CAU, Manipur

Dr. N.K. Krishna Kumar, Hon'ble, DDG (Hort.) addressing the 15th AGM of AICRP (TC) chaired by Dr. B.M.C. Reddy Hob'ble Vice Chancellor, held during 24-25 April 2015 at Venakataramannagudem, Andhra Pradesh

Research-extension-farmers-linkage

The centres were regularly involved in organizing training programmes, conducting demonstrations, participating in exhibitions, radio and television programmes. ICAR Research Complex for NEH Region, Manipur Centre, organized "Village level Incubation Centre for Tuber Crops" at Riha Village of Ukhrul on 17 February 2016 in collaboration with ICAR-CTCRI, Thiruvananthapuram, Kerala. Scientists of Dholi centre participated in farmers training cum Kisan Gosthi held in different blocks of Bettiah districts under "Krishi Vigyanik Apke Gaon Me" held during 13 May 2015 to 11 August 2015 and tried to solve the queries related to tuber crops and other crops. ICAR-CIARI organized two days "Kisan Ghosti on tuber crops" at Harminder Bay from 28 – 29 October 2015. Altogether 42 tribal farmers, including 22 female and 20 male participants attended the Kisan Ghosti.

AICRP centres from 19 states participated in the 'Tuber Food Fest', tuber crops food festival-2015 organized by ICAR-CTCRI, Thiruvananthapuram during 24-25 November 2015 along with two tribal farmers of their respective states and displayed ethnic food preparations from tuber crops.

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Institute Publications

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42nd IRC Salient Achievements, ICAR-CTCRI, 2015-2016.

41st IRC Proceedings and Activity Milestones, ICAR-CTCRI, 2014-2015.

Annual Report of AICRP on Tuber Crops, 2015-2016.

Technical Report of 15th Annual Group Meeting of AICRP TC held at Dr. YSRHU, VR Gudem, Andhra Pradesh.

Proceedings of 15th Annual Group Meeting of AICRP TC held at Dr. YSRHU, VR Gudem, Andhra Pradesh.

Proceedings of Midterm Review Meeting of AICRP TC, 2015, held at ICAR-CTCRI, Thiruvananthapuram.

Radio Talks

James George. 2016. Live phone in program at AIR, Thiruvananthapuram on 26 February 2016, 11 am-12 noon on the 'Role of Tuber Crops for Food, Feed and Industrial Purpose'.

Susan John, K. 2015. Participated as expert in the panel discussion on 'To Save the Poison Fed Kerala' at AIR, Thiruvananthapuram on 18 May 2015 broadcast on 25 May 2015.

Susan John, K. 2015. A five minutes talk on 'Annam Muttunna Karshakanu Aadaravode' at AIR, Thiruvananthapuram on Chingam 1, 1191 (Karshakadinam) on the need to promote balanced nutrient management and soil health.

Susan John, K. 2015. Live phone in program (Harithum) at AIR, Thiruvananthapuram on 11 December 2015, 11 am-12 noon on 'Soil Testing and Soil Test Based Nutrient Management'

Susan John, K. 2015. A small talk for a documentary titled 'Mrinmaya' of AIR recorded on 11 December 2015.

Susan John, K. 2016. Participated as guest in the Gramapoornima program under Radio gramarangam in AIR on 23 March 2016 which was broadcast on 2 April 2016.

Ongoing Projects

Institute projects

Sl.No.	Project code	Project title	PI	C0-PIs
1	HORTICARCTCRI SIL 201500101457	Conservation and utilization of germplasm of tuber crops for sustaining production	M. N. Sheela	Archana Mukherjee , K. I. Asha, A. Asha Devi ,KalidasPati, N. Krishna Radhika, T.Makeshkumar,Rajasekhara Rao Korada,Saravanan Raju,ShirlyRaichal Anil, P. S. Sivakumar, J. Sreekumar, C. Mohan, M.L. Jeeva, A. N. Jyothi, S. S. Veena
2	HORTICARCTCRI SIL 201500101458	Genetic improvement of tuber crops through conventional breeding and molecular approaches	Archana Mukherjee	K. I. Asha, A. Asha Devi , S. K. Chakrabarti, M. L. Jeeva, A. N. Jyothi , KalidasPati , N. Krishna Radhika, K. Laxminarayana, T. Makeshkumar, C. Mohan, M. Nedunchezhiyan, Rajsekhara Rao Korada, R. C. Ray, V. Ravi, Saravanan Raju, M. N. Sheela, J. Sreekumar, Shirly Raichal Anil, G. Suja, S. Sunitha, S. S. Veena
3	HORTICARCTCRISIL 201500301459	Integrated crop, water and nutrient management for improving productivity of tropical tuber crops	G. Byju	Archana Mukherjee, A. Asha Devi, James George, K. Laxminarayana, T.Makeshkumar, R. Muthuraj, M. Nedunchezhiyan, V. Ramesh, V. Ravi, V.S.Santhosh Mithra, Saravanan Raju, M. N. Sheela, J. T. Sheriff, ShirlyRaichal Anil, J. Sreekumar, G. Suja, S. Sunitha, K. Susan John, S.S. Veena
4	HORTICARCTCRISIL 2015 004 01460	Studies on impact of climate change and devising mitigation and adaptation strategies for sustaining productivity of tuber crops	V. Ravi	G. Byju, K.L. Laxminarayana, V. Ramesh, V. Ravi, M. Sankaran,V.S.Santhosh Mithra, Saravanan Raju, M.N. Sheela, G.Suja
5	HORT CTCRI SIL 2015 005 01461	Eco-friendly strategy for the management of insect pests in tuber crops	C. A. Jayaprakas	Rajasekhara Rao Korada, Kalidas Pati

6	HORT CTCRI SIL 2015 006 01462	Development and refinement of integrated disease management and forecasting system for improved tuber crop production	M. L. Jeeva	K. I. Asha , G. Byju , S. K. Chakrabarti, A. N. Jyothi , T. Makeshkumar, R. S. Misra M. Nedunchezhiyan, V. Santhosh Mithra, J. Sreekumar, S. S. Veena
7	HORTICARCTCRISIL 201500701463	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	J. T. Sheriff	A. N. Jyothi Namrata Ankush Giri, M.S. Sajeev, Saravanan Raju, M. N. Sheela, G. Suja
8	HORTICARCTCRI CIL 201500801464	Improving knowledge and skill of stakeholders for sustainable production of tuber crops	Sheela Immanuel	G. Byju , C. A. Jayaprakas, A.N. Jyothi, Namrata Ankush Giri, C. Mohan , M. Nedunchezhiyan , S. Ramanathan , V. S. Santhosh Mithra, P. Sethuraman Sivakumar, M. N. Sheela, P. Shinoj J. Sreekumar, G. Suja
9	HORTICARCTCRI SIL 201500901465	Cassava mosaic disease-variability, diagnostics, vector relation and management	T.Makeshkumar	S. K. Chakrabarti, E.R.Harish, C. A. Jayaprakas, M.L.Jeeva, C. Mohan, R. Muthuraj, M.N.Sheela, K. Susan John, S. Sunitha, J. Sreekumar
10	HORTICARCTCRI SIL 201501001466	Development of cassava starch based novel products and functional foods from other tuber crops	M. S. Sajeev	Archana Mukherjee, A.N. Jyothi, Namrata Ankush Giri, M. Nedunchezhiyan, R .C. Ray M. S. Sajeev, J.T.Sheriff, P. Sethuraman Sivakumar, K. Susan John

Externally aided projects

Sl. No	Title	PI	Co-PIs	Funding agency
1	Consortium research project (CRP) on agrobiodiversity	M. N. Sheela	K. I. Asha, A. Asha Devi, Shirly Raichal Anil, N. Krishna Radhika, Vivek Hegde	ICAR
2	Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro	Archana Mukherjee	J. Tarafdar, Kalidas Pati	PPV& FRA, New Delhi
3	Establishment of varietal gene bank and development of standards of DUS testing in yam bean (*Pachyrrhizus erosus*) and greater yam (*Dioscorea alata*)	Archana Mukherjee	P.P.Singh, M.N. Sheela, Kalidas Pati, M. Nedunchezhiyan	PPV & FRA, New Delhi
4	Adapting clonally propagated crops to climatic and commercial changes	Archana Mukherjee	J. Sreekumar	European Union
5	Development of tuber crops	James George	S. Sunitha, R. Muthuraj, M. N. Sheela, T. Makeshkumar, M.S Sajeev	Department of Agriculture, Govt. of Kerala
6	Network on organic farming in horticulture crops (NOFH)	G. Suja	S. Sunitha, V. Ramesh, A. N. Jyothi, P. Subramanian	ICAR- Indian Institute of Spices Research
7	Network project on organic farming (NPOF)	G. Suja	G. Byju, S. Sunitha, S.S. Veena, A. N. Jyothi M. N. Sheela	ICAR-Indian Institute of Farming Systems Research, Modipuram
8	Enhancing the economic viability of coconut based cropping systems for land use planning in Kerala state	K. Susan John	S. Sunitha, S.S. Veena	Kerala State Planning Board
9	Assessment of soil fertility and preparation of soil fertility maps for various agro-ecosystems of Odisha	K. Laxminarayana	M. Madhumita Das (ICAR-IIWM, Bhubaneswar)	Directorate of Horticulture, Govt. of Odisha under Rashtriya Krishi Vikas Yojana

10	Participatory technology transfer of cassava based biopesticides for the management of vegetable pests	C.A. Jayaprakas	C.K. Peethambaran CISSA, S. Leena, KVK, ICAR-CPCRI, Kasaragod	Department of Agriculture, Govt.of Kerala
11	Outreach programme on the management of sucking pests	C.A. Jayaprakas	-	ICAR
12	CRP on borers	Rajasekhara Rao Korada	C. A. Jayaprakas	ICAR
13	PhytoFuRa: Leaf blight of taro	M. L. Jeeva	R. S. Misra, S. S. Veena	ICAR network (IISR outreach project)
14	Indo – Swiss cassava network	T. Makeshkumar M. N.Sheela	-	Indo-Swiss collaboration on Biotechnology (ISCB)-DBT, Govt. of India
15	Disease diagnostics in tropical tuber crops	T. Makeshkumar	M. L.Jeeva, R.Muthuraj, K.I. Asha	ICAR-CRP on Vaccines and Diagnostics
16	Refinement of starch indicator developed by CTCRI and design of next generation gadget for measuring starch content of cassava (*Manihot esculenta* Crantz) tubers	J. T. Sheriff	M. S. Sajeev, G.Padmaja	Department of Science and Technology
17	Improving the livelihoods of smallholder cassava farmers through better access to growth markets (Cassava Gmarkets)	J. T. Sheriff	M.S .Sajeev, A.N. Jyothi, V. Ravi	European Commission-Food Security Thematic Programme (FSTP) Component 1 – Research and Technology
18	Consultancy project on integration of sweet potato production and processing in Belgaum	J. T. Sheriff	S. Ramanathan, M.S .Sajeev, A.N.Jyothi, P. Sethuraman Sivakumar, Namrata Ankush Giri	M/S Belgaum Minerals, Belgaum
19	ICAR-EMR project on establishment of mechanized cassava and sweet potato model farms	J. T. Sheriff	M. S. Sajeev, G. Suja	ICAR
20	Techno-Incubation centre	M.S.Sajeev	J. T.Sheriff A. N.Jyothi Namrata Ankush Giri	SFAC, Govt. of Kerala

21	ICAR Network project on high value compounds/ phytochemicals	A.N. Jyothi	J. Sreekumar, Shirly Raichal Anil	ICAR Network Project
22	Development and evaluation of starch based functional polymers for controlled plant nutrient delivery	A.N. Jyothi	M. S. Sajeev, K. K. Susan John	Kerala State Council for Science, Technology and Environment, Govt. of Kerala
23	XII th Plan IP & TM Scheme National Agricultural Innovation Foundation (NAIF)	P. Sethuraman Sivakumar	V. Ravi, M. S. Sajeev, M. L. Jeeva, V. S. Santhosh Mithra R. Bharathan	NAIF-ICAR
24	Tribal sub plan	M. Nedunchezhiyan	Archana Mukherji, R. C. Ray, K. Laxminarayana, K. Rajasekhara Rao Korada, Kalidas Pati, S. Ramanathan, J.T.Sheriff, M.S.Sajeev, ORRISSA (NGO), Kandhamal, PRAGATI (NGO), Koraput, SOVA (NGO) Ramakrishna Mission, Ranchi, Jharkhand, Ramakrishna Mission, Naranyanpur, Chhattisgarh	ICAR
25	Establishment of techno-incubation centre at the ICAR-Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar, for the commercialization of value added products from sweet potato and other tuber crops	M. Nedunchezhiyan	R.C.Ray, M.S.Sajeev	Rashtriya Krishi Vikas Yojana

Institute Research Council, Research Advisory Committee, Institute Management Committee

Institute Research Council

The 42nd Annual Institute Research Council

The 41st Annual Institute Research Council meeting of ICAR-CTCRI was held during 30 March to 1 April 2015 under the chairmanship of Dr. S. K. Chakrabarti, Director, ICAR-CTCRI. All the scientists from head quarters as well as Regional Centre attended the meeting. Dr. M. L. Jeeva, Secretary, IRC, welcomed the chairman and all the scientists, especially the new members, Dr. Sheela Immanuel, Dr. R. Muthuraj and Dr. Namrata Ankush Giri. She congratulated the awardees, Dr. G. Padmaja and her team for the ICAR team research award, Dr. S. K Chakrabarti for bagging Dr. S. Ramanujam award and Dr. L. C. Sikka Endowment award of NAAS, Dr. K. Susan John for IPI-FAI award, Dr. R. C. Ray for Samanthchakra award and Dr. T. Makeshkumar, Dr. R. Muthuraj and Dr. Rajasekhara Rao Korada for fellow/poster awards in different fora.

The Director mentioned that 2014-2015 was a glorious year for the institute that brought several prestigious awards and laurels. He congratulated and thanked all the staff of our institute for successful conduct of ICAR group meeting and cassava G-Market annual meeting. He talked about the QRT recommendations and stated that the approved recommendations of the QRT would be the road map for the next five years of our research. He also mentioned about the constitution of new RAC committee and their intensive review and recommendations. He urged all the scientists of the institute to include the recommendations of QRT and RAC in the projects. He referred to the achievements of each division especially, the germplasm collection from new areas like Joida in Uttarkannada, Belgaum and unexplored areas in Arunachal Pradesh and Meghalaya under Crop Improvement. He also appreciated sustainable technologies like weed control ground cover, organic farming, SSNM, drip fertigation etc. developed by the Division of Crop Production. The kairomones, volatile and resistant varieties against sweet potato weevil in Crop Protection; low- moist gelatinized dough for cassava pappad through contract research and field testing of super absorbent polymer in Crop Utilisation; Popularisation of cassava var. Sree Athulya, work under NEH and TSP under Social Sciences and Extension were also specified by him. He also informed that as per the instruction from the council all the ongoing projects will be closed, revised and formulated into eight new projects along with two flagship projects with the suggested titles.

There were six sessions, which covered division wise presentation of progress of the ongoing institute projects and new project proposals. Each session was led by the head with briefing of overall achievements followed by presentation of progress in each activity by the activity leaders. The document on salient achievements 2014-2015 was distributed to all the members of IRC. In total, the progress of 17 projects with 51 activities were discussed and 10 new projects were proposed and presented by the respective PIs. The IRC members appreciated and honored Dr. M. Anantharaman and Dr. R. S. Misra, who will superannuate during 2015, for their outstanding contribution in research, technology transfer and other institutional activities at ICAR-CTCRI. The decisions taken and the activity milestones of new projects for 2015-2016 have been documented.

The 42nd Annual Institute Research Council

The 42nd Annual Institute Research Council meeting of ICAR-CTCRI was held during 29-30 March 2016 under the chairmanship of Dr. James George, Director (Acting). All the scientists from Head quarters and Regional Centre attended the meeting. Dr. M. L. Jeeva, Member Secretary, IRC welcomed the chairman

and all the scientists especially new scientists, Dr. H. Kesava Kumar, Shri. K. Hanume Gowda, Ms. Pradeepika Chintha, Ms. B. G. Sangeetha, Ms. Sirisha Tadigiri, Shri. Venkataraman V Bansode, Shri. Vijay Bahadur Singh Chauhan, Dr. Visalakshi Chandra and Dr. Vivek Hegde. She thanked the Director for chairing the pre IRC meetings conducted during 8 to 10 March 2016 and the discussions made for the first time with the scientists of RC through video conferencing. She congratulated Dr. S. K. Chakrabarti, former Director, ICAR-CTCRI who has joined ICAR-CPRI as the Director in January, 2016 and expressed gratefulness for his support and contributions in research and conduct of IRC meetings for the last four years. She also congratulated him for obtaining NAS fellowship, Dr. C. A. Jayaprakas for the Best Scientist Award instituted by Kerala Farm Journalist Forum and Dr. V. B. S. Chauhan for the Best Poster Award.

The Director in his introductory remarks, welcomed all the scientists and congratulated the scientists for the excellent research work carried out and the technologies developed. He also pointed out that the gaps in important problems have to be addressed/ improved for which innovativeness is needed. He asked to initiate work on pollen culture, relook into POP, transfer of protection technologies to the field and development of products from underutilised tropical tuber crops. He also insisted the need to address the cassava mosaic disease and sweet potato weevil, which are the two major persisting problems.

Dr. M. L. Jeeva, Secretary, IRC, presented the 41st IRC recommendations and action taken, which was followed by the presentation of RAC recommendations by Dr. G. Suja, Member Secretary, RAC. There were totally 10 ongoing institute projects, which were presented by the PIs, which covered 56 activities under four Divisions viz., Crop Improvement, Crop Production, Crop Protection, Crop Utilisation and Extension and Social Sciences. The activities are being given the status of project by the PME for assessment purpose. The Heads of Divisions presented the overall achievements of their Division. Thirteen new activities were presented by the respective activity leaders. All the projects were thoroughly discussed and the suggestions have been recorded and documented in the proceedings. During the plenary session, the Director, in his concluding remarks expressed happiness about the successful conduct of the 42nd IRC and appreciated the young scientists who have presented the new activities. He also appreciated the work of Dr. S. Ramanathan, Head, Section of Extension and Social Sciences, who will be superannuating in June 2016, for his work and contributions made in extension and transfer of technology, especially in the north-eastern states and Odisha. Director also appreciated the role played by Dr. M. L. Jeeva as Member Secreatry, IRC during the past five years, very efficiently conducting the IRC

42nd Annual Institute Research Council

and documenting the proceedings. Dr. Saravanan Raju has been nominated as the new Member Secretary of IRC

Research Advisory Committee

The second meeting of RAC VII was held during 2-3 March 2016 in the Millennium Hall, ICAR-CTCRI. Dr. P. Rethinam, Former ADG, ICAR, chaired the meeting. The following members were present:

Dr. Umesh Srivastava, Former ADG, Hort. Sci., ICAR

Dr. P.S. Naik, Former Director, ICAR-IIVR

Dr. V.G. Malathi, Adjunct Faculty & Emeritus Scientist, TNAU

Dr. Srinivasa Murthy, Principal Scientist, ICAR-IIHR

Dr. Saiprasad G.V.S. Lead Scientist, Agriscience, ITC Limited, Bengaluru

Shri. Salim P. Mathew (IMC Rep.)

Dr. James George, Director (Acting), ICAR-CTCRI

Dr. G. Suja, Principal Scientist, ICAR-CTCRI (Member Secretary)

The meeting commenced at 11.00 am after a field visit by the chairman and members.

Dr. G. Suja, Member Secretary, RAC, welcomed the Chairman and members of RAC and all the Scientists. Dr. James George, Director (Acting), ICAR-CTCRI gave a brief account of ICAR-CTCRI, summing up significant research achievements, technologies developed and commercialized, publications, infrastructure developed, equipment procured, planting material production, field level demonstrations/OFTs conducted and the priorities for research as indicated in vision 2050 and QRT report 2014. Dr. James George, Project Co-ordinator, AICRP on tuber crops also briefed about the activities and achievements of AICRP on tuber crops.

Members of RAC gave their preliminary observations. Dr. P. Rethinam, Chairman, in his opening remarks indicated that food security in the context of climate change is one of the major challenges faced by humanity. Tropical tuber crops hold great promise in this regard as food security crops and they also contribute immensely to nutritional and livelihood security. The significance of tuber crops as health foods needs to be emphasized. Proper labeling of value added products with the nutrient contents would attract the consumers in both urban and rural areas. The Techno-Incubation Centre of ICAR-CTCRI and the Tuber Food Fest 2015 organized with an array of food products from all over the country were well appreciated by the chairman and members. The highlights of the suggestions in the opening remarks are:

- Cassava Mosaic Disease and Sweet Potato Weevil are the two important long lasting problems, which need more intensified research efforts particularly in identifying more resistant varieties.
- Tuber crops based cropping/farming systems should be popularized in tuber crop growing areas and more particularly in Lakshadweep islands.
- Basic research should be taken up and attempts should be made to control viruses using bioagents/ biopesticides.
- Documentation of germplasm is a priority item and passport data should be made available online. Available germplasm after evaluation should be grouped for various important aspects like high yield, resistance to pests and diseases, quality aspects, drought tolerance etc.,
- Greater emphasis for popularization of tuber crops based health foods by blending with other flours of multi-grains (2-3 pulses, minor millets etc.) is needed.
- Efforts for branding of tapioca chips to be made. The problems in year round chip making to be identified and off-season availability and storage of raw materials to be ensured.
- A Pilot Project Incubation Centre with machineries set up at subsidized rate by Govt. of

India may be started in various important tuber crop growing regions of the country.

- Tuber Food Fest conducted last year received good response and it should be organized in different metro cities of the country and documentation of the recipes of the various food items may be done.
- Greater thrust may be given to mechanization in the cultivation, harvest and processing in view of the labour shortage.
- Efforts to be strengthened to popularize the technologies developed by the institute among the farming community.

The action taken report of the first meeting of RAC VII was presented by the Member Secretary, which was discussed and approved. The project leaders presented the salient achievements of 10 ongoing institute projects and 21 external funded projects and highlighted the future thrusts. Based on the presentations and discussions as well as effective interaction of RAC members, the following recommendations were made for consideration and implementation:

RAC chairman and members visiting the field (left) and techno-incubation centre (right)

Recommendations

Crop Improvement

- Systematic and comprehensive characterization, documentation and utilization of the germplasm for identification of donors for different traits of interest in various tuber crops should be done. Thereafter it may be used for development of mapping population for different traits of interest for marker development. The crop improvement programme should be carried out in future by marker assisted breeding for reducing breeding cycles and also in pyramiding multiple targeted traits.
- Entire germplasm of tuber crops may be evaluated in a phased manner for priority traits at suitable locations. About 200-300 accessions may be evaluated simultaneously at different locations for a period of two years to identify promising accessions. A schedule for such scheme may be developed and work initiated. Meanwhile all available information may be catalogued. More areas for specific traits such as drought and salinity tolerance may be identified and collections made.

Crop Production

- Organic farming technology for tuber crops based cropping systems may be developed. Good Agricultural Practices (GAP) on organic farming (including both production and protection

aspects) of tuber crops may be brought out. In organic farming experiment, earthworms may be introduced *in situ* along with the other organic practices.

- Studies on adaptation to climate change may be intensified. All experiments may be conducted under proper environmental conditions.

RAC meeting in progress (left) and Dr. P. Rethinam, RAC chairman being greeted

Crop Protection

- Studies on nematode management in tuber crops (especially elephant foot yam and white yam) including the use of biopesticides may be given top priority. Use of cassava based biopesticides for the control of other pests/diseases in tuber crops has to be documented. The results of the use of cassava based biopesticides on different crops have to be compiled and presented in the next RAC.
- Pheromone technology popularized in Odisha against sweet potato weevil should be tested on a large scale at ICAR-CTCRI. All data on *Menma* biopesticide from KVKs, ICAR institutes etc., for the management of pests and diseases on different crops may be compiled. Enrichment of *Menma* and testing for a wider spectrum biopesticide may be given importance. The nematode problem recently causing anxiety should be dealt with on priority basis. Detailed studies may be conducted on the effect of *Menma* on nematodes and sweet potato weevil.

Crop Utilization

- Multi-grains including pulses and millets may be blended in various tuber crops based health foods. Proper labelling of the products with information on bioassays, health claims and ingredients used for the health claim should be done. Packing may be done in smaller consumer preferred packets.

Extension and Social Sciences

- ICT tools developed under different institute programmes may be combined into crop based platform under E-solutions. A suitable alternate name may be given to E-Crop. Hand-held Variety Identifier for tuber crops may be developed before next RAC.

General

- The entire research done on important aspects of tuber crops in different disciplines since the inception of CTCRI may be compiled for understanding what has been done so far, which will help for future research planning. The Director may form different teams for this purpose and complete on a mission mode approach.
- Attempts may be made to incorporate the different plant protection strategies (chemical, organic, biological) and develop holistic integrated plant protection schedule for each tuber crop.

- The Technical Bulletins on Released Varieties of Tuber Crops, Cassava Mosaic Disease and Sweet Potato Weevil may be brought out. Available data on area, production and productivity of various tuber crops over years may be compiled and documented as a Technical Bulletin.
- Cassava mosaic virus and sweet potato weevil are the two most important problems in tuber crops. It is suggested that CTCRI may hold one day Brain Storming Session on each of these problems. In this Brain Storming Meeting, experts from different organizations may be invited for their valuable inputs.
- Current effort of pyramiding cassava mosaic disease (CMD) genes, CMD 1 and CMD 2 gene in achieving resistance to CMD may continue.
- Location-specific genetic stocks may be registered under geographical indicators (eg. Dasheen type taro from Joida, Karnataka).
- Cost-benefit analysis of the identified technologies should be worked out.
- Pests and diseases of different tuber crops in farmers' fields are to be monitored to generate data for their management and prediction. It is necessary to precisely identify *Trichoderma* spp. which helps in effective management of collar rot and taro blight.
- Attempts may be made for genome sequencing of truly CMD resistant and susceptible lines and their derivatives showing recovery phenomena.
- Possibility of synthetic seeds using embryoids of CMD resistant lines may be explored.
- Top priority may be given for the isolation of resistance gene for CMD available in resistant genotypes and using it for incorporating resistance. Analysis of data available on diseases (% incidence, resistance/susceptibility, intensity, yield loss) may be done taking all the available data from AICRP and CTCRI reports and other publications for understanding changes in disease scenario in India.
- Feasibility of super absorbent polymer and polymer-coated slow release fertilizers may be studied at the field level comparing them with the products available in the market.
- By-product utilization for high value product development needs to be attempted.
- Efforts may be made to open Technology Parks at some of the important AICRP Centres with the financial support from SHM and RKVY.
- AICRP (Tuber Crops) Centres may be involved, wherever possible, in collection of information at multi location points and particularly for consumer acceptance studies of tuber crops based food products as well as livelihood analysis of tuber crop farmers.
- Socio-economic impact of released varieties and technologies need to be estimated.
- Tuber crops programme introduced successfully last year in the north-east seems to be stand still for want of adequate fund. This may be looked into urgently. Otherwise negative impact will be created.

Institute Management Committee

The XIII Institute Management Committee Meeting of ICAR-CTCRI was held on 31st October 2015 under the Chairmanship of Dr. S.K. Chakrabarti, Director, ICAR-CTCRI, Thiruvananthapuram, in the conference hall and the following Members/ Dignitaries/Officers attended the meeting.

1.	Dr. S.K. Chakrabarti, Director, ICAR-CTCRI, Thiruvananthapuram	Chairman
2.	Shri. R. Ajithkumar, Director of Agriculture, Govt. of Kerala	Member
3.	Dr. V. Krishnakumar, Head, RC of ICAR-CPCRI, Kayamkulam, Kerala	Member
4.	Dr. B.R. Reghunath, College of Agriculture, Vellayani	Member
5.	Dr. P. Sivarama Bhat, Principal Scientist, ICAR-IIHR, Bangalore	Member
6.	Dr. P. Murugesan, Principal Scientist & SIC, IIOPR Regional Station, Palode	Member
7.	Dr. M. Nedunchezhiyan, Principal Scientist, Regional Centre of ICAR-CTCRI, Bhubaneswar	Member
8.	Shri. M. Radhakrishnan, Finance & Accounts Officer, ICAR-IISR, Calicut	Member
9.	Dr. C.A. Jayaprakas, Head, Division of Crop Protection, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
10.	Dr. J.T. Sheriff, Head, Division of Crop Utilization, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
11.	Dr. M.N.Sheela, Head, Division of Crop Improvement, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
12.	Dr. S. Ramanathan, Head, Section of Extension & Social Sciences, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
13.	Dr. V. Ravi, Principal Scientist & SIC (PME), ICAR-CTCRI, Thiruvananthapuram	Special Invitee
14.	Dr. M.S. Sajeev, Principal Scientist & SIC (E&M), ICAR-CTCRI,Thiruvananthapuram	Special Invitee
15.	Dr. J. Sreekumar, Senior Scientist & SIC (Farm), ICAR-CTCRI,Thiruvananthapuram	Special Invitee
16.	Smt. R. Sari Bai, FAO, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
17.	Shri. Davis Joseph, Administrative Officer, ICAR-CTCRI, Thiruvananthapuram	Member Secretary

At the outset, Chairman of the IMC & Director, ICAR-CTCRI, Sreekariyam, Thiruvananthapuram, welcomed all the members. The meeting started with a brief note by the Director narrating about the mandate of the institute and also the research activities being carried out along with the various achievements by the Scientists of the institute, since the last IMC meeting. This was followed by a brief discussion by all the members of the IMC who appreciated the efforts of the institute in fulfilling their mandated activities and wished that the research programs being undertaken by the Scientists at present as well as those to be contemplated in future would address not only the Council's expectations, but also the welfare of the growers of tuber crops in Kerala as well as other parts of India.

The Finance & Accounts Officer presented the Plan BE/RE of 2015-16 and also the Non-Plan RE 2015-2016 and Progressive Expenditure during the financial year 2015-2016.

Then, the Action taken report of the XII IMC Meeting was presented by the Member Secretary which was passed by the house. The Member Secretary presented the agenda items in the house for perusal, discussion and recommendation by the esteemed IMC members. IMC approved the proposed work, purchase of equipments, furniture and fixtures after observing all codal formalities.

Participation of Scientists in Conferences, Meetings, Workshops, Symposia etc. in India

Programme	Particulars of the Programme	Name of the participants
State Level Workshop of the Kerala State Planning Board Project on Enhancing the Economic Viability of Coconut Based Cropping Systems for Land Use Planning in Kerala State	ICAR-Central Plantation Crops Research Institute, Kasaragod, 9 April 2015	Dr. K. Susan John
CIP-IFAD Project Workshop	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 16 April 2015	Dr. S. K. Chakrabarti
36th Annual Convention of Bhubaneswar Chapter of Indian Society of Soil Science	Orissa University of Agriculture and Technology, Bhubaneswar, 17-18 April 2015	Dr. K. Laxminarayana
15th Annual Group Meeting of ICAR-AICRP on Tuber Crops	Dr. YSR Horticultural University, Venkataramana Gudem, Andhra Pradesh, 23-25 April 2015	Dr.S.K.Chakrabarti Dr. James George Dr. S. Sunitha Dr. M. N. Sheela Dr. S. Ramanathan Dr. C. A. Jayaprakas Dr. V. Ravi Dr. R. Muthuraj Dr. M. S. Sajeev Dr. T . Makeshkumar Dr. C. Mohan Dr. J. Sreekumar Dr.V.S. Santhosh Mithra Dr. Shirly Raichal Anil Dr. R.S. Misra Dr. Archana Mukherjee Dr. M. Nedunchezhiyan
Meeting of Principal Investigators of New Centres of Network Project on Organic Farming (NPOF)	ICAR-Indian Institute of Farming Systems Research, Meerut, Modipuram, 24-25 April 2015	Dr. G. Suja
Workshop on RNAi in Crop Improvement	National Research Centre on Plant Biotechnology, New Delhi, 5 May 2015	Dr. T. Makeshkumar
Technology Day 2015	Kelappaji College of Agricultural Engineering and Technology, Kerala Agricultural University, Tavanur, Malappuram, 11 May 2015	Dr. M. S. Sajeev
Workshop on State Level Package of Practices	Kerala Agricultural University, Vellanikkara, Thrissur, 5-6 June 2015	Dr. K. Susan John Dr. G. Suja
International Conference 'ICHAP'	New Delhi, 5-6 June 2015	Dr. Archana Mukherjee
Meeting to fix Guidelines for Safe-to-eat Food	Directorate of Agriculture, Vikas Bhavan, Thiruvananthapuram, 9 June 2015	Dr. G. Suja

Launch Workshop of AICRP on Tuber Crops and Brain Storming Session	Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, 9 June 2015	Dr. M. S.Sajeev
First Meeting of Reconstituted Institute Biosafety Committee Meeting	ICAR-Indian Institute of Spices Research, Calicut, 24 June 2015	Dr. T. Makeshkumar
FSR Project Co-ordination Group Meeting	College of Agriculture, Vellayani, 2 July 2015	Dr. G. Suja
Meeting on Pre kharif Tuber Production Technologies	Nagercoil, Tamil Nadu, 10 July 2015	Dr. C. Mohan Dr. V. Ramesh
Zilla Krushak Sammelan-2015	KVK, ICAR – Central Institute of Freshwater Aquaculture, Bhubaneswar, 20 July 2015	Dr. K. Laxminarayana
Group Meeting on *Phytophthora* Diseases of Horticultural Crops and their Management	RC, ICAR- Central Tuber Crops Research Institute, Bhubaneswar, Odisha, 29 July 2015	Dr. S. K. Chakrabarti Dr. C.A.Jayaprakas Dr. V. Ravi Dr. S.S. Veena Dr. M. L. Jeeva Dr. T. Makeshkumar Dr. Shirly Raichal Anil Ms. N. Krishna Radhika Dr. R. Muthuraj Dr. Sheela Immanuel Dr. R.S.Misra Dr. Archana Mukherjee Dr. M. Nedunchezhiyan Dr. K. Laxminarayana Dr. Rajasekara Rao Korada Dr. K. Pati
Technical Support Group meeting	Directorate of Horticulture, Govt. of Odisha, Bhubaneswar, 4 August 2015	Dr. K. Laxminarayana
Launch Workshop of the Out-reach Programme of the KSPB Coordinated project	ICAR-CARD KVK, Pathanamthitta, 5 August 2015	Dr. K. Susan John
International Conference on Science, Technology and Zero Hunger Challenges	M. S.Swaminathan Research Foundation, Chennai, 8-10 August 2015	Dr. Archana Mukherjee
XXII Zonal Workshop of KVKs	KVK, Ujjain, Madhya Pradesh, 9-11 August 2015	Dr. K. Laxminarayana
X Annual Group Meeting of the Network Project on Organic Farming (NPOF)	Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, 19-21 August 2015	Dr. G. Suja
Meetings on EU aided INEA Taro Project and CIP-IFAD aided "FOODSTART" Project	KAB-II, New Delhi, 24 August 2015	Dr. Archana Mukherjee
Meeting of DUS Task Force Committee	PPV & FRA, NASC Complex, Pusa, New Dehi, 7 September 2015	Dr. Archana Mukherjee

Third International Symposium on *Phytophthora:* taxonomy, Genomics, Pathogenicity, Resistance and Disease Management	ICAR-Indian Institute of Horticultural Research, Bengaluru, 9-12 September 2015	Dr. M.L .Jeeva Dr. S. S .Veena
Launch Meeting of ICAR-CTCRI developed bio-pesticides	Sanghamythri Farmers Forum, Pallichal, Thiruvananthapuram, 15 September 2015	Dr. C. A. Jayaprakas Dr. M. L. Jeeva Dr. S. S. Veena
Mid-term Review Meeting of AICRP on Tuber Crops	ICAR- Central Tuber Crops Research Institute, Thiruvananthapuram, 24-25 September 2015	Dr. Archana Mukherjee Dr. C.A. Jayaprakas Dr. M. L. Jeeva
Annual Project Review Workshop of GAINS (Generating Advances in Incomes and Nutrition through Sweet potato) Project under RKVY	International Potato Center, Bhubaneswar, 25 September 2015	Dr. K. Laxminarayana
National Dialogue on Efficient Nutrient Management for Improving Soil Health	ICAR-Indian Agricultural Research Institute, New Delhi, 28-29 September 2015	Dr. K. Susan John
National Workshop on Effective Management of E- Resources in Research Libraries	ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala, 12-17 October 2015	Mrs. B. S. Deepa
Workshop on Preparation of Road Map for Agricultural Development	ICAR-Central Coastal Agricultural Research Institute, Old Goa, 16 October 2015	Dr.S.K. Chakrabarti
Midterm Review Meeting of ICAR-Regional Committee-II	ICAR-Central Inland Fisheries Research Institute, Kolkata, 19 October 2015	Dr. Archana Mukherjee
Workshop on Potentials and Opportunities of Horticulture in Odisha	Directorate of Horticulture, Govt. of Odisha, Jayadev Bhavan, Bhubaneswar, 30 October 2015	Dr. K. Laxminarayana
Librarians Meet	Vikram Sarabhai Space Centre, Thiruvananthapuram, 18 November 2015	Mrs. B. S. Deepa
Workshop on Strategies for Development of Agriculture and its Allied Sectors of Island Region	ICAR – Central Island Agricultural Research Institute, Port Blair, Andaman & Nicobar Islands, 18 November 2015	Dr. K. Laxminarayana
Leveraging Agriculture for Nutrition in South Asia (LANSA) programme	Bhubaneswar, 20 November 2015	Dr. Archana Mukherjee
Extension Meet -2015	Kerala Agricultural University, Vellayani, 23 November 2015	Dr. P. Sethuraman Sivakumar
India Germany Bilateral Cooperation DUS Workshop	ICAR-Indian Agricultural Research Institute, New Delhi, 23-24 November 2015	Dr. Archana Mukherjee
Review Meeting on Soil Health Card Scheme	Directorate of Agriculture & Food Production, Govt. of Odisha, Bhubaneswar, Odisha, 27 November 2015	Dr. K. Laxminarayana
Workshop on Strengthening Impact Assessment in the CGIAR (SIAC)	International Potato Centre, Bhubaneswar, Odisha, 1 December 2015	Dr. K. Laxminarayana

World Soil Day Celebration	Senat Hall, Kerala University, Thiruvananthapuram, 5 December 2015	Dr. S.K. Chakrabarthi Dr. K. Susan John Dr. H. Kesava Kumar Dr. M. L. Jeeva
World Soil Day Programme	Orissa University of Agriculture & Technology, Bhubaneswar, 5 December 2015	Dr. R.C. Ray Dr. K. Laxminarayana
National Seminar on Developments in Soil Science – 2015	University of Agricultural Sciences, GKVK, Bangalore, Karnataka, 5 - 8 December 2015	Dr. K. Laxminarayana
National Symposium organized by the Gregor Mendel Foundation	Malabar Botanical Garden and Institute for Plant Sciences, Calicut, 7 December 2015	Dr. C. A. Jayaprakas
International Symposium on Biodiversity, Agriculture, Environment and Forestry	Udhagamandalam (Ooty), 11-12 December 2015	Ms. N. Krishna Radhika
Meeting of Sensitization Programme on Biodiversity Act, 2002 and Rules for Scientists and Academicians	Bhubaneswar, Odisha, 19 December 2015	Dr. Archana Mukherjee Dr. Kalidas Pati
17th All India Congress on Cytology and Genomics (AICCG)	CSIR-Indian Institute of Chemical Biology, Kolkata, 22 December 2015	Dr. S. K. Chakrabarti
Karshika Mela Seminar	Gandhiji Study Centre, Newman College Ground, Thodupuzha, Kerala, 27-30 December 2015	Dr. James George Dr. G. Byju Dr. K. Susan John Dr. G. Suja
Technical Support Group meeting	Centre of Excellence, Mendasal, Directorate of Horticulture, Govt. of Odisha, 6 January 2016	Dr. K. Laxminarayana
Technical Group Meetings of Agri-Hort Departments of Govt. of Odisha	Directorate of Horticulture, Govt. of Odisha, January-March, 2016 at periodic intervals	Dr. Archana Mukherjee
Organic Agriculture Summit	Adlux International Convention Centre, Angamali, Kerala, organized by ATMA SAMETI, 8 January 2016	Dr. G. Suja
International Conference on Kerala Studies	St. Josephs Higher Secondary School, Thiruvananthapuram, 9 January 2016	Dr. G. Suja
National Symposium on Innovations in Coastal Agriculture – Current Status and Potential under Changing Environment	ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha, 14-17 January 2016	Dr. K. Laxminarayana
11th National Symposium of Indian Society of Coastal Agricultural Research (ISCAR)	Bhubaneswar, 15 January 2016	Dr. C. A. Jayaprakas
Scientist-Farmer Interface	Kollam, Kerala, 20 January 2016	Dr. K. Susan John
Farmer's Meeting on Bio-pesticides	Nagercoil, Tamil Nadu, 22 January 2016	Dr. C. A. Jayaprakas Dr. C. Mohan Dr. V. Ramesh

Kandhamal Sita Mahotsav	Kandhamal, Phulbani, Odisha, 22-24 January 2016	Dr. K. Laxminarayana
4th ICAR Institutes-SAU-State Departments Interface Meet 2015-16	Orissa University of Agriculture & Technology, Bhubaneswar, Odisha, 27-28 January, 2016	Dr. K. Laxminarayana Dr. Kalidas Pati
Annual Review Workshop of NABARD Regional Office	Bhubaneswar, Odisha, 28 January 2016	Dr. K. Laxminarayana
28th Kerala Science Congress	Kozhikode, Kerala, 28-30 January 2016	Dr. V. S. Santhosh Mithra
Machinery Expo 2016	Angamali, Kochi, Kerala, 28-30 January 2016	Dr. M. S.Sajeev
Brain Storming on Gender sensitization on Agro-Innovation	ICAR-Central Institute for Women in Agriculture, Bhubaneswar, 7 February 2016	Dr. Archana Mukherjee
National Seminar on Horticultural Diversity	Orissa University of Agriculture and Technology, Bhubaneswar, 7-8 February 2016	Dr. Archana Mukherjee
HortIP2016: South Horticulture ZTMC Annual Review Meeting 2015	ICAR-IIHR, Bengaluru, 8 February 2016	Dr. P. Sethuraman Sivakumar
Farmers Meet and Demonstration of CTCRI Developed Biopesticide	Krishi Bhavan, Pavarati, Thrissur, 9 February 2016	Dr. C. A. Jayaprakas
Regional Seminar on Emerging Trends in Conservation Biology-Botanica 2015	S.N. College, Chempazhanthi, Thiruvananthapuram, 12-13 February 2016	Dr. S.S .Veena
Annual Meeting of ORP on Sucking Pest	ICAR- Indian Institute of Horticultural Research, Bengaluru, 13 February 2016	Dr. C. A. Jayaprakas
Meeting on Tuber Crops Technologies to Safe guard Soil Health	Theerthahalli, Karnataka, 15 February 2016	Dr. S. Ramanathan Dr. C. Mohan Dr. V. Ramesh
National Conference on Genomics and Society- Prospects, Challenges and Concerns	University of Kerala, 17 February 2016	Dr. S. S.Veena Dr. T .Makeshkumar
Brainstorming Session on IPM in Major Crops	NASC complex, New Delhi, 17 February 2016	Dr. C. A. Jayaprakas
APEDA Meeting	Odisha, 17 February 2016	Dr. Archana Mukherjee
Certificate Course on Profitable Rambutan Cultivation	ICAR-CARD KVK, Pathanamthitta, Kerala, 19 February 2016	Dr. G. Byju
Agri-Hort Fair and Farmers-Scientists Interaction Meet (Kisan Gosthi)	Bargarh, Odisha, 20-22 February 2016	Dr. Archana Mukherjee
Workhop on Zika Virus a Looming Threat	Mascot Hotel, Thiruvananthapuram, 22 February 2016	Dr. C. A. Jayaprakas Dr. S. S. Veena
Training Workshop on Environmental Risk Assessment of Genetically Engineered (GE) Plants	Ministry of Environment, Forest and Climate Change, New Delhi, 22-23 February 2016	Dr. T. Makeshkumar Ms. N. Krishna Radhika

6thInternational Conference on Plant, Pathogens and People: Challenges in Plant Pathology to Benefit Humankind	New Delhi, 23-27 February 2016	Dr. S.K. Chakrabarti Dr. T. Makeshkumar Dr. M. L. Jeeva
National Seminar on Plant Science Technology for Sustainable World	School of Biosciences, National Institute of Plant Science Technology, Mahatma Gandhi University, Kottayam, Kerala, 25-26 February 2016	Dr. C. A. Jayaprakas Dr. G. Byju
Interaction Meeting of the Directorate of Agriculture & Food Production with ICAR Institutes for Agriculture Technology Development	IMAGE, Bhubaneswar, Odisha, 26 February 2016	Dr. K. Laxminarayana
10th DUS Review Meeting	Rahuri, Maharashtra, 26-27 February 2016	Dr. Archana Mukherjee Dr. K. Pati
Seminar on Current Advances in Plant Science	Govt. College for Women, Thiruvananthapuram, 3-4 March 2016	Dr. A. Asha Devi
National Seminar on Recent Advances in Molecular Biology	Kannur University, 9 March 2016	Dr. C. A. Jayaprakas
Review Meeting of RCSE for Science Research Schemes	Kerala State Council for Science, Technology and Environment, Thiruvananthapuram, 16 March 2016	Dr. A. N. Jyothi
First Meeting of Institute Biosafety Committee Meeting of Kerala Agricultural University	Kerala Agricultural University, Vellayani, 17 March 2016	Dr. T. Makeshkumar
Technology and Machinery Demonstration Mela	Changaramkulam, Malappuram, Kerala, 18 March 2016	Dr. M. S.Sajeev
Second Meeting of Reconstituted Institute Biosafety Committee Meeting	ICAR-Indian Institute of Spices Research, Calicut, 18 March 2016	Dr. T. Makeshkumar
Workshop on Nanotechnology in Agriculture: A focus on Insect and Insect Resources	National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka, 19 March 2016.	Dr. H. Kesava Kumar
Technology Week of ICAR KVK (Bapooji Sevaksamaj)	Idukki, Kerala, 23 January 2016	Dr. K. Susan John
Workshop on Promoting Tuber Crops Seed Enterprises for Sustainable Seed Security	Krishi Vigyan Kendra, Sandhiyur, Salem, 23 March 2016	Dr. James George Dr. V. Ravi Dr. P. Sethuraman Sivakumar Dr. R. Muthuraj
National Seminar on Insect Biodiversity Studies: Where does India Stand in the Global Map?	Central University, Kerala, 31 March 2016	Dr. C. A. Jayaprakas

Visits Abroad

Name of the scientists	Period	Place of visit	Purpose
Dr. K. Susan John	15-17 October 2015	Sao Paulo, Brazil	Participated and presented oral research paper in the 4th International Zn Symposium- Improving crop production and human health
Dr. M. N.Sheela	7-8 November 2015	Zurich	Attended the Review Meeting of the Indo-Swiss Cassava Network project
Dr. S.K. Chakrabarti, Dr. M. N. Sheela, Dr. Archana Mukherjee, Dr. J.T. Sheriff, Dr. T. Makeshkumar Dr. Shirly Raichal Anil	18-22 January 2016	Nanning, China	Participated and presented papers in the World Congress on Tropical Tuber Crops
Dr. T. Makeshkumar Ms. Leen N. Abraham, JRF	9 November -9 December 2015 9 November 2015-8 April 2016	ETH, Zurich, Switzerland	Scientific exchange visit for understanding the genetic transformation of cassava under the Indo–Swiss Cassava Network Project
Dr. M. N. Sheela Dr. T. Makeshkumar Ms. Leen N. Abraham, JRF	7-8 December 2015	ETH, Zurich, Switzerland	Attended the First Review Meeting of the Indo–Swiss Cassava Network Project
Dr. J.T.Sheriff	12-15 May 2015	Blantyre, Malawi	Attended the Third Annual Project Meeting of European Commission funded project on Improving the livelihoods of small holder cassava farmers through better access to growth markets (Cassava GMarkets)

Dr. Shirly Raichal Anil, Dr. M. N. Sheela, Dr. Archana Mukherjee, Dr. S.K. Chakrabarti, Dr. J.T. Sheriff and Dr. T. Makeshkumar (left to right) at Nanning, China

Dr. K. Susan John at Sao Paulo, Brazil

Distinguished Visitors

The following distinguished persons visited ICAR-CTCRI during the year:

- Shri. Subrato Biswas IAS, Agriculture Production Commissioner, Government of Kerala.
- Smt. K. B. Valsalakumari IAS, Executive Director, State Mission, Kudumbasree, Thiruvananthapuram.
- Dr. N. K. Krishna Kumar, Deputy Director of Agriculture (Hort. Sci.), ICAR, New Delhi.
- Dr. Gurbachan Singh, Chairman, Agricultural Scientists Recruitment Board, New Delhi.
- Dr. T. Janakiram, Assistant Director of Agriculture, ICAR, New Delhi.
- Dr. P. G. Latha, Director, Jawaharlal Nehru Tropical Botanical Garden and Research Institute, Palode, Thiruvananthapuram.
- Shri. Ravi Varma Raja, Member, Travancore Royal family.
- Shri. R. Ajith Kumar, Director of Agriculture (i/c), Kerala.
- Dr. P. Chowdappa, Director, ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala.
- Dr. H. P. Maheswarappa, Project Coordinator, Palms, ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala.
- Dr. Ravi Maruthachalam, Assistant Professor, School of Biology, Indian Institute of Science, Education and Research, Thiruvananthapuram.
- Dr. M. Anandaraj, Director, ICAR-Indian Institute of Spices Research, Kozhikode, Kerala.
- Dr. H. S. Singh, Head, Central Horticultural Experiment Station, Bhubaneswar, Odisha.
- Dr. Srikanth Attaluri, Program Director, International Potato Centre (India).
- Dr. K. Nirmal Babu, Project Co-ordinator, Spices, ICAR-Indian Institute of Spices Research, Kozhikode, Kerala.
- Dr. Peter J. Mathews, Network Creator and Chief Administrator, National Museum of Ethnology, Senri Expo Park, Suita City, Osaka.
- Dr. Waven William, High Commissioner, High Commission of the Republic of Seychelles.
- Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAARC Agriculture Centre, Dhaka, Bangladesh.
- Prof. V. Ramakrishnan, Director, Indian Institute of Science, Education and Research, Thiruvananthapuram.
- Dr. P. Rethinam, Former Assistant Director of Agriculture, ICAR & Chairman, RAC VII.
- Dr. Umesh Srivastava, Former Assistant Director of Agriculture, Hort. Sci., ICAR & Member, RAC VII.
- Dr. P.S. Naik, Former Director, ICAR-Indian Institute of Vegetable Research & Member, RAC VII.
- Dr. V.G. Malathi, Adjunct Faculty & Emeritus Scientist, Tamil Nadu Agricultural University & Member, RAC VII.
- Dr. Srinivasa Murthy, Principal Scientist, ICAR-Indian Institute of Horticultural Research & Member, RAC VII.
- Dr. G.V.S. Saiprasad, Lead Scientist, Agriscience, ITC Limited, Bengaluru & Member, RAC VII.
- Shri. Salim P. Mathew (IMC Rep.) Member, RAC VII.

Managerial Personnel

Director	:	Dr. S. K. Chakrabarti (up to 26.1.2016)
Director (Acting)	:	Dr. James George (w.e.f. 27.1.2016)
Project Coordinator	:	Dr. James George
Head, Regional Centre, Bhubaneswar	:	Dr. Archana Mukherjee
Senior Administrative Officer	:	Shri. Davis Joseph
Finance and Accounts Officer	:	Smt. R. Sari Bai
Central Public Information Officer	:	Dr. C.A. Jayaprakas
Vigilance officer	:	Dr. Saravanan Raju

Head of Divisions/Section

Crop Improvement	:	Dr. M. N. Sheela
Crop Production	:	Dr. V. Ravi
Crop Protection	:	Dr. C. A. Jayaprakas
Crop Utilisation	:	Dr. J.T. Sheriff
Extension and Social Sciences	:	Dr. S. Ramanathan

Personnel

Director (Relieved on 27.1.2016 FN)	Dr. S. K. Chakrabarti
Director (Acting)	Dr. James George
Project Coordinator (AICRP on Tuber Crops)	Dr. James George
Dr. S. Sunitha	Principal Scientist

Head of Division/Section

Crop Improvement	Dr. M. N. Sheela
Crop Production	Dr. V. Ravi
Crop Protection	Dr. C. A. Jayaprakas
Crop Utilization	Dr. J.T. Sheriff
Extension & Social Sciences	Dr. S. Ramanathan

Division of Crop Improvement

Dr. Asha K. I	Principal Scientist
Dr. C. Mohan	Principal Scientist
Dr. A. Asha Devi	Principal Scientist
Dr. Shirly Raichal Anil	Senior Scientist
Ms. N. Krishna Radhika	Scientist
Dr. Vivek Hegde	Scientist
Dr. Visalakshi Chandra C.	Scientist

Division of Crop Production

Dr. V. Ravi	Principal Scientist
Dr. G. Byju	Principal Scientist
Dr. G. Suja	Principal Scientist
Dr. K. Susan John	Principal Scientist
Dr. V. Ramesh	Senior Scientist
Dr. R. Muthuraj	Senior Scientist

Division of Crop Protection

Dr. M. L. Jeeva	Principal Scientist
Dr. S. S. Veena	Principal Scientist
Dr. T. Makeshkumar	Principal Scientist
Shri. Harish. E. R	Scientist
Dr. H. Kesava Kumar	Scientist
Ms. Sangeetha B.G.	Scientist
Ms. Sirisha Tadigiri	Scientist

Division of Crop Utilization

Dr. M. S. Sajeev	Principal Scientist
Dr. A. N. Jyothi	Principal Scientist
Shri. Saravanan Raju	Senior Scientist
Ms. Namrata Ankush Giri	Scientist
Ms. Pradeepika Chintha	Scientist

Section of Extension & Social Sciences

Dr. Sheela Immanuel	Principal Scientist
Dr. T. Srinivas	Principal Scientist
Dr. V. S. Santhosh Mithra	Senior Scientist
Dr. J. Sreekumar	Senior Scientist
Dr. P. Sethuraman Sivakumar	Senior Scientist

Library/PME Unit/Photography

Shri. R Bharathan	Assistant Chief Technical Officer
Smt. T. K. Sudhalatha	Senior Technical Officer
Shri. V. S. Sreekumar	Technical Officer
Ms. B. S. Deepa	Technical Assistant

Field/Farm/Lab.Technicians

Dr. L. S. Rajeswari	Assistant Chief Technical Officer
Shri. M. Easwaran (Rtd 31.3.2016)	Assistant Chief Technical Officer
Ms. Sujatha Kumari N.	Assistant Chief Technical Officer
Shri. A. Madhu	Assistant Chief Technical Officer
Shri. I. Puviyarasan	Assistant Chief Technical Officer
Shri. C. S. Salimon	Senior Technical Officer
Shri. M. Kuriakose	Senior Technical Officer
Shri. G. Venukumaran	Technical Officer
Shri. L. V. Ajithkumar	Technical Officer
Shri. V. L. Mathew (Rtd on 31.3.2016)	Technical Officer
Shri. V. R. Sasankan	Senior Technical Officer
Shri. V. Ganesh	Technical Officer
Shri. B. Renjith Kishore	Senior Technical Officer
Shri. Patric M. Mascrene	Technical Officer
Shri. S. Natarajan	Technical Officer
Shri. G. Suresh	Technical Assistant
Shri. N. P. Ramadasan	Technical Assistant
Shri. A. S. Manikuttan Nair	Senior Technical Assistant
Shri. Luke Armstrong	Technical Assistant
Shri. T. Raghavan	Senior Technician
Shri. G. Shajikumar	Technical Assistant
Shri. B. Satheesan	Technician
Shri. D. T. Rejin	Technician
Shri. T. M. Shinil	Technician
Dr. S. Shanavas	Technical Assistant
Shri. B. S. Prakash Krishnan	Technical Assistant
Dr. S. Karthikeyan	Technical Assistant
Ms. Pallavi Nair K.	Technical Assistant

Administrative and Accounts

Shri. Davis Joseph	Senior Administrative Officer
Smt. R. Sari Bai	Finance and Accounts Officer
Shri. T. Jayakumar	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. T. Vijayakumara Kurup	Assistant
Shri. P. S. Suresh Kumar	Assistant
Shri. J. Unni	Assistant
Shri. K. Unnikrishnan Nair	Assistant
Smt. S. Geetha Nair	Assistant
Shri. S. Harendra kumar	Assistant
Smt. V. Sathyabhama	U.D.C
Shri. O. C. Ayyappan	U.D.C
Shri. S. Sreekumar	U.D.C
Shri. C. Chandru	L.D.C
Shri. R. S. Adarsh	L.D.C
Shri. N. Jayachandran	L.D.C
Mrs. C. G. Chandra Bindhu	L.D.C

Canteen Staff

Shri. S. Radhakrishnan Nair	Skilled Support Staff

Supporting Staff

Smt. S. Ushakumari	Skilled Support Staff
Shri. P. Udayakumar	Skilled Support Staff
Shri. K. Saratchandra Kumar	Skilled Support Staff
Shri. G. Madhu	Skilled Support Staff
Shri. A. Chandran	Skilled Support Staff
Smt. C. T. Chellamma	Skilled Support Staff
Smt. M. Syamala	Skilled Support Staff
Shri. K. Velayudhan	Skilled Support Staff
Shri. P. Ramankutty	Skilled Support Staff
Shri. T. Lawrence	Skilled Support Staff
Shri. N. Appu	Skilled Support Staff
Shri. K. Sivadas	Skilled Support Staff
Smt. J. Thenmozhi	Skilled Support Staff
Shri. L. Samynathan	Skilled Support Staff
Shri. C. Krishnamoorthy	Skilled Support Staff
Shri. S. Sreekumaran	Skilled Support Staff
Shri. T. Manikantan Nair	Skilled Support Staff
Shri. K. Chandran	Skilled Support Staff
Ms. Rohini K. Nair	Skilled Support Staff
Ms. Sneha S.S.	Skilled Support Staff
Ms. Rini Alocious	Skilled Support Staff
Mr. Aneesh T.	Skilled Support Staff
Ms. Gayathri C.P.	Skilled Support Staff
Ms. Nijamole R.	Skilled Support Staff
Mr. Abhishek S.	Skilled Support Staff
Ms. Jyothi S.L.	Skilled Support Staff
Mr. Stiphin George	Skilled Support Staff
Ms. Vidhya P.	Skilled Support Staff
Mr. Arunraj D.	Skilled Support Staff
Mr. Sreenath Vijay	Skilled Support Staff

Regional Centre, Bhubaneswar

Dr. Archana Mukherjee	Head, Regional Station
Dr. R. C. Ray	Principal Scientist
Dr. M. Nedunchezhiyan	Principal Scientist
Dr. K. Rajasekhara Rao	Principal Scientist
Dr. K. Laxminarayana	Principal Scientist
Dr. Kalidas Pati	Scientist
Dr. Vijay Bahadur Singh Chauhan	Scientist
Shri. Venkatraman V. Bansode	Scientist
Shri. Hanume Gowda K.	Scientist

Technical

Shri. Sushanta Kumar Jata	Technical Assistant
Shri. N. C. Jena	Technical Officer
Shri. Niranjan Pattnaik	Senior Technical Assistant
Shri. Bharat Kumar Sahoo	Senior Technical Assistant
Shri. Pramod kumar Mati	Senior Technical Assistant
Shri. Bibhudi Bhusan Das	Senior Technical Assistant
Shri. Keshab Paikaray	Technician

Administrative and Accounts

Shri. P.C. Noble	Assistant Administrative Officer
Shri. P. K. Acharya	Private Secretary
Shri. A. Lakshamana Rao	U.D.C

Supporting Staff

Shri. Ramachandra Das	Skilled Support Staff
Shri. Bijoykumar Nayak	Skilled Support Staff
Shri. Akshayakumar Nayak	Skilled Support Staff
Shri. Purna Samal	Skilled Support Staff
Shri. Bhajaman Malik	Skilled Support Staff
Shri. Sauri Pradhan	Skilled Support Staff
Shri. K. C. Jena	Skilled Support Staff
Shri. Ramesh Nayak	Skilled Support Staff
Shri. Babuli Sethi	Skilled Support Staff
Shri. Fakirchandran Bhoi	Skilled Support Staff
Shri. Samsudin Khan	Skilled Support Staff

Other Information

Annual Group Meeting of the AICRP on Tuber Crops

The 15th Annual Group Meeting of the AICRP on Tuber Crops was held at Dr. YSRHU, Venkatramanagudem, during 23-25 April 2015. Dr. T. Janakiram, ADG (Hort. Sci.), ICAR formally inaugurated the event on 23 April, which was presided over by Dr. S. K. Chakrabarti, Director, ICAR-CTCRI. Six technical sessions, including the Action Taken Report of 14th AGM and plenary session, were held. A critical, but constructive evaluation of the projects was done by the house, which consisted of several invited experts, including Dr S. B. Dandin, former Vice Chancellor, UHS Bagalkot and Chairman, QRT of ICAR-CTCRI and Dr. P. Rethinam, former ADG (Hort. Sci.) and Chairman, RAC, ICAR-CTCRI and decisions were made for execution in the coming years. A formal valedictory function was held on 24 April presided over by Dr. B.M.C. Reddy, Vice Chancellor, Dr. YSRHU. Dr. N. K. Krishnakumar, Honourable DDG (Hort.), ICAR gave the keynote address. A book on 'Tuber Crops of India' published by AICRP-TC was formally released during the occasion by Honourable DDG. One technical bulletin and four pamphlets prepared by AICRP-TC centres were also released during the occasion by the dignitaries.

15th Annual Group Meeting of the AICRP on Tuber Crops held at Dr. YSRHU, Venkatramanagudem

H.H. Sree Visakham Thirunal Endowment Lecture – 2015

The sixth H.H. Sree Visakham Thirunal Endowment lecture – 2015 was held at ICAR-CTCRI on 2 June 2015. The function was organized by the Indian Society for Root Crops (ISRC) in collaboration with ICAR-CTCRI. This year's lecture was delivered by Dr. Gurbachan Singh, Chairman, Agricultural Scientists Recruitment Board (ASRB), New Delhi. The topic of the lecture was "Challenges of sustainable food security under climate change scenario". In his lecture he commented that, "In a country like India endowed with rich and diverse flora, fauna and environment, judicious use of natural resources like solar power, wind and water energy will go a long

Dr. Gurbachan Singh, Chairman, ASRB, inaugurating the H.H. Sree Visakham Thirunal Endowment lecture – 2015

way in ensuring the food security of the nation". The meeting was presided over by Dr. S. K. Chakrabarti, Director, ICAR-CTCRI. Dr. C. A. Jayaprakas, President, ISRC welcomed the gathering. Shri. M. Ravi Varma Raja, representative from the Royal Family of Travancore and Dr. T. Janakiram, ADG (Hort. Sci.) offered felicitations. Dr. V. S. Santhosh Mithra, Secretary, ISRC, proposed the vote of thanks. Two cassava varieties, Sree Swarna and Sree Pavithra and two greater yam varieties, Sree Neelima and Sree Swathy were released during the function. About 200 participants attended the function.

Foundation Day Celebrations

The 52nd foundation day of ICAR-CTCRI was celebrated on 25 July 2015 at the Millennium Hall of the Institute. The day's celebration was inaugurated by Smt. K. B. Valsalakumari IAS, Executive Director, State Mission, Kudumbasree, Thiruvananthapuram. She called for fostering tie up between Kudumbasree and ICAR-CTCRI for the benefit of farmers as well as for the women folk of Kerala belonging to the low income group. Dr. P. G. Latha, Director, JNTBGRI, Palode, Thiruvananthapuram, was the Guest of Honour. The meeting was presided over by Dr. James George, Director-in-Charge and Project Co-ordinator, AICRP (Tuber Crops). During the function, two progressive tuber crops farmers were honoured and TOMS, the Tuber Crops Online Marketing System was launched. An exhibition of tuber crops and tuber crops based products was also arranged. Dr. M. N. Sheela, Principal Scientist and Head, Crop Improvement, welcomed the gathering and Dr. Sheela Immanuel, Principal Scientist, ICAR-CTCRI, Thiruvananthapuram, proposed the vote of thanks. The inaugural function was followed by a session on Scientist-Farmer interaction.

52nd foundation day of ICAR-CTCRI

Group Meeting on *Phytophthora*

A group meeting on "*Phytophthora* diseases of horticultural crops and their management" was organized on 29 July 2015 at Regional Centre, ICAR-CTCRI, Bhubaneswar, Odisha. The meeting was presided by Dr. N. K. Krishna Kumar, Honourable DDG (Hort), ICAR. Dr. S. K. Chakrabarti, Director, ICAR-CTCRI, Dr. M. Anandaraj, Director, ICAR-IISR, Dr. James George, Project Co-ordinator (Tuber Crops), Dr. R.S. Misra, Head, Regional Centre, ICAR-CTCRI, Dr. H. S. Singh, Head, CHES, Dr. Srikanth Attaluri, Program Director, CIP (India) and Dr. K. Nirmal Babu, Project Co-ordinator (Spices) also graced the occasion.

Detailed status of the management strategies of *Phytophthora* on major horticultural crops were presented and discussed. The major recommendations were *in silico* screening of effector molecules, chemoinformatics of botanicals for development of newer molecules for disease management, reasons for population fluctuation/replacement of mating types,

Group meeting on *Phytophthora* at Regional Centre, ICAR-CTCRI, Bhubaneswar, Odisha

importance to microclimatic factors while studying infection studies and strengthening of phytosanitation measures.

Mid Term Review Meeting of AICRP on Tuber Crops

Mid-term review meeting of AICRP on Tuber Crops was held during 24-25 September 2015 at ICAR-CTCRI, Sreekariyam, Thiruvananthapuram. Annual Report of AICRP 2014-2015 and Package of Practices of Tuber Crops in different languages for north-eastern states of India by Dr. Bijayadevi and Dr. James George were released during the occasion. Scientists from various Centres attended the meeting and actively participated.

Mid-term review meeting of AICRP on tuber crops

Tuber Crops Day-2015

As in previous years, the Tuber Crops Day was celebrated this year also on 24 November with pomp and grandeur by the ICAR-CTCRI in association with the Indian Society for Root Crops at the Institute. Shri. R. Heli, Former Director, Department of Agriculture, Government of Kerala inaugurated the function. He recalled that tapioca acted as Saviour Crop during 1960s, when the people of Kerala experienced a severe food shortage. He also mentioned about the cassava-based bio-pesticides *Nanma*, *Menma* and *Shreya* developed by ICAR-CTCRI to have changed the pest management scenario in Kerala. Mr. Heli stated that these bio-pesticides are befitting alternatives to chemical pesticides, when the Kerala State turns organic by 2016. He stressed that *Malayalis* should not forget the wonder crop tapioca and called for initiating a massive research program on tapioca in a coordinated manner by involving several central and state government agencies and other partners. The meeting was presided over by Dr. S.K. Chakrabarti, Director, ICAR-CTCRI, Dr Ommen V. Ommen, Chairman, Kerala Biodiversity Board, delivered the keynote address. Dr. C.A. Jayaprakas welcomed the gathering and Dr. V.S. Santosh Mithra proposed the vote of thanks. A progressive tuber crops farmer, Sri. Ramkumar was awarded the "Best Tuber Crop Farmer 2014" with a cash award. A large gathering of 500 tuber crop farmers, representing 20 states across the country took part in the celebration.

Tuber Crops Day-2015

Tuber Food Fest-2015

In order to popularize tuber crops and its food products, the ICAR-CTCRI in association with the Departments of Agriculture and Schedule Tribes Development, Government of Kerala, organized a Tuber Crops Food Festival – Tuber Food Fest 2015, in the premises of Kanakakunnu Palace, Thiruvananthapuram during 24-25 November 2015. The mega event was inaugurated by Sri. K. P. Mohanan, Hon'ble Minister for Agriculture, Government of Kerala. Shri. Adoor Prakash, Hon'ble Minister for Revenue and Coir and Sri. Anoop Jacob, Hon'ble Minister for Food and Civil Supplies graced the occasion by their presence. Farmers from 20 different states of India along with scientists from the centres of AICRP (Tuber Crops) participated in the grand gala and exhibited various forms of their ethnic and modern food preparations

made of different tuber crops. In all, there were 40 exhibition stalls, apart from Food Court, which drew a huge crowd estimated to be more than 10,000 people.

Glimpses of Tuber Food Fest-2015

ICAR-CTCRI Developed Bio-formulations Technology Transfer Meet

The Intellectual Property and Technology Management Unit (IPTMU) of ICAR-CTCRI organised a "Technology Transfer and Training of ICAR-CTCRI developed Bio-formulations to KVKs" meeting on 15 December 2015. This function was presided by Dr S. K. Chakrabarti, Director, ICAR-CTCRI and Dr. A. Ajayaghosh, Director, CSIR-National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram was the chief guest. During the meeting, Dr Chakrabarti congratulated the research team, which developed the bio-formulations and appealed to scientists to develop functional collaboration with CSIR Institutes. Dr Ajayaghosh distributed the MoUs to the KVKs. During his address, Dr Ajayaghosh stressed upon the need for translating the research outputs into usable technologies for maximising the utility of scientific research. He called for developing alternative approaches for pest management using natural components like cyanogens present in the ICAR-CTCRI developed bio-formulations like *Nanma* and *Menma*, to combat the pest attack, while conserving the nature. During the function, Dr C. A. Jayaprakas, Head, Crop Protection, who developed the bio-formulations explained the events leading to the development of these successful bio-formulations. Five Krishi Vigyan Kendras from Kerala i.e., Ernakulam, Kasaragod, Pattanamthitta, Kollam and Thiruvananthapuram have executed a Memorandum of Understanding for bulk purchase of active ingredients of ICAR-CTCRI bio-formulations for management of banana pseudostem weevil and participated in the demonstration training.

Dr Ajayaghosh, Director, CSIR-NIIST, addressing the audience

National Science Day Celebrations-2016

The National Science Day-2016 was celebrated at ICAR-CTCRI during 24-25 February 2016 on the focal theme, "Make in India: S & T Driven

Innovations" and the event was sponsored by Kerala State Council for Science, Technology and Environment' and supported by Department of Science and Technology, Government of India. Dr. James George, Director, ICAR-CTCRI inaugurated the celebrations. Various programmes like guest lecture, quiz, innovative project presentation and poster making competitions were conducted during the occasion. The competitions were held for CTCRI staff as well for college students. Apart from staff and students of the Institute, 100 students from 12 colleges in and around Thiruvananthapuram participated in the event. National Science Day speech was delivered by Prof. V. Ramakrishnan, Director, IISER, Thiruvananthapuram. Dr. Joykrushna Jena, DDG (Fisheries), ICAR, New Delhi was the Guest of Honour.

National Science Day Celebrations-2016

World Soil Day on the occasion of International Year of Soils-2015

The state level function to observe 'World Soil Day' was inaugurated on 5 December 2015 at Thiruvananthapuram by Shri. Oommen Chandy, Hon'ble Chief Minister, Kerala, in which Soil health cards were distributed to the farmers. The meeting was presided over by Shri. K.P. Mohanan, Hon'ble Minister for Agriculture, Kerala, which was attended by the Director and Staff of ICAR-CTCRI, dignitaries representing central and state departments, political representatives of the state and over 1500 farmers. Two hundred and fifty soil health cards generated by ICAR-CTCRI representing four blocks (Kottarakkara, Kundara, Chadayamangalam and Pathanapuram) of Kollam district were issued to the farmers on that occasion.

The 'World Soil Day' programme was celebrated on 5 December 2015 at OUAT, Bhubaneswar by the Regional Centre of ICAR-CTCRI in collaboration with the Directorate of Agriculture and Food Production, Government of Odisha. Two hundred and fifty soil health cards belonging to Bhubaneswar block of Khurda district were distributed to the farmers. The function was chaired by Shri. Pradip Maharathy,

World Soil Day Celebration on 5 December 2015 at Thiruvananthapuram

Hon'ble Minister for Agriculture, Fisheries and Animal Resources Development and was attended by a galaxy of eminent personalities from science and administration. Around 500 farmers attended the programme.

SAARC Meeting

Three days Regional Expert Consultation Meeting on 'Assessment of common crop varieties and their demand and supply for the SAARC seed bank' jointly organized by the SAARC Agriculture Centre, Dhaka, Bangladesh, ICAR-Directorate of Seed Research, National Seeds Corporation and Kerala Agricultural University was held at Thiruvananthapuram, during 28-30 December 2015. About 15 participants from Afganisthan, Pakistan, Bangladesh, Bhutan, India, Maldives and Srilanka visited ICAR-CTCRI on 30 December and had an overview of the research and development activities being undertaken here especially, on seed related programmes. The visit was led by Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAARC Agriculture Centre, Dhaka, Bangladesh and the meeting at CTCRI was coordinated by Dr. K. Susan John, Principal Scientist, Division of Crop Production.

Experts of the SAARC Meeting at ICAR-CTCRI, Thiruvananthapuram

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 of Rs. 10 lakhs allotted to the library was utilized for the purchase of following publications:

- A total of 14 Journals (International – 6 and National – 8) worth Rs. 7,44,194
- Books (107 numbers) worth Rs. 1,67,381
- E- Journal (1 number) worth Rs. 42,943
- Online Database (indiastat.com) worth Rs. 53,865

In addition, the following services were also made available to the users of the library

1. **Circulation of books**: A total of 223 books were issued to the users on loan and it was recorded properly in the books issue register.
2. **CeRA:** About 108 Document Delivery Request (DDR) of outside users of CeRA were satisfied by sending hard copy of library materials.
3. **Ready-reference service**: Provided ready assistance and solutions to the queries of users. 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 500 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 M.Sc. and Ph. D project works under the guidance of the institute scientists. They were given necessary guidance on the use of reference resources and also photocopying facility.

5. **Photocopying:** Library continued to provide photocopying service to the institute staff and other library users on official/payment basis. During this period, 51,839 copies were provided upon their work indents, which included 49,179 official copies and 2,660 private copies.
6. **Services to the Regional Centre:** Five books were procured for the library of Regional Centre, ICAR-CTCRI, Bhubaneswar.
7. **Procurement of Hindi publications:** A total of 18 ICAR Hindi publications were purchased from the Directorate of Knowledge Management in Agriculture for the libraries of both Head Quarters and Regional Centre.

Hindi Corner

The Hindi Fortnight 2015 was celebrated in the institute during 14-28 September 2015. The fortnight celebration was inaugurated by Dr. S. K. Chakrabarti, Director, ICAR-CTCRI. Various competitions like recitation, translation, essay writing, calligraphy, elocution, just a minute and anthakshari were conducted for the staff and their children. About 50 persons participated in the various competitions, which was a grand success. A one day workshop cum valedictory function of the Hindi Fortnight Celebration 2015 was conducted on 18 November 2015. The workshop was on the topic, "Salient Points of Official Language Policy, Annual Program, Targets and Incentives available for Doing Work in Hindi" and classes were taken by Mr. M. G. Somashekharan Nair, Senior Hindi Officer, Vikram Sarabhai Space Centre, Thumba, Thiruvananthapuram. He was also the Chief Guest for the valedictory function organized on the same day. Prizes were distributed to the winners of the various competitions conducted.

Hindi Fortnight 2015

Swaccha Bharat Abhiyan

ICAR-CTCRI is actively participating in "Swachha Bharat Mission", a nation-wide programme by the Hon'ble Prime Minister of India. The committee for 'Swaccha Bharat Abhiyan' was constituted by the Director and the first meeting was held on 29 September 2014. The following activities are being implemented under this programme.

- A 'Cleanliness Oath' was administered by the Director with all the members of institute on 2 October 2014.
- Purchased a number of dust bins, hand gloves and brooms for cleaning and used Swaccha Bharat Abhiyan logo and tag line in the institute.
- All members participated in cleaning the office premises and the field area.
- Collected plastics, bottles, papers etc. and destroyed them completely by using the incinerator.
- Thrown old and broken items, furniture, glassware and plastic.
- Swaccha Bharat Abhiyan was conducted

weekly on Saturday and second Friday for one hour to clean different areas and everyone participated in the cleaning and sweeping operations.

- Attendance register was maintained to record presence of members.

Human Chain Formation: On the occasion of New Year, 1 January 2015, a human chain was formed to spread the message of unity and cleanliness. ICAR-CTCRI invited participants from nearby Loyala School, police station.

ICAR-CTCRI also organized an intensive Swaccha Abhiyan (National Cleanliness Campaign) during 25 September to 31 October 2015. ICAR-CTCRI, conducted National Cleanliness Campaign at Govt. High School, Chavadimukku, Sreekariyam on 16 October 2015. The following activities were done:

- Dr. S.K. Chakrabarti, Director, ICAR-CTCRI, explained the concept and the need of the cleanliness campaign to create awareness among the students.
- Mass media coverage of the programme.
- The Director, ICAR-CTCRI and the Principal of the school planted fruit trees and ornamental plants in and around the school campus.
- More than 100 school students participated in the programme and cleaned the school premises and disposed waste material like paper, plastic, weeds etc.


Human chain formation by ICAR-CTCRI staff


Planting a tree by the Director, ICAR-CTCRI and Principal of the School


Students participating in cleanliness drive

State of art of MGMG

Under the flagship programme of the Prime Minister of India titled 'Mera Gaon Mera Gaurav' (MGMG), a scheme to make scientists adopt villages to promote the best farming practices was initiated in our institute during October 2015. All the scientists of the institute are involved in this programme and Thiruvananthapuram district was selected. A total of 49 villages were covered under this programme. The total number of families selected as beneficiaries accounts to 11, 333 and the total area under this programme is 8033.47 ha. Baseline survey was conducted in all the selected villages and data were collected on the socio-economic demography. The farmers were given training on value addition in selected villages. Bio-pesticides were also distributed to selected farmers. Frequent group discussions and meetings were held with the farmers and scientists had interactions with the farmers on different issues related to agriculture and allied activities. The MGMG programme is also in full swing at the Regional Centre of ICAR-CTCRI, Bhubaneswar, in the selected villages (Belapada, Arishal and Ramabili villages in Khordha district and Ostapada village in Nayagarh district). Farmers and scientists' interaction and crop advisories are the major highlights of the programme.

Scientists, Regional Centre, Bhubaneswar, in the cucumber field under MGMG programme

Distribution of orange-fleshed sweet potato (var. ST-14) planting materials under MGMG programme, ICAR-CTCRI, RC

MGMG programme at Andoorkonam, Thiruvananthapuram

Recreation Club Corner

In connection with the International Yoga Day on 21 June 2015, a yoga class was organized for the staff of ICAR-CTCRI by Recreation Club of ICAR-CTCRI. Apart from this two day celebrations in connection with Onam-2015 was also organized. One the first day, members participated in the outdoor games and bagged prizes. The event culminated with an enthusiastic 'Uriyadi ritual' in connection with Onam. On the second day, there was 'athapoo' competition, and in the afternoon, cultural programmes by the staff members were held. A folk music and dance troupe entertained the house thereafter. The New Year was welcomed with a get together of all the club members and presentation of gift. Republic day function 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. Recreation club felicitated the Director, ICAR-CTCRI on his new posting as Director, ICAR-CPRI and also all the club members who retired during this period. Recreation club purchased a table tennis table and also a carom board under the sponsorship of Dr. Archana Mukherjee, Head, Regional Centre, ICAR-CTCRI, Bhubaneswar.

Recreation Club activities 2015-16

Field Level Demonstrations/OFTs conducted

- Twelve front line demonstrations were conducted during this period.
- High yielding varieties (HYV) of elephant foot yam (2 nos.) was taken up at Thodiyur panchayat, Kollam, Kerala.
- HYV of cassava, greater yam and sweet potato was taken up at Kadakkavur, Thiruvananthapuram, Kerala.
- Nine demonstrations, three each with HYV of sweet potato, greater yam and elephant foot yam were laid out in three villages viz., Katel, Wagabandhe and Deriye in Joida region, Uttar Kannada district, Karnataka.

Participation in Exhibitions

ICAR-CTCRI participated in the following exhibitions:

1. Seminar cum Exhibition on 'Food processing and agribusiness potential of Odisha', 15 May 2015.
2. Fruit Festival-2015, YMCA in association with Plantation Corporation, Kerala, Thiruvalla, 9-11 June 2015.
3. Texpo, Government Polytechnic College, Neyyatinkara, 13-20 June 2015.
4. *Kharif Kisan Sammelan*, Krishi Vigyan Kendra, Bhagra, Muzaffarnagar, Uttar Pradesh, 27 June 2015.
5. Tuber Crops Ethnic Food (TCEF) Festival, Jaluki, Nagaland, 23 July 2015.
6. Agricultural Exhibition, Motihari, 20-21 August 2015.
7. Tuber Food Fest-2015, organized by ICAR-CTCRI, Kanakakunnu Palace, Thiruvananthapuram, 24-25 November 2015.
8. Public Information Campaign, Press Information Bureau, Nedumangad, 26 November 2015.
9. National Science and Cultural Expo-2015, TKM College of Arts and Science, Kollam, 30 November - 6 December 2015.
10. NSTE Commercial Expo, TKM College of Arts and Science, Kollam, 30 November to 6 December 2015.
11. Technology Meet-2015, Mithraniketan, Thiruvananthapuram, 9-11 December 2015.
12. Agri Fest-2014, Onnatukara, Kayamkulam, Kerala, 19-23 December 2015.
13. Karshika Mela, organized by Gandhiji Study Centre, Thodupuzha, Kerala, 26 December 2015 to 4 January 2016.
14. ATMA-SAMETI SUMMIT, Angamali, Kochi, 7-8 January 2016.
15. Exhibition-cum-Workshop on 'Food processing technologies', organized by Odisha Industries Federation and Anil Agarwal Foundation, 8 January 2016.
16. RIT Expo-2013-Exhibition, organized by Rajiv Gandhi Institute of Technology, Kottayam, 10-13 January 2016.
17. Agricultural Exhibition, ICAR-IIWM, Bhubaneswar, 14-17 January 2016.
18. Agricultural Exhibition, ICAR-IIWA, Bhubaneswar, 14-17 January 2016.
19. Agricultural Exhibition, OUAT, Bhubaneswar, 27-28 January 2016.
20. 28th Kerala Science Congress, organized by Kerala State Council for Science and Technology and Environment, Government of Kerala, 27-31 January 2016.
21. Machinery Expo, Directorate of Industries and Commerce, 28-31 January 2016.

22. Agricultural Exhibition, OUAT, Bhubaneswar, 10-11 February 2016.
23. Agricultural Exhibition, ATMA-SAMETI, Kottarakara, 19 February 2016.
24. Agri-Horti Exhibition, organized by NHB, Bhubaneswar and NRRI, Cuttack, Bargarh, Odisha, 20-22 February 2016.
25. Centenary Celebration, ICAR-CPCRI, Kasaragod, 12 March 2016.

Hon'ble Minister MSME, Odisha, visiting the exhibition stall

Exhibition at ICAR-IIWA, Bhubaneswar, Odisha

Exhibition at OUAT, Bhubaneswar, Odisha

वर्ष 2015 -16 के दौरान इस संस्थान में की गयी राजभाषा कार्यान्वयन से संबंधित कार्यक्रम

राजभाषा कार्यान्वयन समिति की बैठक का आयोजन

इस संस्थान की निदेशक की अध्यक्षता में, ता. 30.06.2015, 29.09.2015, 19.12.2015 और 22.03.2016 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

संघ सरकार की राजभाषा नीति के अनुपालन में इस संस्थान के सभी कर्मचारियों के लिए 18.11.2015 को राजभाषा नीति के मुख्य बिंदुएं, वार्षिक कार्यक्रम - लक्ष्य और हिंदी में काम करने केलिए उपलब्ध प्रोत्साहन पर एक हिन्दी कार्यशाला आयोजित किया गया । डॉ. एस. के. चक्रबर्ती, निदेशक और अध्यक्ष (राजभाषा), हिन्दी के महत्व पर प्रकाश डालते हुए समारोह का उद्घाटन किया । डॉ. आशा देवी, ए , प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभा का स्वागत किया, विशेष रूप से श्री. एम. जी. सोमशेखरन नायर, वरिष्ठ हिंदी अधिकारी, विक्रम साराभाई अंतरिक्ष केंद्र, तिरुवनंतपुरम का स्वागत किया और कार्यशाला में अच्छी उपस्थिति पर संतोष प्रकट किया। श्री. सोमशेखरन नायर, वरिष्ठ हिंदी अधिकारी ने क्लास लिया। कुल 43 प्रतिभागियों ने कार्यशाला में उत्साहपूर्व भाग लिये । प्रतिभागियों की राय था कि इस तरह के कार्यशालाओं की बारंबारी बढाई जानी चाहिए क्यों कि उन्हें यह बहुत फायदेमंद लगा । श्रीमती. टी. के सुधालता, तकनीकी अधिकारी (हिंदी) ने धन्यवाद प्रस्ताव पेश किया और श्री. सोमशेखरन नायर, की क्लास की सराहना की ।

हिन्दी पखवाड़ा समारोह का आयोजन

संस्थान में दिनांक 14 से 28 सितम्बर तक हिंदी पखवाड़ा 2015 मनाया गया। पखवाड़ा समारोह का उद्धाठन हमारे निदेशक महोदय, डॉ. एस. के. चक्रबर्ती द्वारा किया गया। कर्मचारियों और उनके बच्चों के लिए विभीन्न प्रतियोगिताएं, जैसे कि कविता पाठ, अनुवाद, निबंध लेखन, सुलेख, वाग्मिता, एक पल और अंताक्षरी आयोजित की गई। इसमें लगभग पचास व्यक्तियों ने भाग लिया और इसे शानदार ढंग से सफ़ल बनाया। 18 नवंबर 2015 को हिंदी पखवाड़ा उत्सव 2015 की समापन समारोह आयोजित किया गया जिसमें श्री. सोमशेखरन नायर, वरिष्ठ हिंदी अधिकारी, विक्रम साराभाई अंतरिक्ष केंद्र, तिरुवनंतपुरम मुख्य अतिथि रहे। उन्होंने विभिन्न प्रतियोगिताओं के विजेताओं को पुरस्कार वितरित किए ।

हिंदी पखवाड़ा समापन समारोह

हिंदी पखवाड़ा में पुरस्कार वितरण

प्रोत्साहन योजना

हिन्दी में काम करनेवालों को प्रोत्साहन योजना में भाग लिए/ प्रोत्साहन के पात्र कर्मचारियों को नकद पुरस्कार दिया गया। इस वर्ष 3 प्रतिभागियों को पुरस्कार वितरण किया गया।

हिन्दी में काम करनेवालों का प्रोत्साहन योजना में पुरस्कार वितरण

- इस संस्थान की सभी रबड़ की मोहरें, पत्र शीर्ष, नाम पट्ट, साइन बोर्ड, फॉर्म, मोहरें, पत्र शीर्ष आदि द्विभाषी रूप में बनाया था।
- प्रशासनिक कामकाज में उपयोग द्विभाषी प्रपत्र arisnetshare पर शामिल किया था।
- सभी परिपत्र, धारा 3(3) के सभी कागज़त द्विभाषी रूप में किया था।
- हिंदी में प्राप्त पत्रों के उत्तर हिंदी में दिए गए।
- वार्षिक कार्यक्रम के निर्धारित लक्ष्यानुसार अधिक से अधिक पत्राचार हिंदी में किया था।

हर कदम, हर पल
किसानों का हमसफर
भाकृअनुप की अनुसंधान पत्रिका

Agrisearch with a human touch