CTCRI/QSF/RP/400

वार्षिक प्रतिवेदन
Annual Report
2016 - 2017

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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Front
1. White yam shoot and tubers
2. Elephant foot yam plant and corms
3. Sweet potato shoot and tubers
4. Cassava shoot and tubers
5. Taro leaves and cormels

Back
6. Cassava
7. Sweet potato
8. Elephant foot yam
9. Yams
10. Taro

16 June 2017

Contents

Preface

It is a matter of great pride and happiness to present the *Annual Report of ICAR-Central Tuber Crops Research Institute for the year 2016-2017*. The ICAR-Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram with its Regional Centre at Bhubaneswar witnessed yet another commendable and eventful year with noteworthy scientific contributions serving the mankind with underground tuberous food crops rich in nutrients. Tuber crops, providing 5.4% dietary energy are the third important food crop worldwide after cereals and legumes. Food security and climate change are the twin issues of serious concern, much discussed, in the present-day agriculture. Over 54 years of dedicated efforts of the scientific community of ICAR-CTCRI resulted in farmer/consumer-friendly production, protection and value addition technologies, strengthening the designation of root & tubers as food-cum-nutritional-cum-livelihood security crops besides 'climate smart'.

During the reporting year, 8 varieties were released by Regional Centre, ICAR-CTCRI, Bhubaneswar. This includes 5 varieties of sweet potato for various traits, especially with nutritional attributes and salinity tolerance. Anthocyanin rich, Bhu Krishna and β carotene rich, Bhu Sona deserves special mention. In addition, 1 short-duration greater yam variety, Bhu Swar and 2 taro varieties were released. Besides, CMD resistant hybrids with short-duration, PPD tolerant cassava genotypes, early maturing sweet potato rich in β carotene and anthocyanin, 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 TLB were identified. Protocol for synthetic seed production in cassava was also developed.

Sustainable resource management technologies especially to address some of the government flagship programmes such as 'more crop per drop', safeguarding soil health, enhancing production of pulses and climate smart agriculture, were developed. The major research highlights were irrigation water saving techniques for elephant foot yam, nutrient requirement of cassava for fertigation, drip fertigation for greater yam + maize system, nutrient (N, P & K) efficient cassava genotypes, methodology for climate suitability studies of cassava, nutrient requirement of sweet potato for Island eco-system, elephant foot yam + black gram system, site specific nutrient management schedules, customized fertilizers for cassava, sweet potato and elephant foot yam, weed management practices for elephant foot yam and organic production technologies for tuber crop based systems.

Exploitation of cassava based bio-formulation for pest management, especially thrips in vegetables, 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 were a few notable crop protection technologies. Technologies for the production of sweet potato based gluten free cookies, sweet potato flour fortified nutri bar, vacuum frying for orange-fleshed and purple-fleshed sweet potato chips, sweet potato based functional bars enriched with resistant starch, *jimikand* papad, *jimikand* shorts, particle boards from cassava stems, encapsulated anthocyanin pigments with improved colour stability from sweet potato and greater yam, protein rich, calcium rich and fibre rich functional cookies containing *Curcuma angustifolia* starch and lacto-pickling of greater yam were the significant value addition technologies.

The real-time advisories sent as SMS to the farmers through the electronic device (E-Crop), first of its kind, developed at the institute, addresses the information needs of the farmers. A nutrient decision support system in CD, CASSNUM version 1.1, released for site specific nutrient management of cassava, is yet another achievement. The Tribal Sub Plan programme at Regional Centre, Bhubaneswar, in collaboration with four NGOs spearheaded well benefitting the tribals. The cynosure of all eyes, 'The Techno-Incubation Centre' imparted several training programmes on value addition and entrepreneurship development in tuber crops in a big way. We organized different activities to fulfil the objectives of the 'Mera Gaon Mera Gaurav'' and 'Swachh Bharath Mission', special programmes of Hon'ble Prime Minister. We were graced with the presence of Hon'ble Union Agriculture Minister and Minister of State for Agriculture during a couple of Meetings.

I am extremely grateful to Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his valuable guidance and support. I place on record my gratitude to Dr. N. K. Krishna Kumar and Dr. A. K. Singh the former and present DDG (Horticulture Science), Dr. T. Janakiram, ADG (HS I) and other Officers and Staff of the SMD for their suggestions and timely help. I express my sincere gratitude to Dr. James George, the former Director (Acting), ICAR-CTCRI, for his dynamic leadership and valuable contributions for enhancing the visibility of this institute during the last year. I am also thankful for the external funding by PPV & FRA, EU aided INEA, Indo-Swiss collaboration etc., the network projects and consortia research platforms of ICAR, which enriched our dialogue, added infrastructure and accelerated the research impetus with greater outputs. The constant support from ICAR, coupled with the sincere commitment of the Scientists enabled ICAR-CTCRI to gain global acclaim, for which I sincerely thank one and all! I also appreciate and congratulate the editorial team for bringing out this publication on time.

16 June 2017

Archana Mukherjee
Director

Executive Summary

Crop Improvement

A total of 5558 accessions comprising 1211 cassava, 1124 sweet potato, 1110 yams, 672 edible aroids, 200 minor tuber crops and 1241 collections from regional centre were maintained and conserved in the field gene bank. Three exploration trips were carried out in Chhattisgarh, Assam and Karnataka and a total of 164 accessions of major and minor tuber crops were collected. Sixty accessions were collected from the Bastar region of Chhattisgarh, 89 from Assam and 15 accessions from Joida, Sirsi and Siddapura areas of Uttara Kannada district of Karnataka. A wide variability in tubers were found in the collection.

A total of 1211 accessions of cassava comprising of the indigenous, exotic, landraces and breeding lines were planted in the field for maintenance, characterization and preliminary evaluation. Morphological characterization of 500 accessions of cassava for 12 above ground vegetative plant characteristics using a combination of IPGRI/NBPGR descriptors was completed with digitization of indigenous accessions.

Evaluation of 280 accessions of cassava for 42 tuber traits and yield viz., tuber rind, cortex and pulp colour, shape of tuber, presence of constriction and roots on tuber, tuber taste, tuber rind and cortex texture and ease of peeling, tuber length, diameter, tail and neck length and tuber yield per plant was done. Of the 280 accessions, 173 showed high tuber yield per plant.

Twenty exotic accessions of cassava were analysed for genetic diversity using six SSR markers. The polymorphic primers SSRY-105 and SSRY-28 produced the highest number of four fragments. The primers SSRY-45, SSRY-100 and SSRY-181 showed 100% polymorphism and the similarity coefficient based on SSR markers ranged from 0.45 to 0.90. The accessions CE-56 and CE-84 were 100% similar. These will be assessed further and if identified as duplicates will be pooled together.

A total of 1124 sweet potato accessions is being maintained in the field gene bank. Characterization of germplasm of sweet potato based on morphological descriptors (CIP, 1991) (17 vegetative characters) for 500 accessions has been done. Observation on flowering of accessions was carried out monthly in the germplasm.

Evaluation of tuber traits and yield were performed for 55 accessions from germplasm in three trials. The accession 526/7 exhibited superior performance and was the highest yielder with a per plant yield of 0.49-1.07 kg in these trials. Twenty new accessions of sweet potato were evaluated in augmented design with five released varieties as control. Out of these, RSM-2015-5 from Joida, Karnataka was the highest yielder with 0.58 kg plant^{-1}.

One thousand one hundred and ten accessions of yams comprising of 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. Sixty accessions of greater yam were characterized based on 25 qualitative and 13 quantitative traits including the major yield components and three biochemical characteristics. No duplicate accessions were identified. Principal component analysis showed that the total variance among accessions was contributed mainly by young vein colour, colour of young leaves, leaf shape, petiole length, young leaf vein colour, tuber shape, tuber cortex colour and starch content. The distribution of accessions in the scatter plot revealed high divergence of Da-340, Da-331 and Da-390.

Forty five greater yam accessions were also evaluated for biochemical traits and crude protein content on fresh weight basis, which varied from 2.28% (Da-390) to 5.23% (Da-331). Da-391 had the highest dry matter (48.24%), starch (26.41%) and sugar (3.66%). The sugar content on fresh weight basis ranged from 0.84% (Da-308) to 3.66% (Da-391). Among the accessions Da-331, Da-391 and Da-69 had the highest protein content on fresh weight basis (>5.10%).

Twenty seven accessions of wild yams were characterized using 22 morphological traits comprising of 18 qualitative and four quantitative traits. The biochemical studies of 27 accessions of 18 *Dioscorea* species was done to identify wild yam accessions with better nutritive value. Among the accessions, *D. floribunda* (CTDf-1) had the highest protein content on dry weight basis (14%) followed by *D. hispida*, CTDh-1 (12.46%), while for the fiber and fat content, *D. vexans* (1.29%) and *D. floribunda* (9.31) had the highest values, respectively.

Molecular characterization of 45 accessions of greater yam and 27 accessions of wild yams was carried out using 15 ISSR and 10 SSR primers. The Polymorphism Information Content (PIC) of the primers ranged from 0.6918 (UBC817) to 0.88 (UBC807). The studied primers showed PIC value > 0.8. Dendrogram based on ISSR markers showed that Da340 and Da331 showed maximum genetic divergence from other landraces.

Six hundred and seventy two edible aroid germplasm comprising 429 taro, 203 elephant foot yam and 40 tannia are being maintained in the field gene bank. DNA

of 8 taro; 30 elephant foot yam and 6 tannia lines were deposited in the DNA bank.

ISSR markers were successfully used to differentiate between different aroid species, which were morphologically slightly different from each other. When nine ISSR markers were used in an experiment comprising *Xanthosoma sagittifolium*, *X. violaceum*, a non-acrid *Colocasia* spp., *C. esculenta* and a wild *Colocasia*, all of them grouped separately, except the *C. esculenta* and the wild *Colocasia*, which grouped together, with the wild one as an outlier in the group. The non-acrid *Colocasia* grouped separately suggesting that it is a different species. Its appearance resembles that of *C. gigantea* and once flowering occurs, will be confirmed.

Morphological characterization of 28 elephant foot yam accessions was done using 32 traits (NBPGR minimum descriptors), including aboveground traits and tuber characters. Eighteen quantitative characters were included in this. Weight of the corm was a major contributing factor responsible for separating the accessions in PCA. In the quantitative characters studied, based on the coefficient of variation, the degree of variability was found to be high for fresh weight of corm, height of corm, length of cormels, number of leaflets (primary partition), number of corms, number of tertiary partitions, weight of cormels and number of cormels. Molecular characterization of these accessions was also done using 15 ISSR primers and as in the case of morphological data, no duplicates were present in this set.

A total of 200 accessions comprising Chinese potato, yam bean, arrowroot, *Canna* sp., *Costus* spp., *Tacca* sp., *Arisaema* sp., *Curcuma* spp., *Zingiber* spp., and *Coleus aromaticus* are being maintained in the field gene bank. DNA samples of 20 accessions of Chinese potato accessions were deposited in the DNA bank.

At the Regional Centre, ICAR-CTCRI, Bhubaneswar, different tuber crops comprising 1241 germplasm accessions are being maintained in the field gene bank. It includes taro (506), sweet potato (373), cassava (113), yams (51), elephant foot yam (41), yam bean (146), Chinese potato (5), arrowroot (2), tannia (1) and *Alocasia* (3).

Under the *in vitro* conservation of germplasm of tuber crops, a total of 11 accessions of *Dioscorea rotundata*, 101 accessions of *D. alata* and 192 accessions of sweet potato received from NBPGR are being maintained. Twenty new accessions of sweet potato, 20 taro, 18 cassava accessions from germplasm were brought *in vitro* during this year. Besides, the existing cultures of sweet potato were sub cultured and maintained in the IVAG.

Hexane and ethanol extract of sweet potato leaf and coleus tuber was prepared in the experiment on gene bioprospecting for novel traits in tuber crops. *In ovo* screening of different extracts of purple leaf of sweet potato Acc. No. 1467 was done**.**

The cassava mosaic disease (CMD) resistance of the CMD resistant cassava seedlings screened through grafting and multiplex PCR using ICMV and SLCM specific primers showed that resistance segregated in the ratio 3:1 indicating a dominant gene. Maximum number of CMD resistant hybrids was obtained in the cross 9S-75 x CI-273. Among the CMD resistant hybrids with short-duration, 16S-203 produced the highest tuber yield (7.81 kg plant^{-1}) at the sixth month. Among the CMD resistant hybrids evaluated, 15S-57 had the highest dry matter (44.80%). For culinary purpose, the genotypes, 11S-30, 11S-7, 15S-57, 11S-53 and 11S-4, with high yield (>40 t ha^{-1}), CMD resistance and cooking quality were selected.

Among the triploid cassava evaluated for yield and starch content (>30%), TR44-7 produced the highest yield (64.20 t ha^{-1}). Highest starch content was in Tr44-4 (33.70%). In the trial for identifying cassava lines with good fried chips quality, CMR-100, 8W-5 and CR-21/10 had good quality chips with crispy, soft chips.

In an experiment on pyramiding of genes for cassava mosaic disease (CMD) resistance, the identified 150 true hybrid seedlings having both genes showed 100 per cent field resistance to CMD disease.

For postharvest physiological deterioration (PPD) tolerance in cassava, amongst the 72 cassava genotypes evaluated, Sree Sahya, Kalpaka, CO-1, CR-43-2, CR-20A (2) and CR-24-4 were free of PPD symptom even at 20 days after harvest. Tubers with neck showed less PPD symptoms than the ones without neck. Tuber length, dry matter content and total starch had significant positive correlation with PPD response. Tuber girth, tuber weight and total sugar had significant negative correlation with PPD response.

Among the 159 accessions of cassava screened for drought tolerance on the basis of leaf retention capacity, 31 genotypes had poor, 61 had below average, 53 had average and 14 had above average leaf retention capacity.

During 2016-2017, five varieties of sweet potato for various traits, especially with nutritional attributes and salinity tolerance, were released by Regional Centre, ICAR-CTCRI, Bhubaneswar. ST-13 (Bhu Krishna) is an anthocyanin rich variety (85-90 mg 100g^{-1}); ST-14 (Bhu Sona) is a β carotene rich variety (14 mg 100g^{-1}); ST-10 (Bhu Swami) is a white-fleshed variety suitable for food and processing industries having tolerance to mid-season drought. CIP-440127 (Bhu Kanti) and

CIPSWA-2 (Bhu Ja) are the other released varieties.

In sweet potato breeding, progressive evaluation of 265 genetic resources resulted in selection of 16 lines having more than 18 t ha^{-1} yield, four of which was observed to have 75 days maturity. The accession nos. S30/15, S30/16, Baster-45 and Acc. No. 527 with 75 days maturity also responded to half doses of N and K (37.5: 37.5).

Progressive evaluation of previously selected 29 sweet potato breeding lines generated through open pollination for high starch, β-carotene, anthocyanin and weevil resistance showed 75 days maturity in seven lines, two of which were having white flesh, two orange flesh and three purple flesh. Of the rest, 90 days maturity was recorded in six white, three purple and five orange flesh sweet potato lines. Yield ranged from 18.70 to 20.80 t ha^{-1} for lines with 75 days maturity and 24.90 to 35.50 t ha^{-1} for lines with 90 days maturity, respectively.

Evaluation of the clonal generation of F_1 (C_1F_1 2015-16 and C_2F_1 2016-17) generated through reciprocal crosses in sweet potato, revealed 75 days maturity in eight hybrids, of which four were white, one orange and three purple-fleshed. Starch content ranged from 15-18%, β-carotene 10-16 mg $100g^{-1}$ and anthocyanin 65-100 mg $100g^{-1}$ in these lines.

One short-duration greater yam variety (6-7 months), Bhu Swar (Da-25) was released by Regional Centre, ICAR-CTCRI, Bhubaneswar with good coking quality and yield of 20-25 t ha^{-1}.

Among the 9th clonal white yam hybrids evaluated, Drh-1150 produced the highest tuber yield (46.90 t ha^{-1}) followed by Drh-1125 (43.21 t ha^{-1}). Among the dwarf white yam hybrids (9th clonal) evaluated under irrigated condition, Drd-1157 produced the highest tuber yield (73.20 t ha^{-1}) followed by Drd-1038 (51.70 t ha^{-1}), Drd-1118 (51.10 t ha^{-1}) and Drd-1095 (39.5 t ha^{-1}). The dwarf clones, Drd-9495 and Drd-1060 had better cooking quality than the released dwarf white yam variety, Sree Dhanya. Among the semi-dwarf varieties of white yam, SD-15 produced high yield coupled with excellent culinary quality.

In vitro screening of 71 accessions of greater yam using highly virulent isolate of *Colletotrichum gloeosporioides* for anthracnose showed that eight accessions did not show any infection and 14 showed resistance with a disease scale of 1-2 including the released varieties, Sree Karthika and Sree Keerthi.

Two taro varieties viz., Bhu Kripa (Jhankri) and Bhu Sree (Sonajuli) were released by Regional Centre, ICAR-CTCRI, Bhubaneswar, with good cooking quality and yield of 15-20 t ha^{-1}.

Of the fifteen taro accessions screened artificially, four showed moderate resistance to taro leaf blight in the first season, whereas, nine and seven accessions screened earlier showed tolerance in the second and third seasons, respectively. Flowering was noted in few taro lines. Crossing was attempted with two accessions as female parent (C-157 and C-688) with TLB tolerant lines, Muktakeshi, C-565 and C-203 as male parents. The seeds were collected, dried and stored for further germination studies.

In elephant foot yam, a total of 240 corms were selected from the hybrid progeny of the six crosses from previous two years, the corm weight of which ranged from 5g - 550g. Most of the corms had numerous cormels. Six genotypes with smooth petiole and reasonably higher yield were identified during the second year.

In PYT 1 in tannia, the total yield ranged between 9.61 (Xa-12) to 19.88 t ha^{-1} (Xa-AD/2014-15).

In the AYT for arrowroot, M-1 produced the highest per plant yield (0.64 kg), number of tubers per plant (16) and biggest tuber length (22.11cm). Tuber node length was highest for M-5 (1.51 cm) and tip length highest for M-6 (1.41 cm).

Biochemical analysis in seven arrowroot genotypes showed that the highest dry matter content of 32.35% was recorded in M-7, while the total starch and sugar content were highest for M-1. The total starch content on dry weight basis ranged from 54.15% (M-1) to 50.43% (M-7). Total sugar varied from 2.40% (M-1) to 1.98% (M-5). The total ash content was highest in M-4 (4.23%) and the lowest in M-2 (3.18%). The total crude fibre content was lowest for the accession M-1 (1.71%) and highest for the accession M-7 (2.19%).

In yam bean, the tuber yield in F_2 generation of the five best F_1 hybrids ranged from 30.55 t ha^{-1} (3x9) to 36.11 t ha^{-1} (3x10) as compared to 24.99 t ha^{-1} in RM-1 as a check variety. Starch content ranged from 9.34% (3x8) to 15.33% (3x9) and sugar content ranged from 3.88% (3x8) to 7.55% (3x9). The DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity determination showed that 3×10 had the highest ability (40.11%), while 3×8 had the lowest scavenging ability (28.13%). Lignin content ranged from 1.23% (3×8) to 2.85% (3x9).

In the experiment on genetic modifications for quality improvement in cassava, 9S-127 and CR-4311 (CMD resistant cassava, lines) were multiplied *in vitro*. TMS60444 FEC transformed with glgC gene maintained in maturation media was transferred to regeneration media. New embryogenic callus was initiated from 9S-127 and callusing was initiated in CR-4311.

Using cassava transcript sequences retrieved from the Phytozome website, NovoMIR predicted a total

of twenty nine novel miRNAs from 41,381 cassava transcript sequences. The predicted miRNAs targeting transcript sequences of cassava were subjected to functional annotation by BlastX. The major functions were ADP binding property, ATP binding, ion transport, ATP hydrolysis coupled proton transport, lipid binding and hydrogen ion transmembrane transporter. RNA Hairpin Figure draws hairpin-like text figure from RNA sequence and its secondary structure in dot-bracket notation.

A total of 219 SNP markers and 10,307 SSR markers in *A. paeoniifolius* associated with dasheen mosaic virus were predicted using bioinformatics tools. SNP 748 could differentiate the resistant and susceptible varieties. About 374 novel microRNA's in *Amorphophallus* and 29 novel microRNA's in cassava and its secondary structure were predicted using bioinformatics tools.A database of predicted SNPs and SSRs of cassava and predicted miRNA for *Amorphophallus* was developed.

Crop Production

Fertigation studies in cassava during the third year as well as pooled analysis of data of three years confirmed that N and K_2O @ 75 and 100 kg ha^{-1} was optimum for obtaining maximum tuber yield in short-duration cassava variety (Sree Vijaya) raised through minisetts under drip fertigation.

On-farm validation experiments of customised fertilizers developed for cassava based on SSNM technology were conducted in 35 farmers' fields spread across five agro-ecological units (AEU) zonations of Kerala (Malappuram, Palakkad, Idukki, Alappuzha and Pathanamthitta). In Idukki, Malappuram and Palakkad districts, the customized fertilizer treatment resulted in significantly higher tuber yield (42.50, 62.50 and 48.60 t ha^{-1} respectively) than farmer fertilizer practice (FFP) (35.30, 50.30 and 38.40 t ha^{-1} respectively). On an average, the customized fertilizer treatment resulted in 24% higher yield over FFP in these agro-ecological units. The decision support system for SSNM of cassava, CASSNUM version 1.1 was released.

Sustainability of cassava for continuous cultivation was established after 12th season crop with a tuber yield of 14.27 t ha^{-1}, without manures and fertilizers. Soil test based application of NPK @ 84:0:106 kg ha^{-1} along with FYM @ 5 t ha^{-1} produced tuber yield (23.18 t ha^{-1}) on par with the recommended POP (FYM @ 12.5 t ha^{-1} + NPK @ 100:50:100 kg ha^{-1} +) (23.06 t ha^{-1}). Continuous application of NPK @125:50:125 (25.61 t ha^{-1}), 100:50:100 (23.06 t ha^{-1}), 50:25:100 (28.91 t ha^{-1}), 50:25:50 (21.40 t ha^{-1}) and soil test based @ 84:0:106 kg ha^{-1} (23. 18 t ha^{-1}) were on par with respect to tuber yield.

Different organic manures tried viz., green manuring with cowpea (28.91 t ha^{-1}), coir pith compost (20.09 t ha^{-1}) and vermicompost (21.69 t ha^{-1}) served as alternatives to FYM (23.06 t ha^{-1}). Organics alone applied as combination of crop residue, coir pith compost, vermicompost and ash without any chemical fertilizers (18.99 t ha^{-1}) resulted in a significantly lower yield than other organic sources along with chemical fertilizers. Green manuring with cowpea (32.57 t ha^{-1}) resulted in a significantly higher yield compared to FYM (23.88 t ha^{-1})

Soil test based application of Mg (0.270 meq $100g^{-1}$) as MgSO4 alone @ 15 kg ha^{-1} (32.89 t ha^{-1}) and along with Zn (2.830 ppm) as ZnSO4 @ 2.5 kg ha^{-1} (39.180 t ha^{-1}) were on par and significantly higher in tuber yield than POP (23.06 t ha^{-1}). Soil test based application of single, two nutrient and three nutrient combinations of Mg, Zn and B were on par to POP.

Among the NUE genotypes evaluated for reduction/ substitution of NPK fertilizers, 7 III E3-5 produced significantly highest tuber yield (49. 44 t ha^{-1}), on par with Acc. No. 905 (43.10 t ha^{-1}). Sree Pavithra (39.47 t ha^{-1}) and Acc. No. 906 (39.87 t ha^{-1}) produced yield on par with Acc. No. 905. The four different levels viz., 25 (39.77 t ha^{-1}), 50 (41.58 t ha^{-1}),75 (44.34 t ha^{-1}), 100% (46.20 t ha^{-1}) did not significantly influence the tuber yield indicating that when NPK efficient genotypes were used, the NPK levels could be reduced up to 25%. Apparent recovery efficiency (ARE) and utilization efficiency (UE) were significantly influenced by interaction effect of genotypes and NPK levels. The genotype 7 III E3-5 at 25% NPK had significantly the highest ARE (13.05) and UE (0.77).

Response of cassava to different soil tillage and mulching practices in laterite soils revealed that cassava tuber yield was highest under deep tillage (DT) (31.60 t ha^{-1}) followed by conventional (CT) (27.80 t ha^{-1}) and minimum tillage (MT) practices (26.20 t ha^{-1}). The different types of mulches influenced the yield in the order porous ground cover (GC)>crop residue (CR)>no mulch (NM).

The average volumetric surface soil moisture were 8.20, 9.10 and 9.80 % (v/v) and the soil temperature were 36.2, 35.9 and 35.5^{o}C respectively under CT, DT and MT practices. Among the mulch practices, GC had high moisture content (10.30 %, v/v) when compared to no mulch (7.80 %, v/v). Saturated hydraulic conductivity and sorptivity of CT was 10 and 22% higher than minimum tillage, whereas 16% increase in matric potential was observed under GC as compared to NM. The interaction between minimum tillage and GC mulch showed improved values of sorptivity (0.032 cm $min^{-1/2}$) as compared to the first year (0.023 cm

$min^{-1/2}$), but significantly less than deep tillage treatment. Soil properties viz., soil moisture, bulk density and available P and K had significant positive relationship (r=0.72**) with tuber yield in conventional tilled soils.

On-station developed (at ICAR-CTCRI) organic production technologies for cassava and yams were validated in an organically raised 48 year old coconut plantation at ICAR-CPCRI, Kasaragod, for the second season. Yield under organic mode (0.76 and 0.98 respectively of conventional) was on par with chemical system in both cassava (8.14 and 10.71 t ha^{-1}) and yams (*Dioscorea* spp.) (6.81 and 6.91 t ha^{-1}) intercropped in coconut garden based on average yield data of two years.

Kernel based Possibilistic *c*-means approach developed for cassava acreage estimation was validated for area estimation in Namakkal and Dharmapuri districts. Ground truth data were collected and the area was estimated. The total estimated area was 17125 ha and 19263 ha for Dharmapuri and Namakkal districts respectively.

Future changes in climate and climate suitability over major cassava growing regions of India by 2050 were studied using geoinformatics tools (DivaGIS) and AR5 data of IPCC. The model predicted that by 2050, the mean temperature of cassava growing areas in India will increase on an average by 1.86°C (0 - 2°C). The total precipitation of cassava growing areas in India will increase on an average by 231.60 mm (0-366 mm). The results showed that in the cassava growing environments of India, the climate suitability will increase by 42.30% (-57-100%) in 2050.

On-farm validation experiments of customised fertilizers developed for sweet potato based on SSNM technology were conducted in seven farmers' fields in Denkanal district, Odisha for two consecutive seasons. The tuber yield in SSNM treatment (11.50 t ha^{-1}), was on par with that of FFP (11.80 t ha^{-1}). Secondary-and micronutrient-inclusive customised plant nutrient formulations were developed for major yams and sweet potato growing areas of India.

Application of N, P_2O_5 and K_2O @ 50:25:50 kg ha^{-1}, was found optimum to realize higher tuber yields of sweet potato with good quality tubers in the natural saline soils under island ecosystem of Andaman.

In sweet potato, dolomite followed by gypsum along with foliar application of $CaNO_3$ was the best liming practice. INM along with dolomite and foliar application of 19:19:19 + Zn EDTA during the peak vegetative growth stage and KNO_3 along with solubor twice at tuber bulking stage at an interval of one month was effective for sweet potato.

In greater yam + maize intercropping system, drip irrigation at 100% CPE (cumulative pan evaporation) resulted in higher maize yield. However, greater yam yield (33.80 t ha^{-1}) and tuber equivalent yield (36.50 t ha^{-1}) were higher at 100% CPE 1-90 DAP (days after planting) + 80% CPE 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. However, it was on par with $N:P_2O_{5:}K_2O$ @ 140:90:140 kg ha^{-1}. Drip irrigation at 100% CPE 1-90 DAP (days after planting) + 80% CPE 91-270 DAP along with fertigation of $N:P_2O_{5:}K_2O$ @ 140:90:140 kg ha^{-1} resulted in higher use efficiency of water (50.30 kg ha-mm^{-1}) and nutrient (107.80 kg kg^{-1}) as well as B:C ratio (2.85).

Elephant foot yam corms fumigated with carbon disulphide @ 80 ml 100 kg^{-1} led to higher uniform sprouting (85.49 and 98.45% at 15 and 30 days after planting respectively), canopy growth and significantly higher yield (19.50 t ha^{-1}).

Different water saving techniques were tried along with micro irrigation in elephant foot yam to ascertain the possibility of reducing the water requirement. Significant difference in corm yield was obtained among the treatments. Significantly highest corm yield (27.81 t ha^{-1}) was obtained by providing drip irrigation at 50% CPE, along with weed control ground cover mulching compared to all the other water saving techniques.

In elephant foot yam + pulses intercropping system, the yield of elephant foot yam under intercropping with pulses (14.16 t ha^{-1}) was on par (-8.82%) with sole cropping (15.53 t ha^{-1}), Among the elephant foot yam varieties, Gajendra (18.78 t ha^{-1}) proved superior to Sree Padma (13.16 t ha^{-1}) and Sree Athira (10.54 t ha^{-1}). Black gram was the most suitable pulse crop (228.58 kg ha^{-1}) for intercropping in elephant foot yam. Among the treatment combinations, elephant foot yam var. Gajendra + black gram under full fertility level resulted in yield (21.60 t ha^{-1}), equivalent energy (79.82 x 10^3 MJ ha^{-1}), production efficiency (122.80 kg ha^{-1} day^{-1}) and tuber equivalent yield (22.10 t ha^{-1}) on par with sole cropping of elephant foot yam var. Gajendra (22.53 t ha^{-1}, 81.11 x 10^3 MJ ha^{-1}, 125.16 kg ha^{-1} day^{-1}, 22.53 t ha^{-1}).

Among the various weed management practices in elephant foot yam, use of weed control ground cover resulted in higher weed control efficiency (96.40%), corm yield (36.0 t ha^{-1}) and gross returns (Rs. 5,39,700 ha^{-1}). Higher benefit:cost ratio (2.42) was obtained in two rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) treatment due to low cost of cultivation. Dolomite @ 1.5 t ha^{-1} was the best liming material for elephant foot yam. Soil + foliar application of B, Ca and Mg were beneficial for elephant foot yam.

Field trials conducted at three locations in AEU 3 and

four locations in AEU 9 each for cassava and elephant foot yam under intercropping in coconut to develop best management practices (BMP) taking into account the subsoil acidity revealed no significant effect of BMP comprising of organic manures, NPK fertilizers, liming materials (lime, gypsum and dolomite) and secondary and micronutrients (Zn and B) on corm yield of elephant foot yam compared to POP, farmers practice, NPK+FYM along with liming materials and NPK+FYM along with secondary and micronutrients.

Evolved three custom mixed fertilizer grades comprising of major, secondary and micronutrients for elephant foot yam intercropped in coconut gardens based on STCR approach (targeted yield of 45 t ha^{-1}) and response curve approach and developed three custom mixed formulations for AEU 3 and AEU 9. Field testing of these three formulations at two rates viz., 500 and 625 kg ha^{-1} in one location in AEU 3 and three locations in AEU 9 indicated significantly higher yield with 625 kg ha^{-1}, but the tuber yield was on par under the three grades.

In a study to induce tolerance to high temperature stress through chemical treatments in elephant foot yam, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4^{th} to 8^{th} month increased corm yield by 27.77%, 29.98% and 17.2% respectively as compared to control plants under ~32°C day temperature under field conditions. Under humidified polychamber conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4^{th} to 8^{th} month increased corm yield by 22.70%, 27.12% and 5.04% respectively as compared to control plants under 32-40°C day temperature and >80% RH (10 am – 4 pm). Under polychamber conditions without humidification, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4^{th} to 8^{th} month increased corm yield by 39.73%, 36.43% and 4.26% respectively as compared to control plants under 32-40°C day temperature and ~50% RH (10 am – 4 pm). Compared to field conditions, the corm yield was significantly reduced by 28.78% to 56.68% under polychamber conditions in control as well as under $CaCl_2$, Salicylic acid and BA treatments.

Evaluation of organic, inorganic and integrated management practices in cropping systems involving tuber crops indicated that in taro-green gram and taro-black gram system, the production efficiency was highest for 50% organic + 50% inorganic (60.56 kg ha^{-1} day^{-1}) and 75% organic + 25% inorganic (68.47 kg ha^{-1} day^{-1}) respectively. In cassava-groundnut system, 100% inorganic followed (141.43 kg ha^{-1} day^{-1}) by 100% organic and in cassava-vegetable cowpea system, 100% organic (112.99 kg ha^{-1} day^{-1}) closely followed by 100% inorganic resulted in higher system productivity.

Based on two years' experimentation at ICAR-CTCRI in arrowroot, organic production technologies involving FYM @ 10 t ha^{-1}, green manure @ 10-15 t ha^{-1} and biofertilizers (*Azospirillum*, P solubilizer and K solubilizer @ 3 kg ha^{-1} each) were developed; yield under organic management (12.81 t ha^{-1}) was 2% lower than conventional (13.05 t ha^{-1}) and integrated (12. 93 t ha^{-1}) practices.

Geo-referenced on-farm characterization of organic growers conducted in Thiruvananthapuram district indicated that among the organic farmers surveyed, 94% belonged to small and marginal group with an average land holding size less than 2 ha and the farms were uncertified. Farm animals were an integral part of the organic system. Majority of farmers (79%) practise organic farming mainly for sustenance to provide safe food to their family rather than marketing and making profit. Among the respondents, 42% deployed the on-farm generated organic manures for crop production. Cultural and eco-friendly techniques were mainly adopted for pest management. Among the market centred enterprises, piggery, ornamental fishes and organically produced cut flowers received premium prices with high B:C ratios.

Mass multiplication of virus free planting materials continued through procedures involving indexing, micropropagation, hardening and minisett multiplication under protected environment. Disease free planting materials were produced and supplied in selected areas of Kerala, Tamil Nadu, Odisha and north-east India in a farmer's participatory mode. Farmers' training programme were also organized and popularised. A total number of 250 micro plants of different cassava varieties were indexed against cassava mosaic virus through micropropagation technique in the tissue culture laboratory. A total number of 160 micro plants of elephant foot yam, variety Gajendra were indexed.

Crop Protection

Synthetic pesticides viz., Malathion, Chlorpyrifos, Dimethoate, Fenvalerate, Imidacloprid and Dichlorvos were screened at three concentrations viz., 0.001, 0.01 and 0.05% against sweet potato weevil by feeding the leaves. A positive correlation was noted between mortality of the weevil and concentration of the insecticides used. The toxicity was higher for Imidacloprid followed by Chlorpyrifos, Fenvalerate, Dichlorvos, Dimethoate and Malathion. Systemic action was found very high in Imidacloprid. HCN, the active principle in the biopesticide, *Menma,* was estimated in open condition at regular intervals and the residue was negligible at 24 h after exposure.

Insect pests of sweet potato, taro and yam bean were surveyed in Andhra Pradesh, Kerala and Odisha.

Sweet potato weevil, *Cylas formicarius* was the single and most serious pest causing damage up to 90%, if management practices were not adopted. Koraput, Navranpur, Puri, Khurda, Bargarh, districts of Odisha were surveyed, and in Kerala, the farms of ICAR-CTCRI, Thiruvananthapuram were surveyed. Eighteen insecticides including new generation insecticides viz., Imidacloprid @ 30 g ai ha^{-1}, Dimethoate @ 300 g ai ha^{-1}, Acetamiprid @ 15g ai ha^{-1}, Acephate @ 350 g ai ha^{-1}, Thiomethoxam @ 25 g ai ha^{-1}, Triazophos 35 + Deltamethrin 1EC @ 360 g ai ha^{-1}, Chlorpyriphos @ 200 g ai ha-1, Profenophos + Cypermethrin @ 400 g ai ha^{-1}, Profenophos + Cypermethrin @ 400 g ai ha^{-1}, Fipronil @ 40 g ai ha^{-1}, Buprofezin @ 75 g ai ha^{-1} were evaluated against borer pests of tuber crops during 2016-2017 rabi season at ICAR-CTCRI farm, Bhubaneswar. All insecticides tested were effective in reducing the weevil incidence and infestation in treated plots (0 to 3.1%), whereas, control plots had 18.20% infestation in tubers. Besides, intercropping with marigold resulted in lowest tuber infestation (13.73%), followed by coriander (17.66%), *Cleome viscosa* (32.33%) and yam bean (30.33%). Sweet potato weevil sex pheromone technology was popularized in different districts of Kerala, Andhra Pradesh and Odisha and pheromone lures were sent to different AICRP Centres in Telangana, Chhattisgarh and Maharashtra.

Sweet potato weevil samples 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 using universal primers LCO 5'GGTCCACCAAT CATAAAGATATTGG3'and HCO 5'TTAACTTCAGGGTGACCAAAAAATCA3'. 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.

A random survey was undertaken in elephant foot yam fields of three southern states of India, Kerala (Manyali, Perinthalmanna and Pulpally), Andhra Pradesh (Kovur) and Tamil Nadu (Apakoodal) during April-December 2016. *Rotylenchulus reniformis* was the most predominant nematode in Perinthalmanna, with a prominence value of 75. While, *Pratylenchus* sp. was the most predominant nematode in both Malappuram and Wyanad, with prominence values of 60 and 70, respectively. In Kovvur, *Hoplolaimus indicus and Pratylenchus* sp. were observed in maximum frequency and abundance and their prominence values were 33.80 and 10.30, respectively. While, *Meloidogyne incognita* (30.40) and *Pratylenchus* sp. (14.90) were the most predominant nematodes in Apakoodal. In ICAR-CTCRI campus, *Pratylenchus coffeae* and *M. incognita* were the most abundant nematodes, with a population density of 1.50 and 1.10 nematodes per gram of soil, respectively. Nematode mapping of Block I of ICAR-CTCRI revealed the presence of nine genera of plant parasitic nematodes. *In-vitro* efficacy of biopesticide formulation, *Menma* against second stage juveniles of *Meloidogyne incognita* resulted in 100% mortality up to 100 ppm. Two isolates of *Trichoderma asperellum* (CTCRI TR 9 & CTCRI TR 15) showed significant nematicidal activity against second stage juveniles of *Meloidogyne incognita* with Tr 9 showing more effect compared to Tr 15. Both the isolates of *Bacillus subtilis* (Bs 9 and Bs 19) had significant effect on suppression of infective juveniles of *M. incognita*.

Association of SLCMV (*Srilankan cassava mosaic virus*) and ICMV (*Indian cassava mosaic virus*) was found as mixed infection in all the samples collected from cassava growing areas of Kerala. *Bemisia tabaci* specific 10 ISSR primers were identified for studying genetic variations among whitefly populations. Biotypes specific banding patterns were identified using ISSR primers for whitefly biotypes Asia I and Asia II-5.

Out of the six CMD resistant clones viz., 8W5, 9S-127, CR-43-11, 8S-501-2, CR-24-4, CR-43-2 field evaluated in Salem district, the farmers ranked 8S-501-2 as the best variety followed by CR-24-4 and CR-43-11 owing to its high yield, CMD resistance and close similarity to the locally preferred variety, H-226. ACMV (*African cassava mosaic virus*) resistant transgenic cassava showed high susceptibility to SLCMV infection through whitefly transmission. The SLCMV coat protein gene was expressed in bacterial system and the protein was purified.

The role of micronutrients viz., Si>Zn > Ca >P>B in managing the CMD was observed in a field trial during first season. Protocol for synthetic seed production in cassava has been developed, which will be useful for quality planting material production. The encapsulation of cassava buds with 3% sodium alginate polymerized in 100 mM calcium chloride was the optimal concentration to produce synthetic seeds in cassava.

LAMP (Loop-mediated isothermal amplification) based diagnosis of *Sri Lankan cassava mosaic virus* (SLCMV) and *Dasheen mosaic virus* (DsMV) was developed. The presence of *Badna virus* was detected in taro leaves using genus and virus specific primers. Detection of *Yam mild mosaic virus* (YMMV) from lesser yam tubers was standardized. Among different parts of the tuber, the tuber flesh was good for sampling tubers. Ninety kg of virus free tissue cultured elephant foot yam tubers were planted in farmers' field, which yielded 13 fold (~1196 kg). Tuber samples collected from the farmer's field

were indexed for DsMV and were free from infection. Indexing of field grown elephant foot yam tubers has also been done for DsMV infection using DAS-ELISA. Among 37 samples tested, only 3 (8%) showed positive. The healthy tubers are being multiplied at ICAR-CTCRI and also in farmer's field.

Sixteen *Trichoderma* isolates, which showed consistent pathogen suppressive potential was identified using TEF and ITS region amplification. The isolates were identified as *Trichoderma asperellum* (11 isolates), *T. harzianum* (3 isolates) and *T. virens* (2 isolates). *Piriformospora indica* colonisation in taro plants resulted in growth promotion and less taro leaf blight (TLB) incidence in Sree Kiran and Muktakeshi. In Sree Kiran, *P. indica* colonized plants showed 57.60%, 50.70% and 84.30% disease reduction and in Muktakeshi, it was 39.90%, 56.20% and 72.50% over control at various stages observed.

Subtractive suppression hybridization assay was carried out to study the differential expression of genes in *P. indica* colonized taro plants consequent to *Phytophthora colocasiae* infection. Five genes were identified and their functions were determined. Among the identified genes, senescence associated genes, Cytochrome P450, Delta (12) oleic acid desaturase FAD2 and Calcium-dependent protein kinases (CDPKs) fall under different defense related pathways.

Among the various strategies to manage TLB incidence, the least percent disease incidence (PDI) at different growth stages was noticed with metalaxyl-M @ 0.05%, with PDIs of 8.13, 15.90, 10.80, 14.80 and 15.90 followed by the treatment, borax + *Bacillus subtilis* + vermicompost with PDIs of 10.70, 27.60, 19.30, 20.20 and 22.30 as against 22.90,42.10, 32.7, 39.90 and 45.40 in control. The highest yield was obtained in the treatment with metalaxyl-M (15.70 t ha^{-1}). Among the various strategies to manage collar rot incidence in elephant foot yam, the least disease incidence was recorded in the treatment, mancozeb + carbendazim @ 0.2% (4%) followed by *T. asperellum* + vermicompost (5.3%) as against 16 % in control.

The fungicides, carbendazim (bavistin), mancozeb + carbendazim (sprint and saaf), copper hydroxide (kocide), bio-pesticide (*Nanma*) and neem oil were tested against the mycelial growth of the pathogens associated with post-harvest diseases in elephant foot yam under *in vitro* condition. The fungicide, mancozeb + carbendazim (sprint) could completely arrest the growth of all the pathogens at 100 ppm.

Suitable SSR markers were identified for characterizing *P. colocasiae* from reported SSR markers for *Phytophthora* spp. Resistant Gene Analogues (RGAs) were amplified, sequenced and characterized from resistant (Muktakeshi) and susceptible (Sree Kiran) taro cultivars.

In the second year of field trial on refinement of the management of anthracnose in greater yam, soil application @ 50 g of 10^7 cfu g^{-1} and tuber treatment with 5g of *Trichoderma* in fresh cowdung slurry per kg of tubers along with foliar spraying of carbendazim @ 0.05% seven times, first three at fortnight interval and further at monthly intervals after symptom initiation significantly reduced the disease intensity (63%) and increased yield by 32% compared to absolute control.

A controlled condition pot trial on the effect of cassava based biopesticides on greater yam anthracnose indicated that soil and tuber treatment with *Menma* @ 1% and spraying *Nanma* @ 0.7% at weekly intervals showed maximum reduction in PDI (71%) compared to control. This was followed by soil and tuber treatment with *Nanma* @ 0.7 % (43%) and also soil and tuber treatment with *Menma* @ 1% and spraying neem oil @ 0.2% weekly (37%). One fungal and three bacterial endophytes isolated from tuber crops showed inhibition of growth of *Colletotrichum gloeosporioides*. They were identified as *Trichoderma* sp, *Bacillus subtilis*, *B. amyloliquefaciens* and *B. pumilus*.

The resistant gene analogue (RGA) has been amplified from greater yam using published and newly designed primers. Their expression was increased following *Colletotrichum gloeosporioides* infection. They behaved differently in the response to time in the tolerant and the susceptible varieties. Expression studies on tissue culture plants showed increased expression earlier in tolerant variety, Sree Keerthi (3rd day) than susceptible, Orissa Elite (5th day).

Crop Utilization

Curcuma angustifolia starch based protein rich functional cookies, calcium rich functional cookies and fibre rich functional cookies were developed and analysed for the nutritional quality. Studies were undertaken for the development of vacuum fried purple-fleshed and orange-fleshed sweet potato chips. Ready-to-eat (RTE) nutri bars fortified with sweet potato flour was developed using sweet potato flour (20-30%), bengal gram (10-15%), green gram (10-15%) with oats, nuts etc. Sweet potato based functional bars enriched with resistant starch were developed by incorporating enzymatically modified cassava resistant starch. The recipe for preparation of sweet potato flour based gluten free cookies were optimized using sweet potato flour (40-60%), rice flour (20-25%), sorghum flour (15-20%) and cassava flour (5-15%).

The taro tubers were treated with 1% citric acid followed by blanching (100°C, 5 min.) to remove acridity and to

obtain bright colour flour. Taro flour based gluten free cookies were produced using taro flour (40-60%), rice flour (20-25%), sorghum flour (15-20%) and cassava flour (5-15%). *Jimikand* flour, *Jimikand* papad and *Jimikand* shorts were prepared. Lacto pickling of yam tubers (var. Orissa Elite) was carried out using mixed starter cultures of *Lactobacillus plantarum* and *L. acidophilus* and incubated for 21 days. The shelf life of the pickle without any preservative was 30 days.

In the farm mechanisation programme, two cassava varieties, H-165 and *mulluvadi* were planted under three methods viz., manual mound method, manual ridge method and tractor drawn ridge method to find out the best method of planting for mechanisation. A cassava harvester was evaluated and found that the capacity of the machine ranged between 1800-2580 cassava plants per hour, whereas manually 840 plants could be harvested in an hour. The percentage of damage was 8.40%.

Particle boards were developed from dried cassava stems using cassava starch with glycerol as bio-adhesive. Single phase corrugating adhesive formulations were developed from the acid thinned cassava starch. Modified atmospheric storage of cassava roots was carried out with high concentration of CO_2 in storage container with five varieties of cassava (Sree Jaya, Sree Vijaya, Vellayani Hrashwa, Kalpaka and Sree Swarna) to delay PPD. Shelf-life was marginally increased for the fresh tubers. Wax coating of cassava after selected pre-treatment techniques was developed for increasing shelf-life for one month or more periods for retail sale or export of cassava roots. Screening tool for PPD using Near Infrared Spectroscopy (NIRS) was developed to analyse root samples for PPD and another technique has been developed for analysing the quality changes in tubers under storage.

Two types of thermoplastic starch sheets (TPS) using cassava starch added with glycerol as plasticizing agent in one type and with glycerol and bentonite clay in another type were developed. Cassava and sweet potato starches were subjected to different types of modifications to synthesize resistant starch enriched products, which have significantly lower glyceamic index in comparison to corresponding native starches. Hydrogels prepared from native as well as modified cassava starch and starch composites have been found suitable for incorporation of the therapeutic drug. Structure of anthocyanins present in ST-13 and leaves of accession S-1467 of sweet potato and the purple tubers of greater yam (Acc. Da-340) were determined. Four new acylated anthocyanins were identified in the tubers of greater yam Acc. Da-340. Microencapsulation with maltodextrin increased the colour stability of sweet potato and greater yam anthocyanins by 23.81% and 7.32% respectively.

Spectral properties of cassava tubers such as absorbance and transmittance were measured over a wave number range from 4000 cm^{-1} to 700 cm^{-1} using FT-NIR spectrometer for 21 varieties of cassava. The developed cassava starch meter mainly consists of three units viz., sensor unit, microcontroller unit and a display unit. The sliced sample cassava is placed between the sensor plates. PIC16F877A microcontroller and LM016L LCD are used in the equipment. A cassava slicer for the preparation of sample was developed. The electronic gadget was evaluated at SAGOSERVE, Salem and a high level of correlation was established between the gadget and chemical readings ($P<2.96\times10^{-9}$). During the demonstration it was found that the gadget received good acceptability among the cassava farmers, traders, starch and sago manufacturers. A MoU has been signed with the industrial partner M/s Environmental Measurements and Controls (EMCON), Cochin for commercializing the gadget.

Process production of high quality cassava flour studies 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 and flour from crushed and pressed gratings). The best sample was obtained from crushed and pressed gratings dried in the polycarbonated roofed yard with a loading density of 3 kg m^{-2}.

Five varieties of sweet potato, local, Sree Kanaka, Sree Arun, ST-13 and ST-14 were planted in 15 acres in the mining areas of Belgaum under RBD. The average tuber per plant was highest in Sree Arun (250 g $plant^{-1}$) followed by ST-14 (150-200 g $plant^{-1}$). The bio-chemical and micronutrient properties of these varieties were analysed. The moisture, protein, fat, carbohydrate, ash, and total sugars as sucrose were estimated as 71.1, 1.3, 0.3, 26.4, 0.9 and <0.5% in sweet potato fresh tubers, whereas in the sweet potato flour the corresponding values were 6.4, 4.6, 0.9, 86.5, 1.6 and 13.4%. The vitamin A, C and B12 of sweet potato tubers were estimated as 197.08, 49.20 and 49.20 ppm and in sweet potato flour the values were 227.96, 14.83 and 14.83 ppm. The formulation for the development of sweet potato based weaning food mix powder was standardized. The level of sweet potato flour used was 40-70% with cow pea flour (5-10%), soybean flour (5-15%), peanut flour and milk powder etc. It provided starch 29.79-37.41%, sugar 26.07-32.01%, fat 10.72-15.41%, protein 8.63-18.46% and fiber 1.66-1.78%.

Techno-incubation centre under the Division of Crop Utilization organized 25 on campus and 16 off campus training programmes on value addition and

entrepreneurship development in tuber crops. It was attended by 444 people, including farmers and young entrepreneurs from different districts of the state. The incubation centre was used by 32 incubatees for the production of snack foods like *pakkavada, crisps, nutrichips, murukku, sweet fry and pasta*.

Extension and Social Sciences

Under the Front Line Demonstrations (FLD) conducted at Belagavi, Karnataka under commercial sweet potato systems, Sree Arun produced the highest yield (36.00 t ha^{-1}), followed by ST -14 (20.15 t ha^{-1}) and Sree Kanaka (16.12 t ha^{-1}). The *Kunbi* indigenous people of Joida, Karnataka were found as efficient conservators of varieties of taro and yams. Indigenous knowledge like seed storage, ethnic foods and removing anti-nutritional factors through river streams were documented.

In a consumer acceptability study, the urban pasta consumers preferred cassava pasta because of its aroma (mean = 6.06) and taste (mean = 6.10) and suggested improvements in appearance, colour and texture of pasta. The willingness-to-pay estimates derived from Vicker's second price auction indicated that the respondent's average willingness to pay was Rs. 146.50, which has increased to Rs. 188.00 (increase by 28%) when the crop information was supplied. When the health benefits of cassava pasta were explained, the willingness-to-pay increased to Rs. 191.00 indicating a significant rise over the commercial pasta.

The livelihood analysis study conducted in Kanya Kumari and Tirunelveli districts of Tamil Nadu indicated that the human capital index was more for rice farmers (0.61), when compared to tuber crops farmers (0.49). Physical capital was also high for rice farmers (0.71). Natural capital was marginally high for rice farmers (0.70) and for tuber crops farmers it was 0.66. Financial capital was also more for rice farmers (0.56), but in the case of tuber crops farmers it was 0.45. Social capital was same for both the farmers (0.57). The Rural Sustainable Livelihood index for rice farmers was more (0.63) than tuber crops farmers (0.52). The *t* test revealed that there existed significant differences between the rice and tuber crops farmers in the variables namely experience in farming (t= 3.87), farm size (2.26), annual income (2.57) and access to agricultural institutions (3.57).

Electronic Crop (E-Crop) was installed in sweet potato field for validation. Weather data and soil moisture content was collected by the device with the help of the sensors connected to it. The weather data was collected at 15 minutes interval and uploaded to the website of the institute. At 7:30 pm all these data gets downloaded to the local machine automatically. Once the data is downloaded, the sweet potato model SPOTCOMS runs using the data files downloaded and computes the dry matter produced by the crop till date and calculates the potential yield the crop can achieve as per the growth the crop has already attained. All these information will be sent to the mobile of the farmer in the form of advisory.

Quantitative structure activity relationship of anthocyanins of greater yam and sweet potato were studied. The Tolox Equivalent Antioxidant Capacity (TEAC) activity in radish and egg plant is used as training set to predict the antioxidant activity of anthocyanin isolated from yam and sweet potato. Anthocyanins from both greater yam and sweet potato showed high antioxidant activity. The polyphenolic compounds of yam and Chinese potato were docked against enzyme molecules, Acetylcholin esterase and Angiotensin converting enzyme and the overall drug likeness were tested in silico. Kaemferol and rosmarini acid act as a promising drug, which can inhibit activity of Angiotensin Converting Enzyme (ACE) thereby reducing cardiovascular and neurological disorders. Interactive visualization tools for high dimensional data were developed in R using the package Plotly.

During the reporting period, Nuaguda village (39 household), Potangi block, Koraput district; Kenjaguda village (49 household), Chakapada block, Kandhamal district; Burahkocha village (57 household), Angara block, Ranchi district were adopted for demonstration of farming systems involving tuber crops under Tribal Sub Plan programme on Livelihood improvement of tribal farmers through tuber crop technologies. Planting material of tuber crops were provided to the farmers along with the improved varieties of the major crops grown by them. Two trainings were organized before and after the interventions to up-grade the skill of tribal farmers in these villages. The socio-economic conditions of the farmers improved after the interventions. Farming system involving tuber crops (0.4 ha model) generated B:C ratio of 2.75 (which was 1.5-1.9 prior to the interventions) and additional employment generation of 89-112 man days ha^{-1} over the existing system.

Introduction

ICAR-CTCRI, Head Quarters, Thiruvananthapuram

ICAR-CTCRI, Regional Centre, Bhubaneswar

ICAR-CTCRI (1963-2017)

The ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) was established during the Third Five Year Plan for intensification of research on tuber crops (other than potato). The Institute started functioning in July 1963 with its headquarters (HQ) at Sreekariyam, Thiruvananthapuram, Kerala in an area of 21.50 ha. Later, an area of 26.69 ha was added. ICAR-CTCRI became an ISO (ISO 9001:2008) certified Institute since 31 March, 2014. It has one Regional Centre (RC) at Bhubaneswar with a farm area of 20 ha. The All India Co-ordinated Research Project on Tuber Crops (AICRPTC) was started at ICAR-CTCRI in 1968 for testing and popularizing the location specific tuber crop technologies in various parts of India. It has presently 22 centres including ICAR-CTCRI HQ and Regional Centre. The Institute is also one of the centres of the All India Co-ordinated Research Project on 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.

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

General Achievements

The ICAR-CTCRI is a premier research organisation in the world dedicated solely to the research on tropical tuber crops. The institute celebrated its golden jubilee during 2013 and more than five decades of concerted research have led to the development of several production and processing technologies for tuber crops, besides release of 61 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 5558. 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 61 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. The β carotene rich sweet potato varieties, Bhu Sona, Bhu Kanti and Bhu Ja and anthocyanin rich Bhu Krishna, mid season drought tolerant Bhu Swami were released recently.

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

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

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

Aroids especially elephant foot yam is gradually gaining importance in 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 Institute bagged first prize in the Krishi Mela Centenary Expo 2016, organised by ICAR-CPCRI, Kasargod and won second prize in the Regional Horticultural fair 2017 conducted by ICAR-IIHR, Bengaluru and in Vaiga 2016 organised by Government of Kerala.

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 16 national and international Symposia/Seminars/Workshops.

The infrastructural facilities of the Institute have been

tremendously increased during the X and XII 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. International guest house, modernized canteen, rabbit house for antibody production, maintenance and tarring of the farm roads are some of the latest infrastucture developed.

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. Plant growth chamber, two gel documentation systems, Total Station, Leica Zeno 20 GPS, 75 HP Tractor (John Deere, Model 5975E), Bakery oven are some of the new additions. The infrastructural facilities of the Regional Centre have also been considerably improved through the creation of additional laboratory space and purchase of several new equipments.

Extramural support by way of research schemes from both international (like CIAT, CIP, CIRAD , European union, IFAD, Indo-Swiss etc.) and national agencies like DBT, DIT, DST, DRDO, DSIR, ICAR, JNU, KSCSTE, LSRB, MOEF, DoA, Kerala, KSPB, NABARD, PPIC, 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 and Consortia 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. Various technologies related to value addition have been commercialised through ITMU under consultancy, licensing and contract research mode.

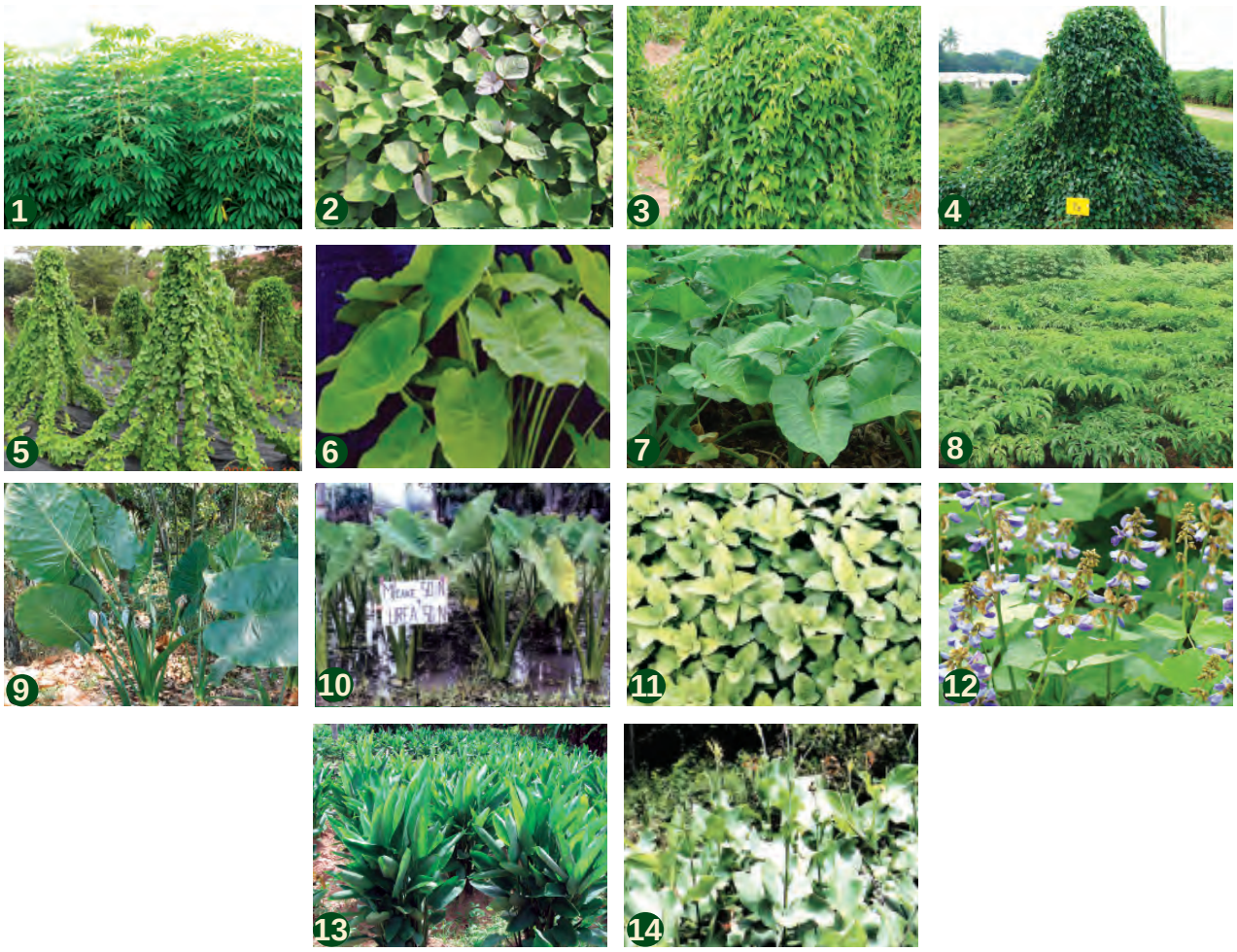
Our Institute has established a full fledged Local Area Network connecting various Divisions, Administration, Accounts, and farm sections of ICAR- CTCRI through a strong fiberoptic backbone. The entire network is supported by state of the art equipments such as fiber optic core switches, routers, firewalls. The entire campus is now wi-fi enabled through access controlled wi-fi devices and controllers. The servers are powered with Microsoft Windows 2012 operating system. The network consists of Windows 2012 staff server, Windows 2012 student server, storage server, internet proxy server, 204 computers, laser printers, inkjet printers, scanners, DTP and multimedia workstations. A VPN connectivity is established for global access to the servers. Legal licensed versions of popular software packages are installed for various type of applications.

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.

Museum

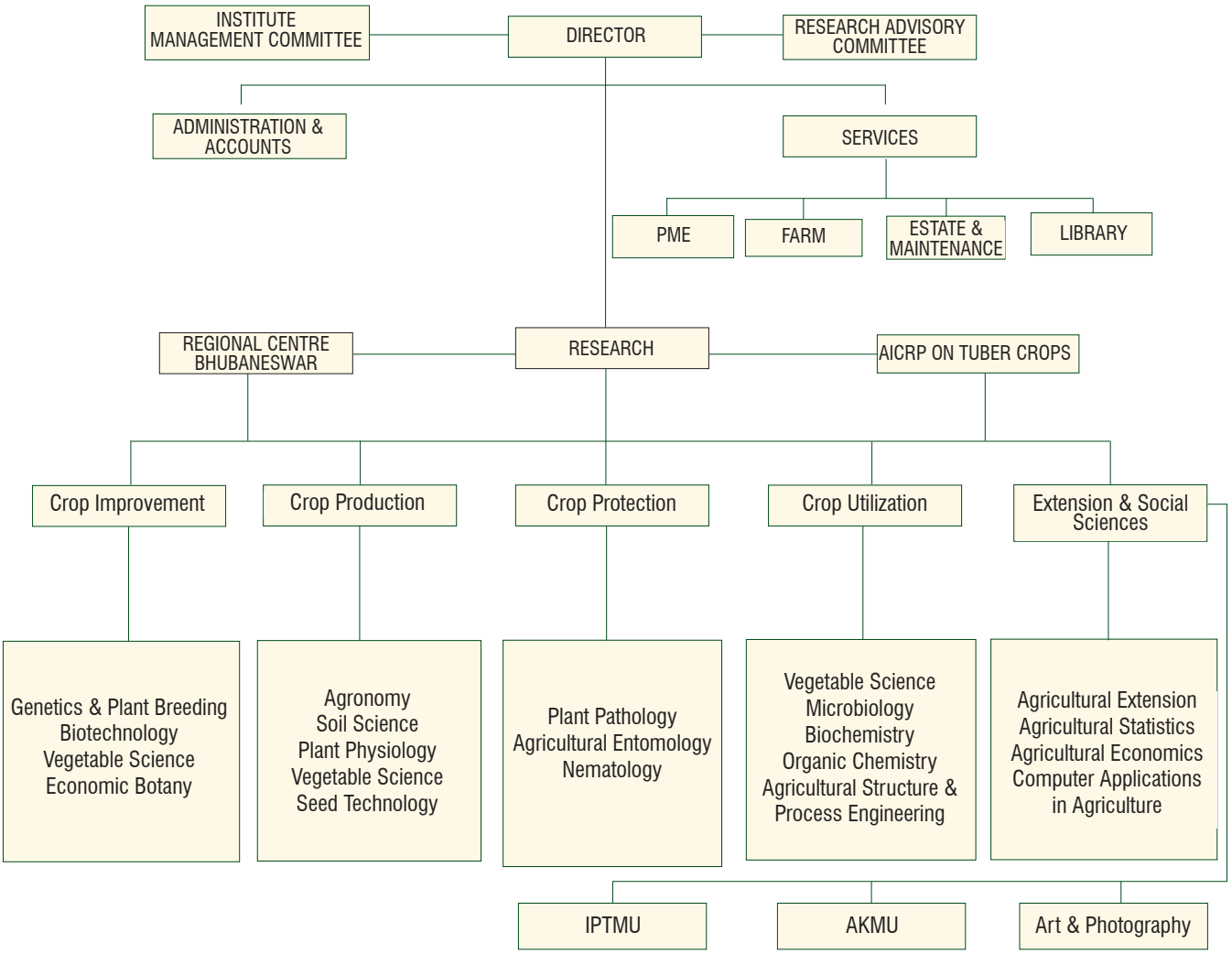
Crop museum

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 (2016-2017)

Category	Sanctioned	Filled	Vacant
RMP	1	1	0
Scientists	52	52	0
Technical	47	38	9
Administratiion	31	24	7
Skilled support staff	55	43	12
Total	186	158	28

Progressive Expenditure (2016-2017)

Plan

(Rupees in lakhs)

Sl. No.	Head of account	BE 2016-17 (₹ in lakhs)	Progressive expenditure (₹)
	CAPITAL		
1.	Works		
	A. Land		
	B. Building		
	i. Office building	141.03	1,41,02,768
	ii. Residential building		
	iii. Minor works		
2.	Equipments	21.42	21,41,996
3.	Information technology	10.91	10,90,875
4.	Library books & journals	1.05	1,05,349
5.	Vehicles & vessels	-	-
6.	Livestock	-	
7.	Furniture & fixtures	15.08	15,08,327
	Total –Capital	**189.49**	**1,89,49,315**
	REVENUE		
1.	Establishment charges		-
2.	Travelling allowances (Instt.+NEH)	24.00	24,00,029
3.	Research & operational expenses (Instt.+TSP+NEH)	94.27	94,27,135
4.	Administrative expenses	71.75	71,74,955
5.	Miscellaneous (Instt.+TSP+NEH)	5.49	5,48,566
	REVENUE (Instt.+TSP+NEH)	**195.51**	**1,95,50,685**
	GRAND TOTAL (CAPITAL + REVENUE)	**385.00**	**3,85,00,000**

Non-plan

(Rupees in lakhs)

Sl. No.	Head of account	BE 2016-17 (₹ in lakhs)	Progressive expenditure (₹)
	CAPITAL		
1.	Works		
	A. Land		
	B. Building		
	i. Office building		
	ii. Residential building		
	iii. Minor Works		
2.	Equipments	5.00	4,99,582
3.	Information technology		
4.	Library books & journals		
5.	Vehicles & vessels		
6.	Livestock		
7.	Furniture & fixtures	3.00	3,00,100
	Total –Capital	**8.00**	**7,99,682**
	REVENUE		
1	A. Establishment charges	1321.94	13,21,94,170
	B. Pension & other retirement benefits	139.00	1,39,00,000
	C. Loans & advances	3.66	3,65,500
2.	Travelling allowances	11.00	10,99,665
3.	Research & operational expenses	71.07	71,07,258
4.	Administrative expenses	134.09	1,34,09,225
5.	Miscellaneous	6.00	6,00,000
	Total – Revenue	**1686.76**	**16,86,75,818**
	GRAND TOTAL (Capital + Revenue)	**1694.76**	**16,94,75,500**

INSTITUTE PROJECTS

CROP IMPROVEMENT

Conservation and Utilization of Germplasm of Tuber Crops for Sustaining Production

New collections

Three exploration trips were carried out in Chhattisgarh, Assam and Karnataka during the period under report. Sixty accessions were collected from the Bastar region of Chhattisgarh (Moglai, Machkot, Bade Sagon, Shemaljodi and Jagadalpur), which included cassava (1), sweet potato (10), greater yam (4), *Dioscorea* spp. (19), taro (8), tannia (1), elephant foot yam (1), *Curcuma* spp. (5), *Amorohophallus* spp. (2), *Ipomoea* sp. (1) arrowroot (1) Canna sp. (1) and minor tuber crops (6). Eighty nine accessions were collected from different places (Katiathuli, Diguljarani, Upper Dillaji, Rupsing Hanse, Rongpi, Rophong Timung, Upper Deopani, Thakarajan, Phuloni, Gurubari, Haflong, Katlicherla etc.) in Assam. Fifteen accessions were collected from Joida, Karnataka. A wide variability in tubers were found in the collection (Figs. 1-3).

Fig.1. Tuber variability in the new collections

Fig. 2. Exploration trip to Bastar region

Fig. 3. Tribals with various species of *Dioscorea* in Assam

Field gene bank

Cassava

A total of 1211 accessions of cassava comprising of the indigenous, exotic, landraces and breeding lines were planted in the field for maintenance, characterization and preliminary evaluation. Morphological characterization of 500 accessions of cassava for above ground vegetative plant characteristics using a combination of IPGRI/ NBPGR descriptors was completed with digitization of indigenous accessions. These accessions were characterized for 12 above ground vegetative plant traits viz., young and mature stem colour, ridges on young stem, prominence of leaf scar on stem, young and mature leaf colour, young leaf hairiness, mature leaf vein and petiole colour, leaflet number and incidence of cassava mosaic disease under field epiphytotic conditions. The mature stem colour showed a wide range of variation from silver green to orange. The young leaf, petiole and vein colour and leaflet number also showed much variation. Out of the 500 accessions screened, 27 showed high incidence of CMD, while 273 accessions were free of any symptoms in the early stages of plant growth.

Evaluation of 280 accessions of cassava for 42 tuber traits and yield viz., colour of tuber rind, cortex and pulp, shape of tuber, presence of constriction and roots on tuber, taste of tuber, texture of tuber rind and cortex, ease of peeling, tuber length, tuber diameter, tuber tail length, tuber neck length and tuber yield per plant was done with digitalization and the database was updated. All the traits showed high variability. Of the 280 accessions, 173 showed high tuber yield per plant.

Twenty exotic accessions of cassava were screened for genetic variability using six SSR markers. The polymorphic primers SSRY 105 and SSRY 28 produced the highest number of four fragments followed by SSRY 100, SSRY 28, SSRY 181 and SSRY 161 producing three fragments. The primers SSRY 45, SSRY 100 and SSRY 181 showed 100% polymorphism and the similarity coefficient based on SSR markers ranged from 0.45 to 0.90. The phylogenetic tree generated using UPGMA grouped the accessions into two major clusters with three outliers in the grouping. Cluster-1 consisted of 15 accessions, Cluster-2 of 2 accessions, while the 3 accessions CE-481, CE-74 and CE-541 remained as the divergent accessions in the grouping. The accessions CE-56 and CE-84 were 100% similar. These will be assessed further and if identified as duplicates will be pooled together.

Eight accessions of cassava germplasm were newly initiated under *in vitro* culture. Hundred accessions of cassava germplasm were sent to AICRP-TC Centre, Yethapur, Tamil Nadu, for evaluation and conservation.

Sweet potato

A total of 1124 accessions are being maintained in the field gene bank. Characterization of germplasm of sweet potato based on morphological descriptors (IPGRI & CIP, 1991), 17 vegetative characters, for 500 accessions was done. Observation on flowering of accessions were carried out monthly in the germplasm. Evaluation of tuber traits and yield were performed for 55 accessions in three trials. In one trial, SV/1 (0.58 kg plant^{-1}) and 526/7 (0.49 kg plant^{-1}) (Fig. 4) gave significantly higher yield than Sree Arun and was on par with the local cultivar. In the second trial also, 526/7 produced the highest yield (0.53 kg plant^{-1}). In one of the evaluation trials, using 26 accessions replicated thrice, the accession, 526/7 was the highest yielder with a per plant yield of 1.07 kg, followed by the local cultivar (0.69 kg plant^{-1}) and

Fig. 4. Sweet potato accession, 526/7

SD-29, H-10, 5-1-6 (0.65 kg plant^{-1} each) and SD-11 (0.44 kg plant^{-1}). Twenty new accessions were evaluated in augmented design with five released varieties as control. In this trial, RSM-2015-5, from Joida, Karnataka, was the highest yielder (0.58 kg plant^{-1}).

Yams

One thousand one hundred and ten accessions of yams comprising of greater yam (591), white yam (158), lesser yam (220), potato yam (6) and wild yams (135) were replanted and conserved in field gene bank.

Sixty accessions of greater yam were characterized based on 25 qualitative and 13 quantitative traits, including the major yield components and three biochemical characteristics. No duplicate accessions were identified. Principal component analysis was carried out and the first six principal components of data accounted for 50.12% of the total variance among accessions and was contributed mainly by young vein colour, colour of young leaves, leaf shape, petiole length, young leaf vein colour, tuber shape, tuber cortex colour and starch content. The distribution of accessions in the scatter plot revealed high divergence of Da-340, Da-331 and Da-390.

Twenty seven accessions of wild yams were characterized using 22 morphological traits comprising of 18 qualitative and four quantitative traits. The biochemical studies of 27 accessions of 18 *Dioscorea* species on starch, sugar, crude protein, crude fat and crude fiber was done to identify wild yam accessions with better nutritive value. Among the accessions, *D. floribunda* (CTDf-1) had the highest protein content on dry weight basis (14%) followed by *D. hispida*, CTDh-1 (12.46%), while for the fiber and fat content, *D. vexans* (1.29%) and *D. floribunda* (9.31%) had the highest values, respectively.

Forty five greater yam accessions were also evaluated for biochemical traits. Crude protein content (on fresh weight basis) varied from 2.28% (Da-390) to 5.23% (Da-331). Da-391 had the highest dry matter (48.24%), starch (26.41%) and sugar (3.66%) contents. Da-56 and Da-70 had the lowest dry matter (27.53%) and starch (13.20%) contents, respectively. The sugar content on fresh weight basis ranged from 0.84% (Da-308) to 3.66% (Da-391). Among the accessions, Da-331, Da-391 and Da-69 had high protein content (on fresh weight basis) (>5.10%), while Da-390 had the lowest protein content (2.28%).

Molecular characterization of yams

Molecular characterization of 45 accessions of greater yam and 27 accessions of wild yams was carried out using 15 ISSR and 10 SSR primers. Total number of bands per ISSR primer ranged from 5 (UBC817) to 12 (UBC809 and $(GA)_9AT$). The Polymorphism Information Content (PIC) of the primers ranged from 0.6918 (UBC817) to 0.88 (UBC807). The studied primers showed PIC value > 0.8. Among the SSR markers studied, the number of the alleles per marker ranged from one to eight.

All the SSR primers showed 100% polymorphism. The observed Heterozygosity values ranged from 0 (YM5) to 0.8396 (Dab2C05). All other SSR primers showed Hobs value>0.7. Dendrogram based on ISSR markers showed the partition of the *D. alata* accessions into three clusters at a similarity coefficient of 0.57 and Da-340 and Da-331 showed maximum genetic divergence from other landraces.

Edible aroids

A total of 68 edible aroids comprising, 43 taro (Karnataka, Assam, West Bengal, Sikkim and Kerala); 6 elephant foot yam (Himachal Pradesh-a variety Palam Zimikand-1, Assam and Chhattisgarh); 16 tannia (Kerala, Sikkim, Assam, Chhattisgarh and Karnataka); 1 *Alocasia* (Kerala) and 2 *Colocasia* spp. (Sikkim) were collected and added to the germplasm collection. New collections were screened for pests and diseases and planted in isolation.

In the field gene bank, 672 edible aroid germplasm comprising 429 taro, 203 elephant foot yam and 40 tannia are being conserved. Under *in vitro* active germplasm, **c**ultures of 20 taro accessions have been initiated for short term conservation. DNA bank was augmented with 8 taro; 30 elephant foot yam and 6 tannia accessions. Cooking quality of 12 tannia accessions was done using six traits. Eight of the accessions showed very good cooking quality with no acridity.

Usefulness of ISSR markers in differentiating between species of important aroids was done using 14 aroid lines comprising, *Colocasia esculenta*, *Colocasia* spp., - one non-acrid (Fig. 5) and one wild as well as *Xanthosoma sagittifolium* and *X. violaceum* accessions using nine ISSR markers. The markers could clearly differentiate between all the species and they formed separate clusters in the dendrogram. The wild *Colocasia* spp. grouped with *C. esculenta* as an outlier, showing that it is *C. esculenta* only. The non-acrid *Colocasia* spp. was grouped separately indicating that it was a different species (Fig. 6). Its appearance resembles that of *C. gigantea* and once flowering occurs, it will be confirmed.

Fig. 5. The non-acrid *Colocasia* spp.

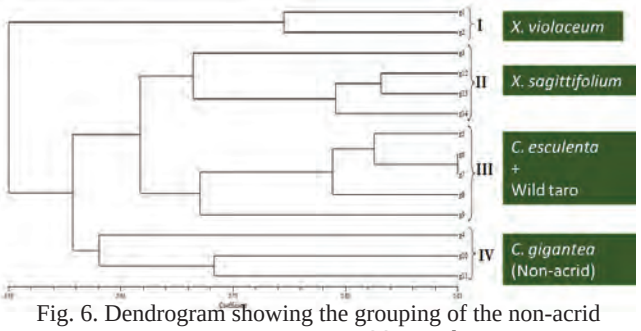


Fig. 6. Dendrogram showing the grouping of the non-acrid accessions using nine ISSR markers

Morphological characterization of 28 elephant foot yam accessions was done using 32 traits as per NBPGR minimum descriptors including above ground traits and tuber characters. Eighteen quantitative characters were included in this. Weight of the corm was a major contributing factor responsible for separating the accessions in PCA. In the quantitative characters studied, based on the coefficient of variation, the degree of variability was high for fresh weight of corm, height of corm, length of cormels, number of leaflets (primary partition), number of corms, number of tertiary partitions, weight of cormels and number of cormels. Molecular characterization of these accessions was also done using 15 ISSR primers. Similar to morphological characterization, no duplicates were present in this set.

Digital database of taro germplasm was updated with plant features of *Colocasia gigantea* and *Amorphophallus bulbifer* as well as tuber photographs of 38 taro and nine tannia accessions.

Minor tuber crops

A total of 200 accessions comprising Chinese potato, yam bean, arrowroot, *Canna* sp., *Costus* spp., *Tacca* sp., *Arisaema* sp., *Curcuma* spp., *Zingiber* spp., and *Coleus aromaticus* maintained in the field gene bank were harvested, tuber yield was recorded. Digitalization of tubers for variability in Chinese potato, yam bean, arrowroot, canna and wild turmeric has been completed (Fig. 7). DNA samples of 20 accessions of Chinese potato germplasm isolated were deposited in the DNA bank.

Arrowroot

Yam bean

Chinese potato

Curcuma spp.

Costus spp.

Fig. 7. Tuber variability in minor tuber crops

Regional Centre

At the Regional Centre, ICAR-CTCRI, Bhubaneswar, different tuber crops comprising 1241 germplasm accessions are being maintained in the field gene bank. It includes taro (506), sweet potato (373), cassava (113), yams (51), elephant foot yam (41), yam bean (146), Chinese potato (5), arrowroot (2), tannia (1) and *Alocasia* (3).

In vitro conservation of tuber crops germplasm

Under the *in vitro* conservation of germplasm of tuber crops, 250 accessions received from NBPGR were sub cultured during the period making a total of 11 accessions of *Dioscorea rotundata*, 101 accessions of *D. alata* and 192 accessions of sweet potato in the IVAG. An average of six cultures was maintained for each accession. Twenty new accessions of sweet potato, 20 taro, 10 cassava from germplasm were brought *in vitro* during this year. Besides the already existing cultures of sweet potato were sub cultured and maintained in the IVAG. The cultures are maintained in basal MS media and in slow growth media (MS + 2% mannitol).

Gene bio-prospecting for novel traits in tuber crops

Tuber crops, like sweet potato, yams and Chinese potato, have been reported with wound healing properties due to the presence of many natural compounds. Angiogenesis is the formation of new blood vessels from existing vasculature and this phenomenon is pivotal in wound healing. However, the stability, availability from natural sources and bioactivity of the natural compounds are typically limited. Bio-prospecting of genes involved in the biosynthesis pathway of pro or anti-angiogenic compounds helps to further enhance the stability and availability of the compounds and thereby enhance the angiogenic effect. It was identified through literature survey that sweet potato, Chinese potato elephant foot yam and yams have angiogenic effects. Hexane and ethanol extract of sweet potato leaf and Chinese potato tuber was prepared and *in ovo* screening of different extracts of purple leaf of sweet potato Acc. No. 1467 was done**.** The ethanol extract of sweet potato leaf extract showed pro-angiogenic effect as indicated with many blood vessels growing towards the discs, similar to VEGF control. Hexane extract did not promote the growth of blood vessels, neither did it prevent the blood vessel growth (Fig. 8).

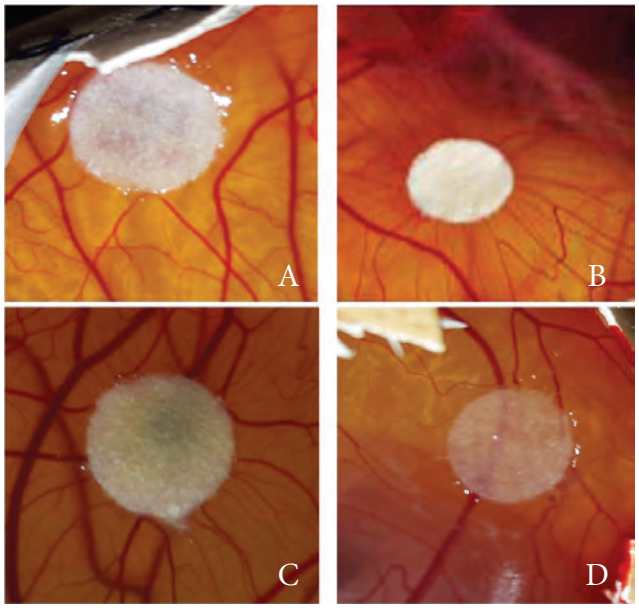


Fig.8. Result of CAM assay. Discs were treated with different groups. Taxol (anti-angiogenic control) (A), VEGF (pro-angiogenic control) (B), ethanol extract of sweet potato leaf (C), hexane extract of sweet potato leaf incubated for 48 hours and observed (D)

Genetic Improvement of Tuber Crops through Conventional Breeding and Molecular Approaches

The megaproject on **"**Genetic Improvement of Tuber Crops Breeding" is undertaken to address the gaps prevailing with regard to yield, diseases, pest and other quality traits for different crops. The progress made during the year under report is presented crop wise as follows:

Cassava

Development of CMD resistant lines

Four hundred and fifty one hybrids developed by crossing short-duration varieties with CMD resistant genotypes were evaluated for CMD resistance, earliness, starch content and culinary quality. The CMD resistance of the seedlings were screened through grafting and multiplex PCR using ICMV and SLCM specific primers (Fig.9). CMD resistance segregated in the ratio 3:1 indicating

dominant gene contributing to resistance. Maximum number of CMD resistant hybrids was obtained in the cross 9S-75 X CI-273. Among the CMD resistant hybrids with short-duration, 16S-203 produced the highest tuber yield (7.81 kg plant^{-1}) at the sixth month followed by 16S-330 (7.21 kg plant^{-1}), 16S-51 (5.4 kg plant^{-1}), 16S-143 (5.31 kg plant^{-1}) and 16S-205 (5.03 kg plant^{-1}). The dry matter content ranged from 16.40% (16S-191) to 46.40% (16S-47). Forty five hybrids with CMD resistance and short-duration were selected and planted in replicated trial for studying different parameters contributing to early bulking nature.

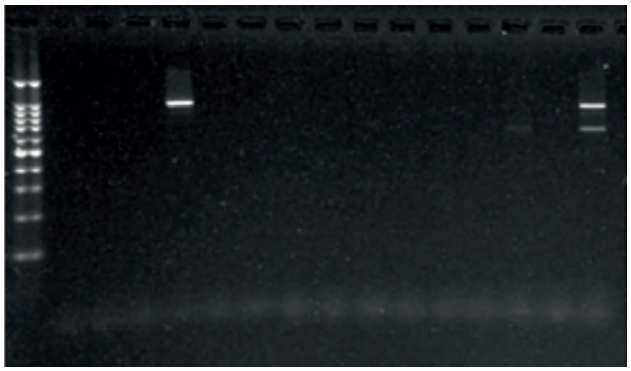


Fig.9. Gel profile of multiplex PCR using ICMV and SLCM specific primers in the resistant lines. Lanes 1 to 16 - 100 bp DNA ladder, 8W-5, CR43-4, CR43-7, Sree Pavithra, 15S-255, 15S-442, 15S-184, 15S-155, 15S-156, 15S-389, 15S-96, 15S-113, Negative control, Positive control

Among the CMD resistant hybrids evaluated, 15S-57 had the highest dry matter (44.80%) followed by 11S-53 (41.80%), 15S-352 (41.60%), 15S-239 (40.60%) and 11S-7 (40.20%). For culinary purpose, the genotypes (11S-30, 11S-7, 15S-57, 11S-53 and 11S-4) with high yield (>40 t ha^{-1}), CMD resistance and cooking quality were selected.

Triploid cassava for industrial purpose

Among the triploids evaluated for yield and starch content (>30%), TR44-7 produced the highest yield (64.20 t ha^{-1}) followed by Tr44-4, Tr1-19, Tr7-9, Tr45-15 and Tr7. Highest starch content was recorded in Tr44-4 (33.70%).

Fried chip varieties

For improvement of cassava for chips quality, a trial was conducted with seven lines (CMR-100, 8W-5, CR-21/10, 11S-33, 9S-165, CR-24/4, CR-20A/2) and one released variety (Sree Vijaya). Among all the lines, CMR-100, 8W-5 and CR-21/10 had good quality chips, whereas, 11S-33, 9S-165 and CR-24/4 had moderate quality, while CR-20A/2 and Sree Vijaya produced poor quality chips.

Development of PPD resistant lines

In the activity on identification of molecular markers associated with post-harvest physiological deterioration (PPD) in cassava, a total of 72 cassava genotypes including released varieties, breeding lines and germplasm accessions have been characterized with respect to PPD tolerance. Evaluation of tubers was done at 0, 5, 10, 15 and 20 days after harvest by taking transverse sections at 25, 50 and 75% of the total length of roots from the proximal to the distal end. The evaluation for PPD was done using three methods namely, Wheatley method (1982), Uarrota et al. (2015) and complete tuber storage. The roots were categorised based on the visual scoring using two different scales of Wheatley et al. (1982) for peripheral symptoms and Venturini et al. (2015) for non-peripheral symptoms. Average of the scores of all the three sections were taken as the PPD score for the genotype. Morphological tuber characteristics such as tuber length, tuber girth and tuber weight, biochemical characters such as total starch, total sugar and dry matter content were also recorded. PPD symptoms increased through time from 5 days after harvest (DAH) to 20 DAH and microbial deterioration was observed after 15 DAH. Significant variation was observed for PPD response as well as other traits. Sree Sahya, Kalpaka, CO-1, CR-43-2, CR-20A (2) and CR-24-4 were free of PPD symptoms even at 20 DAH (Fig.10) whereas, Sree Padmanabha, Sree Jaya, Sree Vijaya and Vellayani Hraswa developed deterioration symptoms even at 5 DAH. Other genotypes showed moderate tolerance to PPD symptoms. Mostly the genotypes developed peripheral symptoms compared to non-peripheral symptoms and the non-peripheral PPD symptoms were more pronounced in median portion of the tuber compared to the proximal and distal regions. Tubers with neck showed less PPD symptoms than the ones without neck. The association of other characters recorded with PPD response was studied. Tuber length, dry matter content and total starch had

significant positive correlation with PPD response. Tuber girth, tuber weight and total sugar had significant negative correlation with PPD response. The polymorphism among the parents chosen for hybridization was studied using molecular markers specific to PPD. Putative screening of resistance gene specific alleles were performed using 37 gene based SSR markers coding for amino cyclopropane 1 carboxylate (ACCOX), phenyl alanine ammonia lyase (PAL), glucanase (GLU), catalase (CAT), hydroxyproline rich glycoproteins (HRGP), cysteine protease inhibitor (CCPI-2) and aspartic protease (cASP-1). The genetic frequencies of PPD related genes ranged from as low as 0% or none to 98.67%. Flowering behavior of the identified lines and varieties was studied systematically to select suitable parents for hybridization. Pollination block has been laid out for carrying out hybridization between the identified parents to establish a mapping population segregating for PPD tolerance.

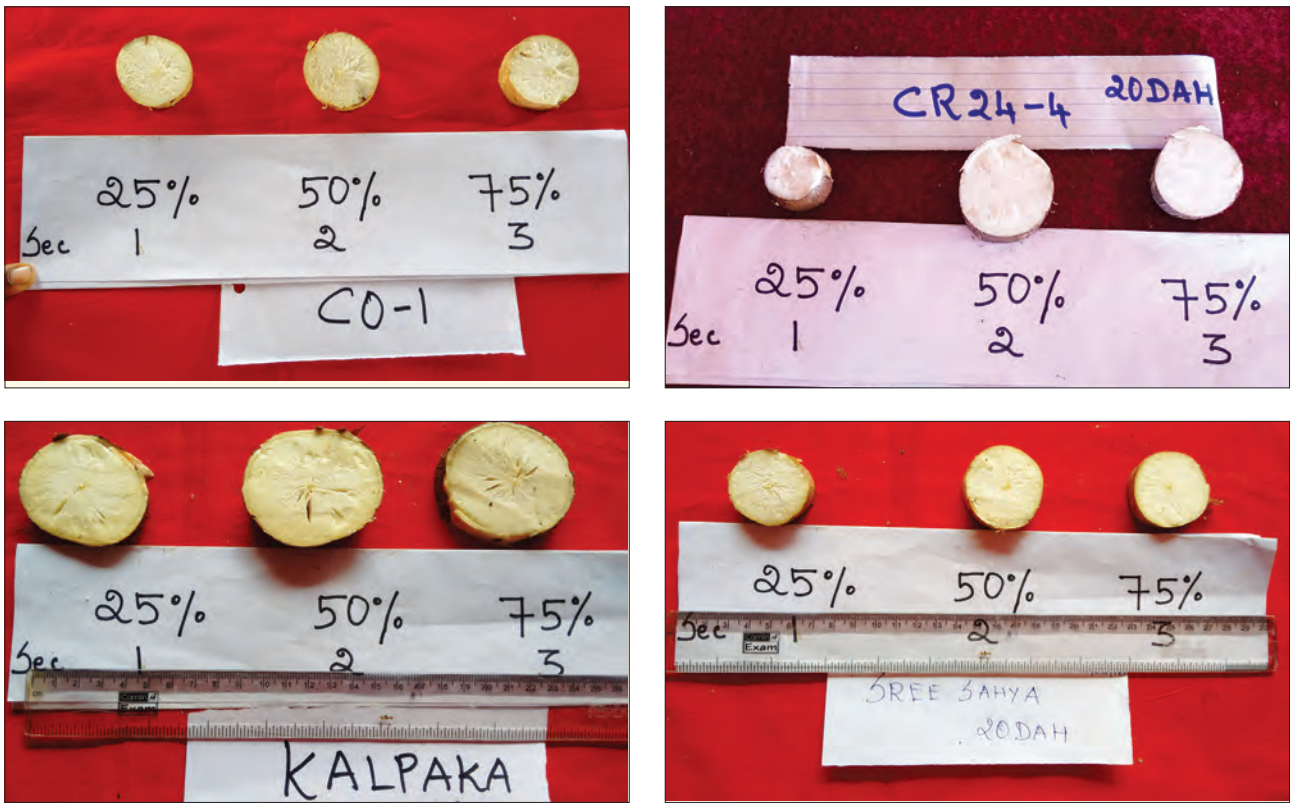
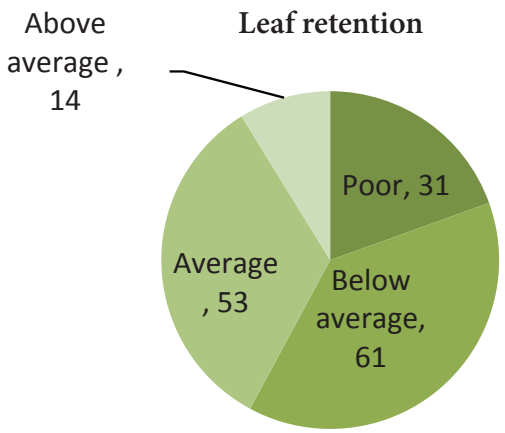


Fig.10. Promising PPD tolerant genotypes showing no symptoms at 20 DAH

Screening for drought tolerance

For drought tolerance screening in cassava, indigenous cassava germplasm numbering 159 was studied for their leaf retention capacity at six months after planting as it is one of the major components that contribute towards drought tolerance. Plants were classified into five groups based on their leaf retention capacity as outstanding, above average, average, below average and poor (Fig. 11). Plants with 100% leaf retention were grouped as outstanding, but, none of the genotypes under study qualified for it. Genotypes with leaves up to the top 3/4th of the length of the stem were considered as above average and 14 genotypes fell



in this category. Average genotypes had leaves on the top half portion of the stem and 53 genotypes had such habit. Sixty one genotypes were found to have below average leaf retention capacity and they were characterized as stems containing leaves on the top 1/4th portion of the stem. Genotypes with poor leaf retention capacity had leaves less than 1/4th portion of the stem and 31 genotypes belonged to this category.

Fig. 11. Leaf retention. Above average (A), Below average (B), Poor (C)

Sweet potato

During the period under report, five sweet potato varieties were released by the Regional Centre, ICAR-CTCRI, Bhubaneswar (Fig.12). Bhu Sona (ST-14) is a β carotene rich variety (14 mg 100 g^{-1}) having a dry matter content of 27-29%, starch 20%, total sugar 2-2.4% and an average yield of 19.8 t ha^{-1}. It has good cooking quality and is suitable for the nutritious food processing industry. Bhu Krishna (ST-13) on the otherhand, is an anthocyanin rich variety with an anthocyanin content of 85-90 mg 100g^{-1}. It has an average yield of 18.0 t ha^{-1} with fair cooking quality and non-mealy. The dry matter ranges between 24-25.5%, extractable starch 19.5% and total sugar 1.9-2.2%. Bhu Kanti (CIP-440127) is an orange-fleshed variety with a β carotene content of 6.5 mg 100g^{-1} and an average yield of 20 t ha^{-1} with good cooking quality. The dry matter ranges from 24-25.5%, total sugar from 1.9-2.2% and starch 16%. Bhu Ja (CIPSWA-2) is another orange-fleshed variety with a β carotene content ranging from 5.5-6.4 mg 100g^{-1} having an average yield of 22 t ha^{-1} and good cooking quality. The dry matter content ranges from 23.2-24.8%, starch 16.6-17.2% and total sugar 2.4-3.0%. These four varieties are tolerant to salinity stress (6.0 - 8.0 dS m^{-1}). Another white-fleshed variety, Bhu Swami (ST-10) is tolerant to mid season drought and is suitable for food and processing industry having an extractable starch of 21%. The dry matter ranges from 27.4-29.7% and total sugar 3.0-3.7%. It has excellent cooking quality and an average yield of 20 t ha^{-1}.

Bhu Sona (ST-14) Bhu Krishna (ST-13) Bhu Kanti (CIP-440127)

Bhu Ja (CIPSWA-2) Bhu Swami (ST-10)

Fig. 12. Latest varieties of sweet potato

To address the national and international lacuna as well as to satisfy demands of growers, the targeted objectives of sweet potato breeding were – higher yield (>17 t ha^{-1}), starch (>18%), β-carotene (>14 mg $100g^{-1}$) and anthocyanin (>90 mg $100g^{-1}$) with short crop growth cycle (75-90 days) and weevil resistance (infestation <10%).

To achieve that, germplasm stock, breeding lines generated through open pollination and reciprocal crosses were evaluated. The results of evaluation of their clonal generations are presented as follows:

Germplasm evaluation

Progressive evaluation of 265 genetic resources resulted in selection of 16 lines having more than 18 t ha^{-1} yield, four of which was observed to have 75 days maturity. The accession nos. S30/15, S30/16, Baster-45 and Acc. No. 527 with 75 days maturity also have responded to half doses of N and K (37.5 : 37.5).

Evaluation of OP generated breeding lines

Progressive evaluation of previously selected 29 sweet potato breeding lines generated through open pollination for high starch, β-carotene, anthocyanin and weevil resistance showed 75 days maturity in 7 lines, 2 of which were having white flesh, 2 orange flesh and 3 purple flesh. Of the rest, 90 days maturity was recorded in 6 white, 3 purple and 5 orange flesh sweet potato lines. Yield recorded ranged from 18.70 to 20.80 t ha^{-1} for lines with 75 days maturity and 24.90 to 35.50 t ha^{-1} for lines with 90 days maturity, respectively.

Reciprocal crosses

Reciprocal crosses are being continued to evolve early maturing sweet potato with valued traits.

Fig. 13. C_1F_1 of selected white flesh parents

Fig.14. C_1F_1 of selected purple and white flesh parents

The evaluation of the clonal generation of F_1 (C_1F_1 2015-2016 and C_2F_1 2016-2017) revealed 75 days maturity in 8 hybrids, of which 4 were white, 1 orange and 3 purple-fleshed (Figs. 13 and 14). Starch content ranged from 15-18%, β-carotene, 10-16 mg $100g^{-1}$ and anthocyanin, 65-100 mg $100g^{-1}$ in these lines.

All the early maturing lines were observed to have no weevil infestation. To study inheritance of valued traits, 1330 reciprocal crosses were made among selected parents during 2016-2017, seed setting was recorded within 450 combinations.

Yams

During this year, one short-duration greater yam Bhu Swar (Da-25) was released from the Regional Centre, ICAR-CTCRI, Bhubaneswar (Fig.15). This variety has a duration of 6-7 months with an average yield of 20-25 t ha^{-1} with excellent cooking quality. The dry matter content ranges from 32.0-33.0%, starch 18.0-20.0% and total sugar 1.0-1.5%.

Fig. 15. Bhu Swar (Da-25), short-duration greater yam variety

Among the 9th clonal white yam hybrids evaluated, Drh-1150 produced the highest tuber yield (46.90 t ha^{-1}) followed by Drh-1125 (43.21 t ha^{-1}). Among the dwarf white yam hybrids (9th clonal) evaluated under irrigated condition, Drd-1157 produced the highest tuber yield (73.20 t ha^{-1}) followed by Drd-1038 (51.70 t ha^{-1}), Drd-1118 (51.10 t ha^{-1}) and Drd-1095 (39.50 t ha^{-1}) (Fig. 16). Among the dwarf clones, Drd-9495 and Drd-1060 had better cooking quality than the released dwarf white yam variety, Sree Dhanya. Among the semi-dwarf varieties of white yam, SD-15 produced high yield coupled with excellent culinary quality.

Fig.16. Drd-1157

In vitro screening of greater yam for anthracnose

A total of 71 accessions of greater yam from germplasm were screened *in vitro* using highly virulent isolate of *Colletotrichum gloeosporioides* causing anthracnose. Among them, eight accessions did not show any infection and 14 showed resistance with the disease scale of 1-2, including the released varieties, Sree Karthika and Sree Keerthi.

Taro

Two taro varieties were released by the Regional Centre, ICAR-CTCRI, Bhubaneswar, viz., Bhu Kripa (Jhankri) having an yield of 15-20 t ha^{-1} and good cooking quality (Fig.17). The dry matter content ranged from 23.5-24.6%, starch 12.3-14.2% and total sugar 1.3-1.7%. The variety, Bhu Sree (Sonajuli) has an average yield of 15-20 t ha^{-1} and good cooking quality. The dry matter content ranged from 23.0-24.8%, starch 15.6-17.3% and total sugar 1.2-1.5%.

Bhu Kripa (Jhankri) Bhu Sree (Sonajuli)

Fig.17. New varieties of taro

AYT I with six taro accessions gave a cormel yield, which ranged from 2.30 t ha^{-1} (IC211587) to 3.79 t ha^{-1} (U-29). The check, Sree Rashmi gave 2.97 t ha^{-1}. However, all the accessions were on par. Total yield ranged from 3.95 (IC211587) to 5.72 t ha^{-1} (U-29) and was on par. IC211587 had round tubers.

Introgression of TLB resistance in taro

Fifteeen taro accessions were screened artificially and amongst them, four showed moderate resistance to taro leaf blight in the first season, whereas, nine and seven accessions screened earlier showed tolerance in the second and third seasons, respectively. Flowering was noted in few taro lines planted in the breeding block. Crossing was attempted with two accessions as female parent (C-157 and C-688) with TLB tolerant lines - Muktakeshi, C-565 and C-203 as male parents. The seeds were collected, dried and stored for further germination studies.

Breeding for quality improvement in taro

At the Regional Centre, 50 high yielding lines of taro were selected based on available data and planted in 2016 for estimation of different quality parameters. All lines were assessed for total antioxidant by DPPH assay and CUPRAC assay. Free radical scavenging ability against DPPH assay ranged from 27% to 68.57% in corms and 32.92% to 85.47% in leaf. CUPRAC assay ranged from 11.37µ mol trolox g^{-1} dry weight to 26.58 µ mol trolox g^{-1} dry weight in corms and 30.46 µ mol trolox g^{-1} dry weight to 95.93 µ mol trolox g^{-1} dry weight in leaf. Total phenolic content ranged from 1.1 mg gallic acid g^{-1} dry weight to 6.29 mg gallic acid g^{-1} dry weight in corms and 17. 98 mg gallic

acid g^{-1} dry weight to 60.71 mg gallic acid g^{-1} dry weight in leaf. Sugar content (1.22 to 2.52%) and starch content (11.34 to 58.70%) were analysed in corms.

Elephant foot yam

In elephant foot yam, during 2016-2017, the F_1 progeny (from the cross between two high yielding local elephant foot yam lines crossed during 2014-2015) and the F_1C_1 progeny (from the cross between Am 159 (F) x Am 158 (M) crossed during 2013-2014) were harvested and the corm weight, shape and presence of cormels were recorded. The seeds from four crosses made during 2015-2016 were sown and the corms were harvested. Gajendra was the male parent in all the crosses. The female parents were Am 158, Am 157 and Am 156. The roughness of petiole/pseudostem was recorded in the standing crop. A total of 240 corms were selected from hybrid progeny of the six crosses, the corm weight of which ranged from 5 – 550 g (Fig. 18). Most of the corms had numerous cormels. The harvested tubers were planted in the field to obtain big sized corms for recording yield and acridity. Six genotypes with smooth petiole and reasonably higher yield were identified during the second year. During this year, seeds obtained from a cross between Am 158 (female parent) and Gajendra (male parent) were sown.

Two accessions were planted, having high acridity and RNA isolation is in progress from tuber samples for transcriptome analysis for identification of gene (s) associated with acridity.

Fig.18. Variability in the tuber characters of elephant foot yam hybrids

Tannia

An experiment was initiated for polyploidy induction in tannia with two accessions (AKI/2015-8 and AKI/2015-9). Two concentrations of colchicine (0.05 and 0.10%) was tried for three time intervals (24, 48 and 72 h). Though germination was there for all the three intervals and concentrations, survival was a problem. This experiment will be repeated with modifications in time intervals and method of treatment.

PYT I in tannia with seven accessions gave cormel yield, which ranged from 1.69 (Xa-12) to 4.25 (Xa-MNS/14-1) t ha^{-1}, whereas, total plant yield ranged between 3.38 (Xa-UV3-Yerkadu) to 6.82 (Xa-MNS/14-1) t ha^{-1}.

Arrowroot

In the activity on arrowroot improvement for high yield with high starch, low fibre content and good culinary quality, an advanced yield trial was conducted with seven arrowroot genotypes for eight quantitative yield and yield attributing traits. The results showed that the genotype M-1 produced the highest yield (0.64 kg per plant), number of tubers/plant (16) and biggest tuber length (22.11 cm). Tuber node length was highest for M-5 (1.51 cm) and tip length highest for M-6 (1.41 cm). Biochemical evaluation of tubers for total starch, sugar, ash and crude fibre was done and the data were statistically analysed. Analysis of biochemical parameters (on dry weight basis) in the seven arrowroot genotype tuber samples in three replicated trials showed that the highest dry matter content of 32.35% was recorded in M-7, while the total starch and sugar content were highest for the accession M-1. The total starch content ranged from 54.15% in the accession M-1 to 50.43% in M-7. Total sugar varied from 2.40% in M-1 to 1.98% in M-5. The total ash content was

highest in M-4 with 4.23% and the lowest of 3.18% in M-2. The total crude fibre content was lowest for the accession M-1 (1.71%) and highest for the accession M-7 (2.19%).

Yam bean

For evaluation of yield and other yield contributing traits, F_2 generation of five best F_1 hybrids along with check variety (RM-1) were planted in 2016 (Fig. 19). Another set of 5 F_2 generation seeds were raised for production of F_3 generation for evaluation of successive generation. Tuber yield in F_2 generation of best F_1 hybrids ranged from 30.55 t ha^{-1} (3x9) to 36.11 t ha^{-1} (3x10) as compared to 24.99 t ha^{-1} in RM-1 as a check variety. Starch content ranged from 9.34% (3x8) to 15.33% (3x9) and sugar content ranged from 3.88% (3x8) to 7.55% (3x9). The DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity determination showed that 3×10 had the highest ability (40.11%), while 3×8 had the lowest scavenging ability (28.13%). Lignin content ranged from 1.23% (3×8) to 2.85% (3x9). Two F_1 hybrids were made among white and violet colour genotypes to know the inheritance pattern of flower colour. Forty five F_1 seeds were obtained in both the hybrids.

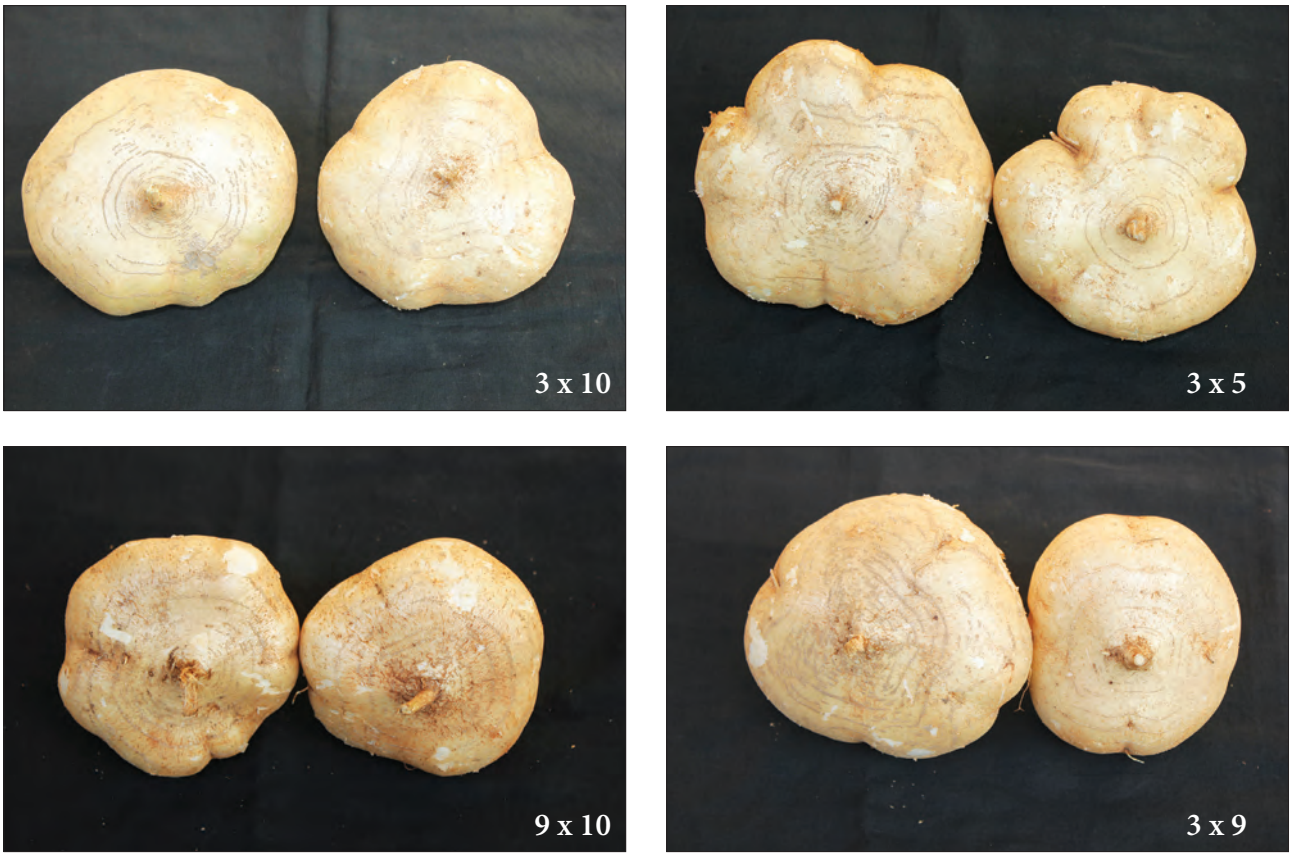


Fig. 19. F_2 generation of promising F_1 hybrids in yam bean

Pyramiding of genes for cassava mosaic disease (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. The identified 150 true hybrid seedlings having both genes were evaluated in the field for CMD resistance. All these lines are having 100% field resistance to CMD disease.

Identification of marker linked to high starch in cassava

For identification of markers linked to high starch content in cassava, a total of two high starch (CR 43-2 and 9S-127) and low starch lines (CR 43-7 and Sree Padmanabha) were selected for developing hybrid seedlings. Among the two lines, high starch line, 9S-127 was crossed with the low starch variety, Sree Padmanabha (MNga-1) during May to July 2016 and from the mature fruits 275 hybrid seeds were collected. These seeds will be used for raising F_1 seedling progenies and identification of markers linked to high starch content.

Genetic modifications for quality improvement in cassava

In vitro cultures of CMD resistant cassava accessions, 9S-127 and CR-4311 were multiplied in sufficient numbers and callusing was initiated in both the accessions. New embryogenic callus of 9S-127 was initiated for getting sufficient friable embryogenic callus for transformation. Transformation of TMS60444 FEC with GUS reporter gene was done along with *glgC* gene transformation. To develop waxy cassava, hairpin construct of *gbss* gene is being made. Cloned the *gbss* I 676bp fragment to pBluescript and transformed the construct to *E. coli*, DH5α. Colonies were selected through blue white screening.

Statistical tools and technologies for tuber crops research and development

A total of 219 SNP markers and 10, 307 SSR markers in *A. paeoniifolius* associated with dasheen mosaic virus were predicted using bioinformatics tools. SNP 748 could differentiate the resistant and susceptible varieties.

Amorphophallus transcript sequences of healthy and dasheen mosaic virus infected samples were used for novel miRNA prediction, secondary structure representation and annotation. About 374 novel microRNA's in *Amorphophallus* and 29 novel microRNA's in cassava and its secondary structure were predicted using bioinformatics tools.

Molecular marker development for dasheen mosaic disease resistance in *Amorphophallus* using bioinformatics tools

The preliminary dataset of about 25152 sequences was obtained from transcriptome sequencing and profiling of mosaic infected *A. paeoniifolius*. About 7000 contigs were obtained after aligning and assembling using Cap3 alignment and assembly tool. A total of 19 contigs with 219 SNPs were identified using QualitySNP and about 10,307 SSRs were identified using MISA (Table 1). Primers were synthesized for 10 contigs and were validated using five *Amorphophallus* varieties. SNP 748 was able to clearly differentiate between the resistant and susceptible varieties.

Table 1. Distribution of predicted SSRs and SNPs in *Amorphophallus paeoniifolius*

Characterization	Type of SNP	SNPs	Total
Transition	C/T	86	197
	G/A	111	
Transversion	A/C	10	22
	A/T	5	
	C/G	4	
	T/G	3	

Type of SSR	No: of SSR
Mono	3279
Di	4255
Tri	2499
Tetra	219
Penta	48
Hexa	7
Poly	0
Total	10307

Identification and characterization of novel microRNA candidates from *Amorphophallus*

The *Amorphophallus* transcript sequences of 3 healthy samples and 1 virus infected samples were used. A total of 90030 *Amorphophallus* transcript sequences were subjected to predict the novel miRNA using NovoMIR. A total of 374 novel miRNAs were identified. The major

molecular function annotated were ATP binding, copper ion binding, protein kinase activity, lipid binding, oxidoreductase activity, transferase activity, glutathione dehydrogenase activity, post transcriptional gene silencing, catalytic activity, viral RNA genome replication, phosphatase activity, RNA binding, RNA–directed RNA polymerase activity, etc. RNA hairpin Figure is used for drawing hairpin-like text figure from RNA sequence and its secondary structure in dot-bracket notation.

Fig.20. Front end of the database

Database development

A database of predicted SNPs and SSRs of cassava and predicted miRNA *Amorphophallus* was developed (Fig. 20).

Identification and characterization of novel microRNA candidates from cassava

Cassava transcript sequences (variety from AM305, JDI annotation V 4.1) were retrieved from the Phytozome website. NovoMIR was used to predict the novel miRNA from 41,381 cassava transcript sequences. A total of 29 novel miRNAs were predicted. The predicted miRNAs targeting transcript sequences of cassava were subjected to functional annotation by BlastX. The major functions were ADP binding property, ATP binding, ion transport, ATP hydrolysis coupled proton transport, Lipid binding and Hydrogen ion transmembrane transporter. RNA Hairpin Figure draws hairpin-like text figure from RNA sequence and its secondary structure in dot-bracket notation.

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. Disease free planting materials were produced and supplied in selected areas of Kerala, Tamil Nadu, Odisha and north-east India in a farmer's participatory mode. Farmers' training programme were also organized and popularised. A total number of 250 micro plants of different cassava varieties were indexed against cassava mosaic virus through micropropagation technique in the tissue culture laboratory. A total number of 160 micro plants of elephant foot yam, variety Gajendra were indexed. Hardening of micro plants were done in cassava. Those hardened micro plants were further multiplied in the net house at ICAR-CTCRI and in field condition. The details of quality planting material production of tuber crops at ICAR-CTCRI, Thiruvananthapuram and Regional Centre, Bhubaneswar and distribution to farmers are shown in the Table 2 and field view of some of the plots are shown in Fig. 21.

Table 2. Quality planting material production of tuber crops

Sl. No.	Crop	Variety	Quantity of planting material produced	
			Number of stems/vine cuttings	Tonnes
1.	Cassava	Sree Vijaya	24000	-
		Sree Jaya	26000	-
		Sree Pavithra	6000	-
		Sree Swarna	5000	-
		Vellayani Hraswa	4000	-
		Total	65000	-
2.	Elephant foot yam	Gajendra		30.0
3.	Greater yam	Sree Keerthi	-	3.5
		Sree Shilpa	-	1.0
		Sree Roopa	-	3.5
		Da-293	-	8.0
		Orissa Elite	-	2.0
		Total	-	18.0
4.	Taro	Telia	-	1.5
		Muktakeshi	-	0.8
		Total	-	2.3
5.	Sweet potato	ST- 14	100000	-
		Kishan	120000	-
		Total	2,20,000	-
6.	Yam bean	RM-1		0.3

Fig. 21. Quality planting material production in cassava (left) and yams (right)

In another experiment, planting materials subjected to hot water soaking treatment resulted in zero cassava mosaic virus infection up to 3 months and it was 15 and 18% at 4th month and 35 and 40% at 8th month of planting in Sree Vijaya and Sree Jaya respectively. Cassava planted at KVK, Thirupathisaram, Kanyakumari district, Tamil Nadu, showed that the virus infection was zero up to 2 months, which got infected after 2 months and the infection was 30, 38, 42 and 51% at 8th month in the varieties, Sree Vijaya, Sree Pavithra Sree Swarna and Sree Jaya respectively. In the Kalrayan hills of Salem district, Tamil Nadu, the crop showed no virus infection up to 3 months and the incidence was 30 and 42% at 8th month in the varieties, Sree Vijaya and Sree Jaya respectively. In KVK, Santhanpara, Idukki district, Kerala, the crop showed less mosaic virus infection in the early stage and severe infection of up to 60% at 8th month in the varieties, Sree Vijaya, Sree Jaya, Sree Swarna and Sree Pavithra.

Induction of early and uniform sprouting in elephant foot yam

The results of the second season field experiment indicated that elephant foot yam corms fumigated with carbon disulphide @ 80 ml 100 kg^{-1} led to higher uniform sprouting (85.49 and 98.45% at 15 and 30 days after planting (DAP)), followed by carbon disulphide fumigation treatment @ 40 ml 100 kg^{-1}, which resulted in 80.45 and 94.25% sprouting at 15 and 30 DAP. Greater plant height (60 cm), stem girth (20 cm) and canopy spread (85 cm) were also recorded in the treatment, carbon disulphide @ 80 ml 100 kg^{-1} followed by GA3 @ 200 ppm treatment at 60 days after planting. Significantly higher corm yield of 19.15 t ha^{-1} was obtained in the carbon disulphide treatment @ 80 ml 100 kg^{-1} followed by carbon disulphide treatment @ 40 ml 100 kg^{-1} (17.62 t ha^{-1}) and GA3 200 ppm treatment (16.96 t ha^{-1}) (Fig. 22).

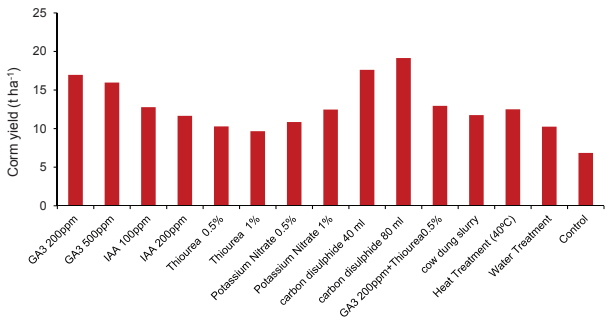


Fig. 22. Effect of growth regulators on corm yield of elephant foot yam

Cropping systems involving tuber crops and legumes

Intercropping system involving elephant foot yam and pulse crops

The field experiment to evaluate the feasibility of intercropping elephant foot yam and pulse crops was carried out for the first season (Fig. 23). The treatments comprised of factorial combinations of three varieties of elephant foot yam, Gajendra, Sree Padma and Sree Athira, three pulse crops, green gram, black gram and soybean and two fertility levels, (full FYM, N and K; half FYM and N, full K to elephant foot yam) (Fig. 24). Sole crops of all varieties of elephant foot yam under full FYM, N,

P and K were also maintained for comparison. The yield of elephant foot yam under intercropping with pulses (14.16 t ha^{-1}) was on par (-8.82%) with sole cropping (15.53 t ha^{-1}), during the first year (Fig. 24). Among the elephant foot yam varieties, Gajendra (18.78 t ha^{-1}) proved superior to Sree Padma (13.16 t ha^{-1}) and Sree Athira (10.54 t ha^{-1}). Effect of pulse crops and fertility levels on the yield of elephant foot yam was not significant, which indicates that the fertility level could be reduced to half (Fig. 24). Black gram was the most suitable pulse crop (228.58 kg ha^{-1}) for intercropping in elephant foot yam. The effect of varieties of elephant foot yam and fertility levels on grain yield of pulse crop was not significant. Among the treatment combinations, elephant foot yam var. Gajendra + black gram under full fertility level resulted in yield (21.60 t ha^{-1}), equivalent energy (79.82 x 10^3 MJ ha^{-1}), production efficiency (122.80 kg ha^{-1} day^{-1}) and tuber equivalent yield (22.10 t ha^{-1}) on par with sole cropping of elephant foot yam var. Gajendra (22.53 t ha^{-1}, 81.11 x 10^3 MJ ha^{-1}, 125.16 kg ha^{-1} day^{-1}, 22.53 t ha^{-1}). The soil chemical properties and tuber biochemical constituents were not affected due to intercropping.

Elephant foot yam + black gram

Elephant foot yam + green gram

Elephant foot yam + pulse crops

Fig. 23. Intercropping of elephant foot yam with pulse crops

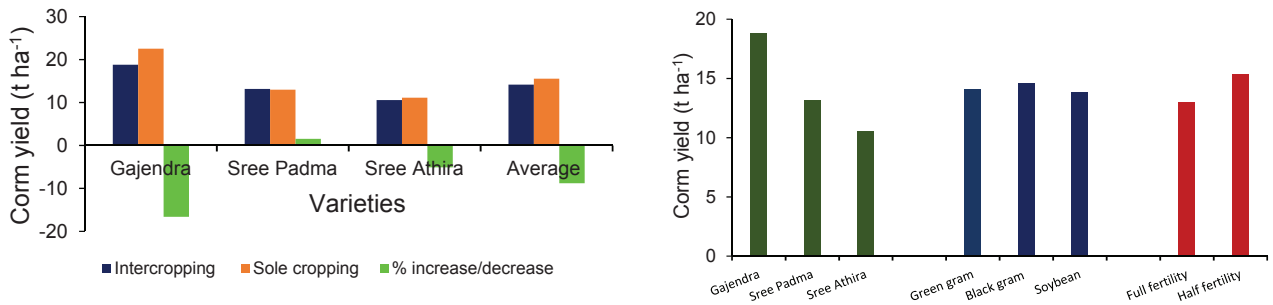


Fig. 24. Effect of varieties, pulses and fertility levels on corm yield of elephant foot yam

Weed management in elephant foot yam

The field experiment was taken up for the second season in randomized block design with three replications. The experiment consisted of eleven treatments; Pendimethalin (1 DAP) + Glyphosate (45 DAP) (T_1), Metribuzin (1 DAP) + Glyphosate (45 DAP) (T_2), Pendimethalin (1 DAP) + Tank mix of 2,4-D amine salt and Quizalofop ethyl (45 DAP) (T_3), Metribuzin (1 DAP) + Tank mix of 2,4-D amine salt and Quizalofop ethyl (45 DAP) (T_4), Pendimethalin (1 DAP) + 2 rounds of manual weeding (60 and 90 DAP) (T_5), Metribuzin (1 DAP) + 2 rounds of manual weeding (60 and 90 DAP) (T_6), 2 rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) (T_7), 2 rounds of manual weeding (30 and 60 DAP) + Tank mix of 2,4-D amine salt and Quizalofop ethyl (90 DAP) (T_8), Weed control ground cover (WCGC) (T_9), 4 rounds of manual weeding (30, 60, 90 and 120 DAP) (T_{10}) and Control (No weeding) (T_{11}). Observations on weed dry weight, weed control efficiency and corm yield were recorded. The crop was harvested at 8 MAP.

Significantly higher corm yield (36.00 t ha^{-1}) was obtained with weed control ground cover, which was on par with four rounds of manual weeding (30, 60, 90 and 120 DAP) (34.7 t ha^{-1}) and two rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) (33.4 t ha^{-1}). This was due to lower weed dry matter production and higher weed control efficiency (96.40% in T9 and 94.70% in T10). Maximum gross return (Rs 5, 39, 700 ha^{-1}) was obtained in weed control ground cover treatment. Maximum net return (Rs 2, 55, 700 ha^{-1}) was observed in four rounds of manual weeding (30, 60, 90 and 120 DAP). However, higher benefit:cost ratio (2.42) was noticed in two rounds of manual weeding (30 and 60 DAP) + Glyphosate (90 DAP) treatment due to lower cost of cultivation.

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

A field experiment was conducted during 2016-2017 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 1-270 DAP, I_2-100% CPE 1-90 DAP + 80% CPE 91-270 DAP and I_3-100% CPE 1-270 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 was applied in 5 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 was applied in 3 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). The greater yam cut tubers of 200 g were planted on ridges formed at 90 cm spacing. The plant to plant distance of 90 cm was maintained. In the intra-rows, in between two greater yam plants, 3 maize seeds were sown on the same day at a spacing of 30 cm. The irrigation was withheld 10 days before harvesting in all the treatments. The crop was harvested 280 days after planting.

The results revealed that I_3 resulted in higher maize yield, but on par with I_2. However, higher greater yam and tuber equivalent yields (TEY) were obtained from I_2. The decrease in greater yam yield in I_3 may be due to higher shoot growth owing to higher level of irrigation. Drip irrigation at I_1 (80% CPE 1-270 DAP) resulted in lower maize, greater yam and tuber equivalent yield. This may be due to moisture stress caused by lower level of drip irrigation. Increasing fertigation levels, 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 in F_4, were on a par with F_3. Interaction effect revealed that maize yield in I_3F_4 was on par with I_2F_4, I_3F_3 and

I_2F_3. But, greater yam and tuber equivalent yields were significantly higher in I_2F_4, which was on par with I_2F_3. The treatment I_2F_3 resulted in 66.20, 61.60 and 61.90% higher maize, greater yam and tuber equivalent yields respectively than control (IW/CPE=1 surface irrigation; no fertilizer), and 20.20, 25.40 and 25.10% higher maize, greater yam and tuber equivalent yields respectively than control (IW/CPE=1 surface irrigation; soil application of fertilizer).

The consumptive use of water by greater yam + maize intercropping system was 793.1 mm. The contribution of irrigation water, effective rainfall and soil profile moisture was 274.20, 470.10 and 48.80 mm, respectively in I_1 (80% CPE 1-270 DAP). The contribution of irrigation water, effective rainfall and soil profile moisture was 300.70, 448.40 and 44.00 mm, respectively in I_2 (100% CPE 1-90 DAP + 80% CPE 91-270 DAP). The contribution of irrigation water, effective rainfall and soil profile moisture was 345.20, 440.50 and 7.40 mm, respectively in I_3 (100% CPE 1-270 DAP). The water use efficiency of greater yam + maize intercropping system was higher in I_2F_4 (51.2 kg TEY/ha-mm) followed by I_2F_3 (50.3 kg TEY/ha-mm). Further, water required per kg of TEY production decreased with increasing fertilizer level. This may be due to higher yield. The treatment I_2F_4 and I_2F_3 resulted in lower water requirement 195 and 199 litre per kg of TEY production, respectively. The treatment I_2F_4 saved 70 litre of water per kg of TEY production compared to surface irrigation (with recommended dose of fertilizer). The treatment I_2F_3 saved 66 litre of water per kg of TEY production compared to surface irrigation (with recommended dose of fertilizer), whereas, surface irrigation without fertilizer required 524 litre of water to produce 1 kg of TEY. Higher nutrient use efficiency was noticed in I_2F_3 (107.8 kg kg^{-1}). Higher N and K use efficiency was observed in I_2F_1 treatment, whereas, higher P use-efficiency was noticed in I_2F_4. This may be due to moderate yield with lower dose of N and K application in the former case and higher yield in the latter case.

The economics of drip irrigation and fertigation indicated that higher cost of cultivation was worked out for I_2F_4. This was due to higher harvesting charges. Maximum gross and net returns as well as B:C ratio was computed for I_2F_4, which was on par with I_2F_3. This might be due to moderate cost of cultivation and higher maize and greater yam yield.

Water management studies in tropical tuber crops

Water saving techniques in elephant foot yam

The field experiment on water saving techniques in elephant foot yam was done for the second year to assess the possibilities of water saving and reduce the water requirement of the crop. The experiment was laid out in RBD with eight sets of 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 with crop residue mulching, weed control ground cover mulching and antitranspirant along with two controls, 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 36-45 days for initiating sprouting and 51-56 days for achieving 50% sprouting. Full sprouting was achieved within 56-67 days under different treatments. Rainfed crop took 56 days for first sprouting, 61 days for 50% and 73 days for 100% sprouting. Morphological characters recorded at monthly intervals were more or less similar, once the canopy established. However, girth of pseudostem, canopy spread and leaf area index were significantly superior in the treatment, where ground cover mulching was done. Soil samples were collected from two depths, 0-15 cm and 15-30 cm, from the planting zone at monthly intervals and the moisture content was assessed over a period of six months from planting. Available soil moisture varied from 6.98 to 14.5% in the top soil (0-15 cm) and 6.39 to 14.90% in the sub soil (15-30 cm) at different sampling intervals. Under rainfed conditions, moisture varied from 5.88 to 12.04% in the top soil and 6.88 to 12.40% in the sub soil during the different months.

During the second year of the experiment, significant difference in corm yield was recorded among the treatments. Maximum corm yield was obtained by providing 50% irrigation along with weed control ground cover mulching (27.81 t ha^{-1}). The rainfed crop produced the lowest corm yield of 12.53 t ha^{-1}.

The root distribution pattern of elephant foot yam was also studied under irrigated and rainfed conditions by planting the full corms approximately weighing one kg in 2 x 2 x 0.6 m cement tanks filled with soil. The plants were sampled at various stages viz., at sprouting, shoot elongation, leaf emergence, full emergence and then at monthly intervals up to senescence and morphological characters of roots were recorded. Root length attained maximum when the crop had fully emerged, which was maintained up to 5 MAP and thereafter started declining under both the conditions. When the canopy was fully opened, a root length of 116.40 cm and root volume of 890 cm^3 were recorded under irrigated condition, whereas a root length of 76 cm and a root volume of 635 cm^3 were observed for the rainfed crop.

Water management studies in taro

A field experiment was initiated during November 2016 to standardise irrigation scheduling in upland taro (Fig. 25). The experiment was laid out in 3 x 4 factorial design along with two controls, furrow irrigation and a rainfed crop. The factors included were three periods of irrigation (0-8 weeks after planting (WAP), 0-16 WAP, 0-24 WAP) and four levels of micro irrigation (IW/CPE ratio 0.75, 1.0, 1.25 and 1.50). Initial soil samples were collected and analysed for the nutrient status. The site was rich in organic C (1.30%), medium in available N (182.30 kg ha^{-1}) and high in available P (88.80 kg ha^{-1}) and K (175.20 kg ha^{-1}).

Irrigation during the initial period enhanced sprouting, the crop took 30-36 days for 50% sprouting and within 51 days, 100% sprouting was achieved. Only 64% of cormels sprouted after 60 days under rainfed control. Observations on growth `and soil moisture are being recorded at monthly intervals. Soil moisture varied from 8.70 to 13.52 % (v/v) under different levels of micro irrigation, two months after planting. The % soil moisture in the control plots were 17.80 % and 7.60% respectively under furrow irrigation and rainfed crop.

Fig. 25. Drip irrigation in taro

Precision approaches in tuber crops cultivation

Fertigation studies in cassava

The field experiment to arrive at the optimum dose of N and K fertilizers through fertigation in cassava was carried out for the third season. The experiment was laid out in 3^2 factorial design with three levels each of N and K nutrients. The three levels included were 75, 100 and 125 kg ha^{-1} each of N and K and full dose of P was applied as basal soil application. Standard NPK recommendation of 100:50:100 kg ha^{-1} as soil application was kept as control. Planting materials of cassava var. 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. Tuber yield and yield parameters were recorded at harvest after 7 months. During the third year, there was no significant difference among N levels, however among K levels, K_2 and K_3 were superior to K_1 level. Among the interaction effects, 75 kg ha^{-1} N and 100 kg ha^{-1} K resulted in maximum tuber yield (57.41t ha^{-1}) and was on par with recommended dose of 100 kg each of N and K. However, all the interaction effects, except 75 kg each of N and K and 100 kg N and 75 kg K, were on par.

Pooled analysis of data of three years indicated that a combination of 75 and 125 kg each of N and

K respectively resulted in maximum tuber yield (48.68 t ha^{-1}), on par with 100 kg each of N and K (47.09 t ha^{-1}), 75 kg N and 100 kg K (45.01 t ha^{-1}) and other higher nutrient levels. Interaction effect of 75 and 125 kg each of N and K respectively also resulted in the highest B:C ratio of 3.6 among the different fertigation treatments.

The plant parts were separately analysed for major nutrients and total uptake was worked out for fertigation treatments. N uptake was more or less similar under different treatments, K uptake increased with higher levels of K (Fig. 26).

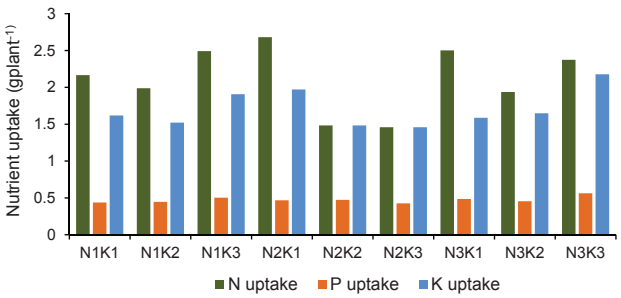


Fig. 26. NPK uptake of cassava (g plant^{-1}) under different fertigation treatments

Long term fertilizer cum manurial experiment in cassava

The results on the effect of continuous application of fertilizers, different organic manure sources, different combinations of secondary and micronutrients on tuber yield, soil chemical properties, nutrient content, uptake of nutrients and dry matter production for the 12th season crop are briefly described. Sustainability of cassava for continuous cultivation was established after 12th season crop with a tuber yield of 14.27 t ha^{-1}, without manures and fertilizers. Soil test based application (STBF) of NPK @ 84:0:106 kg ha^{-1} along with FYM @ 5 t ha^{-1} produced tuber yield (23.18 t ha^{-1}) on par with the recommended POP (FYM @ 12.5 t ha^{-1} + NPK @ 100:50:100 kg ha^{-1}) (23.06 t ha^{-1}). Continuous application of NPK @ 125:50:125 (25.61 t ha^{-1}), 100:50:100 (23.06 t ha^{-1}), 50:25:100 (28.91 t ha^{-1}), 50:25:50 (21.40 t ha^{-1}) and soil test based @ 84:0:106 kg ha^{-1} (23.18 t ha^{-1}) were on par with respect to tuber yield. Green manuring *in situ* with cowpea (28.91 t ha^{-1}), coir pith compost (20.09 t ha^{-1}) and vermicompost (21.69 t ha^{-1}) were found as alternatives to FYM (23.06 t ha^{-1}). Organics alone applied as combination of crop residue, coir pith compost, vermicompost and ash without any chemical fertilizers (18.99 t ha^{-1}) resulted in a significantly lower yield than other organic sources along with chemical fertilizers. Green manuring *in situ* with cowpea along with different combinations of major, secondary and micronutrients (32.57 t ha^{-1}) resulted in significant yield increase compared to FYM combined with major, secondary and micronutrients (23.89 t ha^{-1}) (Fig. 27). The fresh green biomass of cowpea added was 16. 80 t ha$^{-1.}$

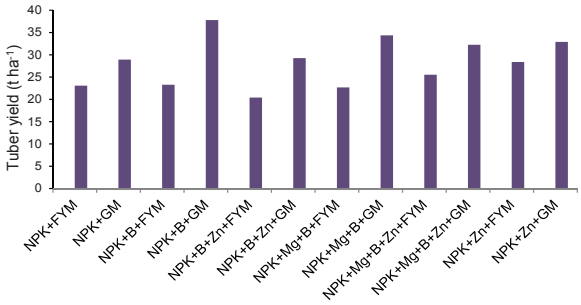


Fig. 27. Effect of green manuring *in situ* with cowpea on cassava tuber yield

Soil test based application of Mg (0.27 meq 100g^{-1}) as $MgSO_4$ alone @ 15 kg ha^{-1} (32.89 t ha^{-1}) and along with Zn (2.83 ppm) as $ZnSO_4$ @ 2.5 kg ha^{-1} (39.18 t ha^{-1}) were on par and produced significantly higher tuber yield than POP (23.06 t ha^{-1}). All the other single, two nutrient and three nutrient combinations of Mg, Zn and B were on par to POP.

Levels of fertilizers, different organic manures and combinations of secondary and micronutrients did not significantly affect the starch and cyanogenic glucoside content of tubers. But B application resulted in low cyanogen content.

Soil samples were collected during April, 2016 for the 12th season crop of cassava in six selected treatments receiving continuous organic manure applications and absolute control and analyzed for basic physical parameters. The bulk density value was highest (1.61 Mg m^{-3}) in absolute control, whereas significant differences and lowest values was observed in plots treated with a combination of organic manures viz., vermi compost, coir pith compost, ash and crop residue (1.46 Mg m^{-3}), which was on par with the plot receiving coir

pith compost along with NPK (1.48 Mg m^{-3}). The maximum water holding capacity was also significant among the different treatments with the maximum (48.60%) under the combined application of organic manures.

Levels of fertilizers exerted significant effect on soil pH, organic C and exchangeable Mg**.** Though there was no significant effect of levels of fertilizers on soil available P status, there was 53% reduction in soil available P than the previous year, especially under STBF and low P application @ 25 kg ha^{-1}. Among the levels, NPK @ 125:50:125 kg ha^{-1} resulted in the highest status of Fe, Cu, Mn and Zn in the soil. The status of pH, organic C and exchangeable Mg was significantly higher under organics alone, having ash as one of the constituents, coir pith compost and FYM respectively. Application of secondary and micronutrients imparted significant effect only on Mg status of the soil with highest levels in treatments having Mg as one of the components, especially under Mg + B (1.59 meq $100g^{-1}$soil), Mg + Zn + B (1.51 meq $100g^{-1}$soil), Zn + Mg (1.42 meq $100g^{-1}$ soil) and Mg (1.38 meq $100g^{-1}$ soil) (Fig. 28). There was comparatively higher B and Zn status in the soil due to the application of secondary and micronutrients. Levels of fertilizers significantly influenced the N uptake with NPK @ 125:50:125 kg ha^{-1} resulting in the highest uptake. However, this was on par with all the other treatments, except absolute control.

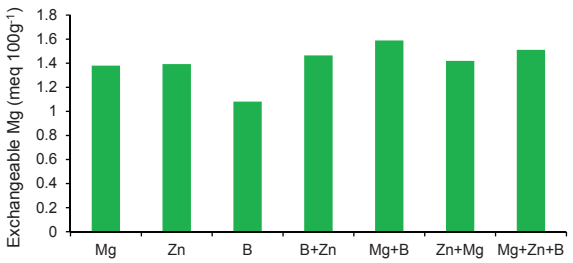


Fig. 28. Effect of soil test based application in cassava on exchangeable Mg status of the soil

Screening nutrient efficient genotypes in cassava for low input management

NUE genotypes for reduction / substitution of NPK fertilizers (I season)

Genotypes varied significantly in tuber yield, biometric characters like plant height at 3 and 6 months after planting (MAP), stem girth at 9 MAP, retained leaves at 3 and 6 MAP, fallen leaves at 3 MAP, stem dry weight, stem N and P, tuber P, agronomic efficiency (AE) and physiologic efficiency (PE). Among the genotypes, 7 III E3-5 gave a tuber yield of 49.44 t ha^{-1}, which was on par with Acc. No. 905 (43.10 t ha^{-1}). Sree Pavithra (39.47 t ha^{-1}) and Acc. No. 906 (39.87 t ha^{-1}) produced yield on par with Acc. No. 905. The four different levels viz., 25 (39.77 t ha^{-1}), 50 (41.58 t ha^{-1}), 75 (44.34 t ha^{-1}) and 100% of the recommended dose of NPK (100:50:100 kg ha^{-1}) (46.20 t ha^{-1}) did not differ significantly in affecting the tuber yield indicating that when NPK efficient genotypes are used, the NPK levels can be reduced up to 25% (Fig. 29).

7 III E3-5 at 25% NPK

7 III E3-5 at 50% NPK

Fig. 29. Tuber yield of 7 III E3-5 under different NPK levels

7 III E3-5 at 75% NPK

7 III E3-5 at 100% NPK

Fig. 29 (contd). Tuber yield of 7 III E3-5 under different NPK levels

The genotype, 7 III E3-5 had significantly the highest agronomic efficiency (212.80 kg tuber per kg NPK applied). Physiological efficiency was significantly higher for Acc. No. 906 (61.99 kg DM per kg NPK uptake), which was on par with Sree Pavithra (61.19) and 7 III E3-5 (59.71) (Fig. 30). Levels of NPK significantly influenced the apparent recovery efficiency (ARE), agronomic efficiency (AE), NPK uptake ratio (NPK UR) and utilization efficiency (UE). ARE (9.98), AE (319.7) and UE (0.58) were significantly highest at 25% NPK. NPK UR was significantly highest at 50% NPK (0.57). ARE and UE were significantly influenced by interaction effect of genotypes and NPK levels, wherein 7 III E3-5 at 25% NPK had significantly the highest ARE (13.05) and UE (0.77).

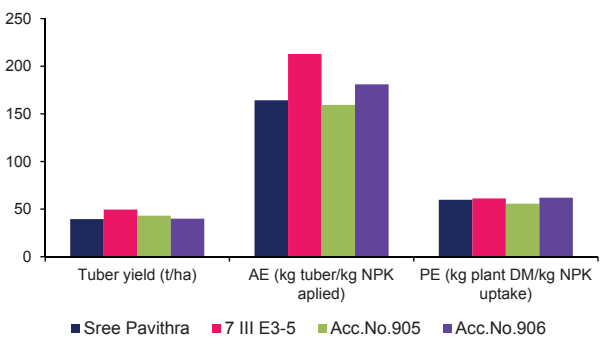


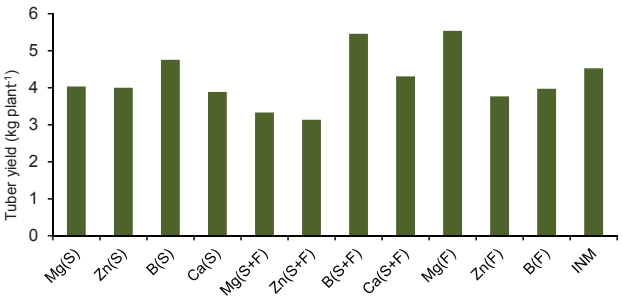
Fig. 30. Tuber yield and NUE parameters of the promising genotypes

Fourteen NUE genotypes are being maintained at ICAR-CTCRI farm. Planting materials of the K efficient cassava variety 'Sree Pavithra' were multiplied in different blocks of ICAR-CTCRI farm and farmer's fields (2000 stems).

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

Response of elephant foot yam to secondary and micronutrients under INM

The experiment to study the response of elephant foot yam to secondary and micronutrients under INM was conducted in tanks of 1 m^3 (lysimeter type structures) with 12 treatments (2 liming materials viz., dolomite and lime @ 120 g $plant^{-1}$, nutrients viz., Zn, B, Mg, Ca applied through soil, foliar and soil + foliar) replicated twice with variety Gajendra. The results indicated that dolomite was the best liming material @ 1.5 t ha^{-1}. B, Ca and Mg were important for elephant foot yam and soil + foliar applications of these nutrients gave better results compared to the other treatments (Fig. 31).



S: soil application, F: foliar application

Fig. 31. Effect of secondary and micronutrients on tuber yield of elephant foot yam

Response of sweet potato to liming

An observational trial on response of sweet potato to liming was conducted for three seasons with 12 treatments using the variety Sree Arun (liming materials viz., dolomite, lime, gypsum (soil application @ 120 g plant^{-1}), foliar application: calcium nitrate, $MgSO_4$, @ 0.5% at fortnightly intervals). During the first season, among the liming materials, dolomite followed by gypsum was better. Foliar application of $CaNO_3$ gave good results. During the second season, INM + dolomite along with foliar application of 19:19:19 + Zn EDTA during the peak vegetative growth stage and KNO_3 along with solubor twice at tuber bulking stage at an interval of one month was effective. Third season trial is in progress.

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

Four on-station experiments were continued for cassava, elephant foot yam, greater yam and white yam to generate input data for QUEFTS model. On-farm validation experiments of customised fertilizers developed for cassava based on SSNM technology were conducted in 35 farmers' fields spread across five agro-ecological unit (AEU) zonations of Kerala (Malappuram, Palakkad, Idukki, Alappuzha and Pathanamthitta). In Idukki, Malappuram and Palakkad districts, the customized fertilizer treatment resulted in significantly higher tuber yield (42.50, 62.50 and 48.60 t ha^{-1} respectively) than farmer fertilizer practice (FFP) (35.30, 50.30 and 38.40 t ha^{-1} respectively). On an average, the customized fertilizer treatment resulted in 24% higher yield over FFP in these agro-ecological units. On-farm validation experiments of customised fertilizers developed for sweet potato based on SSNM technology were conducted in seven farmers' fields in Denkanal district, Odisha for two consecutive seasons. The tuber yield in SSNM treatment (11.50 t ha^{-1}), was on par with that of FFP (11.80 t ha^{-1}). Secondary-and micronutrient-inclusive customised plant nutrient formulations were developed for major yams and sweet potato growing areas of India. The decision support system for SSNM of cassava, CASSNUM version 1.1 was released. A mobile app for SSNM of tropical tuber crops has been developed and is in the final stage of testing. Two other decision support systems for SSNM of elephant foot yam and sweet potato have been developed and are in the final stages of testing.

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

A field experiment was conducted during Kharif 2016-2017 at Regional Centre, ICAR-Central Tuber Crops Research Institute, Bhubaneswar, to study the effect of integrated use of lime, inorganic and organic manures on soil quality, yield and bio-chemical constituents of elephant foot yam. The experimental soil is sandy loam, acidic (pH 5.16), non saline (0.24 dS m^{-1}), and had 0.256% organic C, and 226, 24.64 and 189 kg ha^{-1} of available N, P and K. The experiment was laid out with 14 treatments viz., Control (T_1), Soil Test Based Fertilizer (STBF) i.e. N, P_2O_5 and K_2O @ 94:30:80 kg ha^{-1}(T_2), 150% STBF (T_3), 50% STBF (T_4), FYM (Eq. wt. based on N conc.) (T_5), vermicompost (Eq. wt. based on N conc.) (T_6), Neem cake (Eq. wt. based on N conc.) (T_7), Lime + STBF (T_8), FYM + NPK + $ZnSO_4$ @ 10 kg ha^{-1} (T_9), Lime + FYM + NPK + $ZnSO_4$ @ 10 kg ha^{-1} (T_{10}), FYM + NPK + Borax @ 5.0 kg ha^{-1} (T_{11}), Lime + FYM + NPK + Borax @ 5.0 kg ha^{-1} (T_{12}), FYM + NPK + $MgSO_4$ @ 25 kg ha^{-1} (T_{13}) and Lime + FYM + NPK + $MgSO_4$ @ 25 kg ha^{-1} (T_{14}). The treatments were replicated thrice in a randomized block design. Elephant foot yam (cv Gajendra) corms were cut into pieces of 250 g, and planted in 45 cm^3 pits at a spacing of 75x75 cm. Black gram seeds were dibbled in between elephant foot yam crop as an inter crop and grown up to 70 days. The crops were harvested at maturity, yield parameters were recorded and plant samples were analyzed for proximate composition and nutrient contents.

Highest corm yield (9.25 t ha^{-1}) was obtained due to integrated application of lime + FYM + NPK + $ZnSO_4$, with highest yield response of 105% over control. The increase in tuber 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 vermi compost resulted in higher tuber yield (11.30 t ha^{-1}) 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 alone. Of all the treatment combinations, significantly highest starch and total sugars on fresh weight basis and dry matter content was obtained due to application of lime + FYM + NPK + borax (16.53, 1.61 and 26.46%, respectively). Among the organic manures, application of neem cake resulted in highest starch, sugars and dry matter contents in the corms of elephant foot yam. Total sugars ranged from 1.29 to 1.61%, and the dry matter varied from 20.92 to 26.46%.

Significantly highest uptake of N and P (147.10 and 13.69 kg ha^{-1}, respectively) by elephant foot yam corms was observed under integrated application of lime + FYM + NPK + $MgSO_4$ during 2015-2016; however, the K uptake was highest due to integrated use of lime + FYM + NPK + $ZnSO_4$ (38.38 kg ha^{-1}). Highest uptake of Fe, Cu, Mn and Zn in the corms of elephant foot yam (1443.40, 88.50, 2429.70 and 680.20 g ha^{-1}, respectively) was recorded due to integrated use of lime + FYM + NPK + $MgSO_4$. Integrated application of soil test based NPK in combination with lime, FYM and $MgSO_4$ resulted in higher dehydrogenase (1.526 µg TPF hr^{-1} g^{-1} soil), fluorescein diacetate activities (1.624 µg g^{-1} hr^{-1}), acid phosphatase and alkaline phosphatase activities (49.64 and 42.08 µg PNP g^{-1} h^{-1}, respectively). All the soil properties showed significant relationship with dehydrogenase activity of the soil and the 'r' values were found to be 0.43, 0.67**, 0.45, 0.65**, 0.40, and 0.66** in respect of pH, organic C, total N, available N, P, and K. In conclusion, integrated use of balanced dose of fertilizers along with organic manure, lime and $ZnSO_4$ or $MgSO_4$ improved the soil quality and productivity in elephant foot yam-black gram system.

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) representing 20 locations adjacent to mines and industrial areas from Sundargarh and Jharsuguda districts of Odisha were collected during 2016 to assess the accumulation of heavy metals due to pollutants released from mines and industries into the arable lands. The soils were non saline and varied widely in pH (5.94 – 7.25), low to high in organic C (0.16 - 1.98%) and had 101 - 244, 5.38 – 82.88, and 83 - 483 kg ha^{-1} of available N, P, and K, respectively. The soils also contained 11.5 - 578.0, 0.69 - 9.02, 4.2 - 173.7 and 0.72 - 8.80 mg kg^{-1} of available Fe, Cu, Mn and Zn, respectively. Dehydrogenase activity and fluorescein diacetate activity in the soils ranged from 0.894 – 2.881 µg TPF $hr^{-1}g^{-1}$ and 0.224 - 2.019 µg $g^{-1}hr^{-1}$, respectively. The acid and alkaline phosphatase activities in the soils ranged from 10.29 – 42.25 and 14.35 – 42.30 µg PNP g^{-1} hr^{-1}.

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

The tuber yield of cassava was 27.80, 31.60 and 26.00 t ha^{-1} under conventional (CT), deep (DT) and minimum tillage (MT) practices during the second year of experimentation. The different types of mulches influenced the yield in the order, porous ground cover (GC) (28.40 t ha^{-1}>crop residue (CR) (25.30 t ha^{-1}) > no mulch (NM) (23.60 t ha^{-1}). The average values of surface soil water storage (volumetric) and soil temperature estimations made during May, August, December, 2016 and March, 2017 showed that the average soil moisture were 8.20, 9.10 and 9.80% and the soil temperature were 36.2, 35.9 and 35.5°C respectively under CT, DT and MT practices. Among the mulch practices, GC had the highest moisture content (10.30 %, v/v) as compared to no mulch (7.80%, v/v). The hydraulic properties viz., field saturated hydraulic conductivity (HC), matric potential (MP), and sorptivity (SS) estimated during May, 2016 under different treatments indicated that HC and SS of CT

was 10 and 22% higher as compared to minimum tillage, whereas 16% increase in matric potential was observed under GC as compared to NM. The results showed that soil physical characteristics affecting sorptivity seems to be important and must be improved to get the desired effects in minimum tillage soils with time. The interactions among minimum tillage and GC mulch showed improved values of sorptivity (0.032 cm $min^{-1/2}$) as compared to the first year (0.023 cm $min^{-1/2}$) but significantly less than deep tillage treatment. Soil properties viz., soil moisture, bulk density and available P and K had a significant positive relationship (r=0.72**) with tuber yield in conventional tilled soils.

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

Studies on heat stress management in tropical tuber crops

The objective of the study was to induce tolerance to high temperature stress through chemical treatments in elephant foot yam. For this purpose, variety Gajendra was planted in randomized block design with four replications under field conditions. Five foliar spraying treatments were given as follows (1) Control without water spray (2) Control with water spray (3) Foliar spraying of 0.2% $CaCl_2$ during 4-8th month at fortnight intervals (4) Foliar spraying of 0.2% Salicylic acid during 4-8th month at fortnight intervals (5) Foliar spraying of 1000 ppm Benzyl adenine (BA) during 4-8th month at fortnight intervals. Elephant foot yam was planted inside polyhouse and four treatments were given (T_2 to T_5). Prevailing weather conditions under open field and polyhouse conditions with and without humidification were recorded.

On bright sunny day inside the polyhouse, elephant foot yam plants experienced high temperature stress of ~32 to ~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, leaf area, relative water content in plants, soil and air temperature were recorded under field as well as polychamber conditions. The crop was harvested at 8 MAP.

Under field conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 27.77%, 29.98% and 17.20% respectively as compared to control plants under ~32^{o}C day temperature. Under humidified polychamber conditions, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 22.70%, 27.12% and 5.04% respectively as compared to control plants under 32-40^{o}C day temperature and >80% RH (10 am – 4 pm). Under polychamber conditions without humidification, foliar spraying of $CaCl_2$ (0.2%), Salicylic acid (0.2%) and BA (1000 ppm) during 4th to 8th month increased corm yield by 39.73%, 36.43% and 4.26% respectively as compared to control plants under 32-40^{o}C day temperature and ~50% RH (10 am – 4 pm). Compared to field conditions, the corm yield was significantly reduced by 28.78% to 56.68% under polychamber conditions in control as well as under $CaCl_2$, Salicylic acid and BA treatments.

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

A field experiment was conducted for the second consecutive season in the natural saline soil during rabi, 2016-2017, in the field of Shri. Madan Mohan Joydhar of Chouldari Village, Chouldari Gram Panchayat, South Andaman district, Andaman & Nicobar Islands in collaboration with ICAR - 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. The trial was laid out with 4 levels of P i.e. 0, 20, 40, 60 kg P_2O_5 ha^{-1} and 4 levels of K i.e. 0, 25, 50, 75 kg K_2O ha^{-1}. Sweet potato (cv. Samrat) vine cuttings were planted during December 2016,

harvested during April 2017 and yield parameters were recorded.

Studies on nutrient uptake of the previous season (2015-2016) crop indicated that the highest total uptake of N (154.30 kg ha^{-1}) was recorded due to application of 40 and 50 kg P_2O_5 and K_2O, respectively, whereas highest K uptake (212.8 kg ha^{-1}) was noticed due to application of 60 and 50 kg P_2O_5 and K_2O, respectively. Thus, the results of the study indicated 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 amount of bio-chemical constituents in the natural saline soils under island ecosystem of Andaman.

Nutrient omission trial was laid out for the second consecutive rabi season during 2016-2017 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 applied. Sweet potato (var. Samrat) vine cuttings were planted during December 2016 and harvested during April 2017 and yield parameters were recorded.

Studies on nutrient uptake of the previous season (2015-2016) crop indicated that the total uptake of N, P and K (180, 22, 194 kg ha^{-1}) was highest due to application of N and P @ 50 and 25 kg ha^{-1}, respectively. The overall results indicated that application of balanced doses of NPK produced sustainable crop yields of sweet potato with good quality tubers in saline soils of Andaman.

Response of tuber crops to elevated CO_2

The response of 10 sweet potato varieties to eCO_2 was studied. The net photosynthetic rate (*Pn*), stomatal conductance (g_s) and intercellular CO_2 (*Ci*) was studied in 12 contrasting sweet potato genotypes viz., Sree Arun, Sree Badhra, Sree Kanaka, Kanhangad, Pusa Safed, Pusa Red, Kisan, Gouri, Sankar and ST-13, S-1464 and S-1466 under ambient (400 ppm) and eCO_2 (600, 800 and 1000 ppm) using portable photosynthesis system LI-6400, LICOR, USA. The *Pn* steadily increased due to short-term (ten minutes) exposure at eCO_2 concentrations between 400 ppm and 1000 ppm in 12 sweet potato genotypes. The sweet potato genotypes had the average *Pn* of 26.30, 33.41, 38.02 and 40.32 µmol m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. However, the per cent of increment in *Pn* at eCO_2 significantly declined (average 5.98%) at CO_2 concentrations above 800 ppm. The genotypes, Gouri, Sankar, Sree Arun, and S-1466 showed 61.00 – 74.30% increment in *Pn* at eCO_2 (1000 ppm) as compared to ambient CO_2 (400 ppm). The per cent increment in *Pn* significantly decreased at CO_2 concentrations above 600 ppm. The differences in *Pn* were statistically significant across sweet potato genotypes and CO_2 concentrations (P>0.001), whereas the *Pn* had a quadratic relation with the increase in CO_2 concentration (R^2=0.603). The g_s steadily decreased at eCO_2 concentrations. The sweet potato genotypes had the average g_s of 0.606, 0.508, 0.431, 0.376 mol H_2O m^{-2} s^{-1} at 400, 600, 800 and 1000 ppm CO_2 respectively. The per cent of decrease in g_s at eCO_2 significantly increased (average 38.33%) at 1000 ppm CO_2. The differences in g_s were statistically significant across sweet potato genotypes and CO_2 concentrations (P>0.001). The sweet potato genotypes had the average *Ci* of 271.50, 405.20, 543.00, and 684.00 µmol CO_2 per mol air at 400, 600, 800 and 1000 ppm CO_2 respectively. However, the per cent of increment in *Ci* at eCO_2 significantly declined (average 25.70%) at CO_2 concentrations above 600 ppm. The differences in *Ci* were statistically significant across sweet potato genotypes and CO_2 concentrations (P>0.001) whereas the *Pn* had a quadratic relation with the increase in *Ci* (R^2=0.504). The interaction effect of genotypes and CO_2 concentration on *Ci*, *Pn* and g_s was insignificant. The gas exchange parameters were not influenced by the total chlorophyll and protein content.

Two sweet potato varieties viz., Sree Arun and Kanhangad were planted under Open Top Chamber conditions exposing the plants to elevated CO_2 (600 ± 50 ppm CO_2) and control ambient air (400 ± 10 ppm CO_2) at ICAR-CTCRI on 16 January 2017 and ICAR-Central Potato Research Institute,

Regional Station, Jalandar on 15 February 2017 . The experiment is in progress.

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

Kernel based Possibilistic *c*-means approach developed for cassava acreage estimation was validated for area estimation in Namakkal and Dharmapuri districts. Ground truth data were collected and the area was estimated. The total estimated area was 17125 ha and 19263 ha for Dharmapuri and Namakkal districts respectively. The change in climate and climate suitabilities over major cassava growing regions of India by 2050 were studied using the spatially downscaled Global Climate Model (GCM), BCC_CSM1. The scenario selected for the modelling was Representative Concentration Pathways (RCP 4.5), which is medium green house gas trajectories adopted by International Panel for Climate Change (IPCC) for its fifth Assessment Report (AR5). The resolution of the model used was 30 arc seconds. Future changes in climate and climate suitability were studied using geoinformatics tools (DivaGIS) and AR5 data of IPCC. The model predicted that by 2050, the mean temperature of cassava growing areas in India will increase on an average by 1.86^{o}C (0 - 2^{o}C). The total precipitation of cassava growing areas in India will increase on an average by 231.60 mm (0-366 mm). The results showed that in the cassava growing environments of India, the climate suitability will increase by 42.30% (-57-100 %) in 2050.

Climate smart agriculture practices for climate literacy to cassava farmers

Two on-station experiments were started during the year to study the effect of 14 different climate smart agriculture (CSA) practices of cassava on growth and yield and to study the mitigation potential of each of the selected practice in comparison to conventional practice. One experiment each was laid out at ICAR-CTCRI, Thiruvananthapuram and ICAR-Regional Centre of CTCRI, Bhubaneswar. The 14 components of CSA practices are *A. Nutrient smart practices*: 1. Liming to increase the soil pH to 6.0 (SMP buffer method), 2. Fertilizer application based on CASSNUM version 1.1, 3. Neem coated urea, 4. *Azospirillum* and *Phosphobacterium* @ 3 kg ha^{-1}, 5. Green leaf manuring with *Pongamia pinnata*, 6. Green leaf manuring with *Gliricidia*, 7. Cowpea green manure incorporation, 8. Black gram haulm incorporation 9. Hybrid Napier fodder grass, Co-3 on the bunds; *B. Water smart practice* : 10. Drip irrigation, only when necessary; *C. Carbon and energy smart practices*: 11. Ridge and furrow method of planting using energy efficient machinery, 12. Quality planting material – minisett technique, 13. Green manure cowpea-cassava-black gram sequential cropping and 14. Weed control ground cover. The second treatment, conventional practice, includes 1. Recommended agro-techniques and nutrient management and 2. Mound method of land preparation. The experiments are in progress.

CROP PROTECTION

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

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

Screening of insecticides for the management of sweet potato weevil

In order to develop safe insecticidal combination with less toxic insecticide and bioactive molecules isolated from cassava for the management of sweet potato weevil, the locally available synthetic pesticides viz.,. Malathion, Chlorpyrifos, Dimethoate, Fenvalerate, Imidacloprid and Dichlorvos were screened. Leaves sprayed with three concentrations viz., 0.001, 0.01 and 0.05% of these insecticides were fed to sweet potato weevil, and weevil mortality was recorded at regular intervals. A positive correlation was noted between mortality of the weevil and concentration of the insecticides used. One day after treatment, mortality of weevil due to the treatment with 0.001% was high in the treatment with Imidacloprid (56.1%), followed by Chlorpyrifos (46.6), Fenvalerate (43.3%), Dichlorvos (40.0%), Dimethoate (16.6%) and Malathion (3.3%). At 0.01% concentration, mortality of weevil was 93.20% in the batches treated with Imidacloprid, whereas it was 86.60, 73.30, 66.60, 56.60, 16.70% in the treatments with Chlorpyrifos, Dichlorvos, Fenvalerate, Dimethoate and Malathion, respectively. At higher concentration (0.05%), mortality was cent percent in the treatment with Imidacloprid and Chlorpyrifos. High morality was also observed in the batches treated with Dichlorvos (98.00%), Dimethoate (91.20%), Fenvalerate (83.20%) and Malathion (26.60%).

Systemic action of these insecticides was studied by feeding the weevils with leaves treated with different concentration of insecticides. At 0.001% concentration, the mortality of weevil one day after treatment was 56.40% due to Imidacloprid and low mortality was also found in Fenvalerate (21.60%), Dichlorvos (16.20%), Chlorpyrifos (7.20%), Dimethoate (5.40%) and Malathion (5.40%). Whereas in the case of treatment with 0.01%, an increased mortality was noticed in Imidacloprid (77.4%), Fenvalerate (52.2%), Dimethoate (32.4%), Dichlorvos (25.2%), Chlorpyrifos (22.6%) and Malathion (5.4%). A further increase in mortality could be observed at 0.05% treatment in Imidacloprid (77.4%), Fenvalerate (52.2%), Dichlorvos (54.0%), Chlorpyrifos (22.6%), Dimethoate (37.8%) and Malathion (5.4%).

When the leaves were plucked at 3rd day after treatment with 0.001% insecticides and fed to the weevil, high mortality was observed in Imidacloprid (48.6%) followed by Fenvalerate (9.0%), Dichlorvos (3.6%), Chlorpyrifos (3.6%), Dimethoate (12.6%) and Malathion (5.4%). At 0.01% concentration, high mortality was observed in Imidacloprid (72.0%) followed by Fenvalerate (19.8%), Dichlorvos (19.8%), Chlorpyrifos (7.2%), Dimethoate (32.4%) and Malathion (5.4%). Considerable increase in the mortality of weevil was observed at 0.05% concentration. The highest mortality was observed in Imidacloprid (72.0%) followed by Fenvalerate (21.6%), Dichlorvos (19.8%), Chlorpyrifos (12.6%), Dimethoate (32.4%) and Malathion (10.8%).

On the 5th day after treatment, weevil mortality occured in Imidacloprid, Fenvalerate, Dichlorvos and Dimethoate; but the residue in Imidacloprid treated leaves persisted even at 12 days after treatment.

Integrated pest management of borer pests of tropical tuber crops

Insect pests of sweet potato, taro and yam bean were surveyed in Andhra Pradesh, Kerala and Odisha. Sweet potato weevil, *Cylas formicarius*, was the single and most serious pest causing damage up to 90%, if management practices were not adopted. In Odisha, Koraput, Navranpur, Puri, Khurda and Bargarh districts, and in Kerala, Research Farm of ICAR-CTCRI, Thiruvananthapuram were surveyed (Fig. 32). Eighteen insecticides, including new generation insecticides were evaluated against borer pests of tuber crops during 2016-2017 rabi season

at the Research Farm, ICAR-CTCRI, Regional Centre, Bhubaneswar. Sweet potato variety Kishan was planted on 23rd September 2016 in red loamy soils. Out of 18 insecticides, 10 belonged to systemic and combination products (Imidacloprid 17.8SL @ 30 g ai ha^{-1}, Dimethoate 30 EC @ 300 g ai ha^{-1}, Acetamiprid 20SP @ 15 g ai ha^{-1}, Acephate 75 SP @ 350 g ai ha^{-1}, Thiomethoxam 25WG @ 25 g ai ha^{-1}, Triazophos 35 + Deltamethrin 1EC @ 360 g ai ha^{-1}, Chlorpyriphos 20SC @ 200 g ai ha^{-1}, Profenophos 40EC + Cypermethrin 4EC @400 g ai ha^{-1}, Fipronil 5 SC @ 40 g ai ha^{-1}, Buprofezin 25 SC @ 75 g ai ha^{-1}). Among the non-systemic group (contact or stomach or fumigant), Bifenthrin 10 EC @ 50 g ai ha^{-1}, Cypermethrin 10 EC @ 50 g ai ha^{-1}, Spinosad 45 SC @ 73 g ai ha^{-1}, Emamectin benzoate 5 SG @ 10 g ai ha^{-1}, Cartap hydrochloride 50 SP @ 500 g ai ha^{-1}, Chloronatraniprole 18.5SC @ 30 g ai ha^{-1}, Propargite 57EC @ 850 g ai ha^{-1}, Dichlorvos 76EC @ 500 g ai ha^{-1}, Triazophos 40 EC @ 500 g ai ha^{-1} were tried. The insecticides were sprayed twice, once at 45 days after planting and another at 60 days after planting. All insecticides were effective in reducing the weevil incidence and infestation (0 to 3.1%), whereas, in control plots there was 18.20% infestation in tubers. Radish, yam bean, marigold, garlic, *Cleome viscosa* and coriander were used as intercrops (2:2 ratios). Among these, intercropping with marigold resulted in lowest weevil infestation (13.73%) followed by coriander (17.66%), whereas it was highest in *Cleome viscosa* (32.33%) followed by yam bean (30.33%). Sweet potato weevil sex pheromone technology was popularized in different districts of Kerala, Andhra Pradesh (Figs. 32 & 33) and Odisha and pheromone lures were sent to different AICRP centres in Telangana, Chhattisgarh and Maharashtra.

Fig. 32. Pheromone traps at ICAR-CTCRI, Thiruvananthapuram

Fig. 33. Sweet potato weevil pheromone trap demo in Araku, Andhra Pradesh

Molecular characterization of endosymbionts of insect pests associated with tropical tuber crops

Mealy bugs were collected from cassava plants and elephant foot yam tubers. The insect samples from cassava leaves were identified as *Ferrisia virgata* and the samples collected from elephant foot yam tubers were identified as *Rhizoecus amorphophalli*. The metagenomic DNA of cassava mealy bugs was isolated and were sent for metagenomic DNA Illumina sequencing of V3 variable region of 16S rRNA gene. The bacterial endosymbionts associated with the mealy bugs belongs to the genera *Propionibacterium (Actinobacteria-0.8%) Firmicutes (Bacillus), Rhizobiales (Alphaproteobacteria-0.4%), Candidatus tremblaya (Betaproteobacteria-85.9), Enterobacteria, Aeromonas (Gammaproteobacteria- 12.5%)* (Fig. 34). The secondary bacterial endosymbionts associated with the cassava mealy bugs were isolated. The bacterial genomic DNA was isolated and bacterial 16S rDNA of 1500bp was amplified using universal primers: forward primer fD1 AGAGTTTGATCCTGGCTCAG and reverse primer RP2 CGGCTACCTTGTTACGACTT. The PCR amplified fragments were eluted and were cloned into *E. coli* DH5α cells. The presence of gene insert in the transformed colonies was confirmed by colony PCR. The recombinant plasmid DNA were isolated from the transformed colonies and were sequenced. The sequences obtained were aligned using BIOEDIT software. The bacterial isolates were identified as *Lysinibacillus fusiformis* and *Bacillus cereus* with 98-99% similarity.

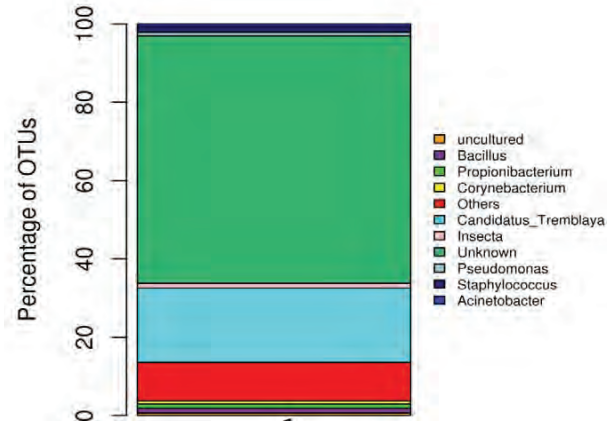
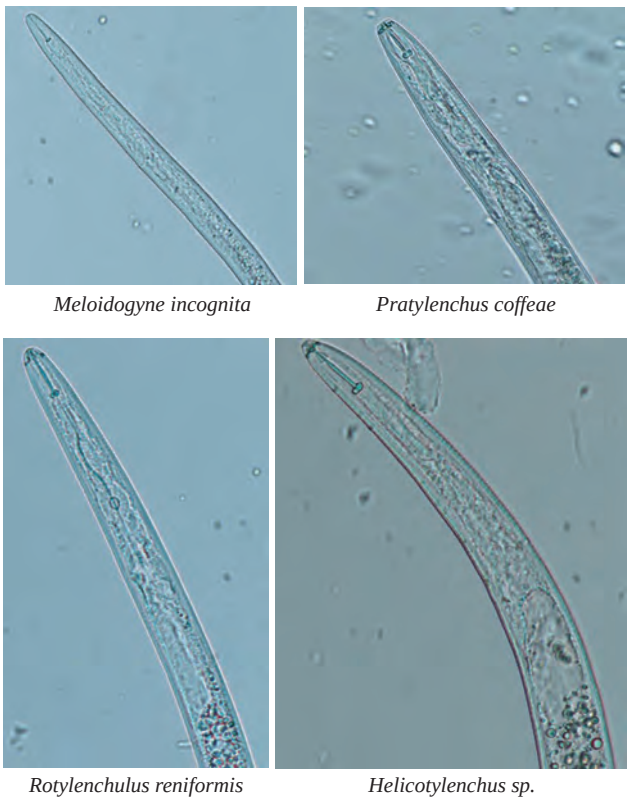


Fig.34. Genus level classification of bacterial endosymbionts by metagenomic DNA sequencing (OUT- Operational Taxonomic Units)

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

In a random survey conducted in elephant foot yam fields in three districts of Kerala, 20 soil samples each from Ernakulam (Manyali), Malappuram (Perinthalmanna) and Wyanad (Pulpally) were collected during April and December 2016. Five genera of plant parasitic nematodes were identified viz., *Rotylenchulus reniformis*, *Pratylenchus* sp., *Meloidogyne incognita*, *Tylenchorhynchus* sp. and *Helicotylenchus* sp. *Rotylenchulus reniformis* was the most predominant nematode in Perinthalmanna with a prominence value of 75 (Fig. 35). While, *Pratylenchus* sp. was the most predominant nematode in both Malappuram and Wyanad with prominence values of 60 and 70, respectively. A total of 20 soil samples were collected from elephant foot yam fields of Kovvur, West Godavari district of Andhra Pradesh during April 2016. Seven genera of plant parasitic nematodes were identified viz., *Hoplolaimus indicus*, *Pratylenchus* sp., *M. incognita*, *R. reniformis*, *Tylenchorhynchus* sp. *Helicotylenchus* sp. *and Tylenchus* sp. Out of which, *H. indicus* and *Pratylenchus* sp. were observed in maximum frequency and abundance and their prominence values were 33.80 and 10.30, respectively. Fifteen soil samples were collected from elephant foot yam fields of Apakoodal, Erode, Tamil Nadu during November 2016. Six genera of plant parasitic nematodes were identified viz., *M. incognita*, *Pratylenchus* sp., *Tylenchorhynchus* sp., *R. reniformis*, *Tylenchus* sp. and *Caloosia* sp. Of which, *M. incognita* and *Pratylenchus* sp. were the most predominant nematodes with prominence values of 30.40 and 14.90, respectively. A total of 15 soil samples were collected from elephant foot yam fields of ICAR-CTCRI. *Pratylenchus coffeae* and *M. incognita* were the most abundant nematodes with a population density of 1.5 and 1.1 nematodes per gram of soil, respectively. Fifty soil samples were collected from different plots of Block I, Research Farm, ICAR-CTCRI. Plant parasitic nematodes associated with cassava, sweet potato, yams, elephant foot yam and coleus in Block I were *M. incognita*, *P. coffeae*, *R. reniformis*, *Scutellonema bradys*, *Helicotylenchus* sp., *H. indicus*, *Tylenchorhynchus* sp., *Xiphinema* sp. *and Tylenchus* sp.



Meloidogyne incognita *Pratylenchus coffeae*

Rotylenchulus reniformis *Helicotylenchus sp.*

Fig. 35. Different nematodes infecting elephant foot yam

Management of nematodes in tuber crops

The efficacy of biopesticide, *Menma* was tested against both second stage juveniles and egg masses of *Meloidogyne incognita* in seven concentrations viz., 5, 10, 50, 100, 300, 500 and 700 ppm and observations were recorded at 24, 48, and 72 h time interval. Cent per cent mortality was observed

up to 100 ppm concentration and mortality rate decreased at lower concentrations. Ninety-five per cent inhibition of egg hatching was observed up to 300 ppm concentration after 5 days. Toxicity was positively correlated with the concentration of these compounds and the exposure time. The nematode infected soil were treated with different concentrations of cassava based biopesticides and incubated at 24, 48, and 72 h exposure time. Significant reduction in the extraction of nematodes was observed with higher concentrations when compared to control. Two isolates of *Trichoderma asperellum* (CTCRI Tr 9 and CTCRI Tr 15) were tested against egg masses and second stage juveniles of root knot nematode. Both isolates showed nematicidal activity against nematodes. CTCRI Tr 9 showed more effect compared to CTCRI Tr 15. Isolates of *Bacillus subtilis* (Bs 9 and Bs 19) were tested against egg masses and second stage juveniles of root knot nematode. Both bacterial strains had a significant effect on suppression of *M. incognita*.

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

Management of fungal diseases of tuber crops

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

One hundred and one isolates were made from eighteen soil samples collected from Chhattisgarh, Karnataka, Kerala and Tamil Nadu. The organisms were screened against *P. colocasiae* and *S. rolfsii* using the methods, direct confrontation, production of metabolites and volatiles. Seven bacterial isolates and six fungal isolates were selected for further study based on their inhibition potential.

Sixteen *Trichoderma* isolates, which showed consistent pathogen suppression under *in vitro* condition, were identified using TEF and ITS region amplification (Fig. 36). The isolates were identified as *Trichoderma asperellum* (11 isolates), *T. harzianum* (3 isolates) and *T. virens* (2 isolates).

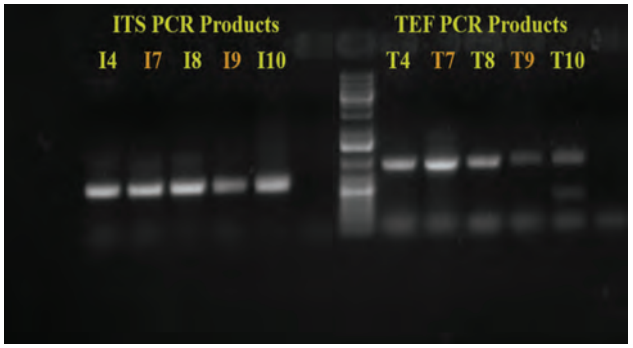


Fig. 36. TEF and ITS region amplification of *Trichoderma* isolates

Exploitation of *Piriformospora indica* for disease suppression and growth promotion

Piriformospora indica is a cultivable endophyte and its culture was obtained from Amity University. *P.indica* could successfully colonize the roots of taro. The effect of *P. indica* on growth and leaf blight incidence in taro was studied using Sree Kiran and Muktakeshi, susceptible and resistant varieties respectively to taro leaf blight incidence. The varieties were planted in grow bags containing *P. indica* mixed @ 1% w/v in soil. The experiment was conducted in completely randomized design in an area, where taro leaf blight incidence occurs every year. The plants were allowed to get infection naturally.

Number of days taken for sprouting in *P. indica* colonized Sree Kiran was reduced to 9 from 10 in the non colonized plants. In Muktakeshi, *P. indica* colonized plants sprouted 6 days earlier than that of control plants. Height of the plant, number of leaves, leaf length, leaf breadth, root length, root weight, total weight, shoot weight and weight of cormels increased due to *P. indica* inoculation (Fig. 37). However, the increase in growth promotion was not statistically significant.

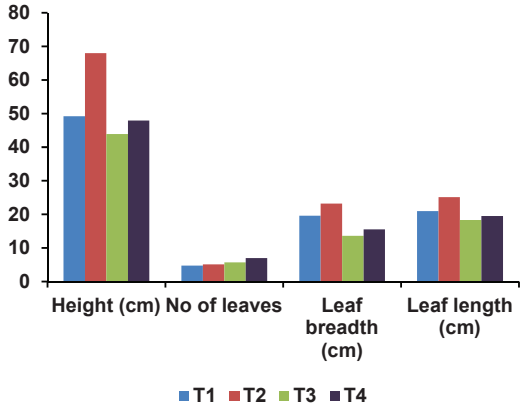
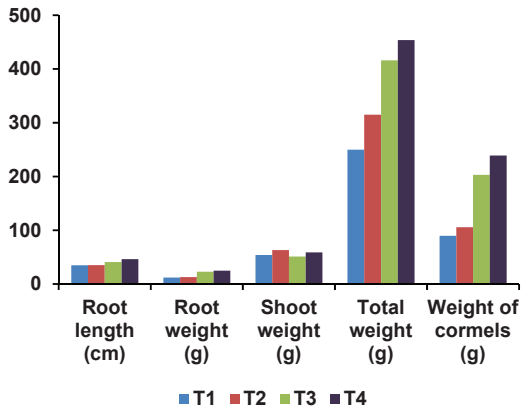


Fig. 37. Plant growth in *P. indica* colonized and non-colonized taro plants



T1-Sree Kiran; T2-*P.indica* colonized Sree Kiran; T3-Muktakeshi; T4- *P.indica* colonized Muktakeshi
Fig. 37 (contd). Plant growth in *P. indica* colonized and non-colonized taro plants

Disease incidence was recorded thrice at 15 days interval during the peak infection period, July-August and the PDI were calculated. In both the varieties, the disease incidence was significantly reduced compared to non-colonized plants (Fig. 38). In Sree Kiran, *P. indica* colonized plants showed 57.60%, 50.70% and 84.30% disease reduction and in Muktakeshi, it was 39.90%, 56.20% and 72.50% over control.

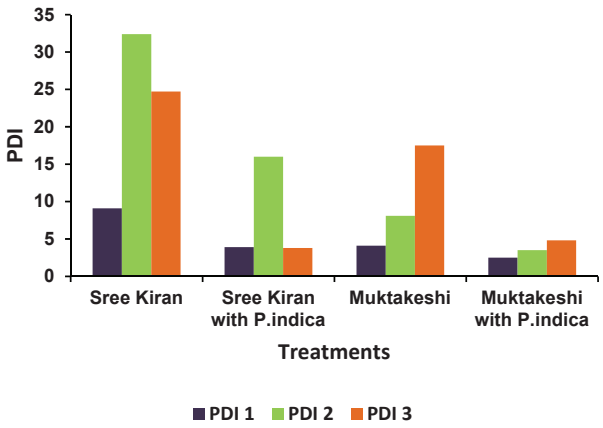


Fig. 38. Taro leaf blight incidence in *P.indica* colonized plants

Differential expression of genes in *P. indica* colonized taro plants consequent to *Phytophthora colocasiae* infection

Sree Kiran and Muktakeshi were planted in grow bags containing *P. indica* mixed @ 1% w/v in sterilized soil. The plants were challenge inoculated with zoospore suspension (50 µl) of *P. colocasiae*. Subtractive Suppression Hybridization (SSH) assay was carried out using Clontech PCR-Select cDNA Subtraction Kit (Clontech, USA) as per the manufacturer's protocol. The sequencing result obtained was annotated using Blast2Go software. The sequences were analyzed and the cellular, molecular and biological functions were determined. Five genes were identified and their functions were determined. Among the identified genes, senescence associated genes, Cytochrome P450, Delta (12) oleic acid desaturase FAD2 and Calcium-dependent protein kinases (CDPKs) are coming under different defense related pathways.

Field experiment to evaluate various strategies to manage taro leaf blight incidence

The experiment was laid out with seven treatments viz., borax @ 0.375g plant^{-1} (T_1), *Bacillus subtilis* (T_2), borax + *Bacillus subtilis* (T_3), borax + *Bacillus subtilis* + vermicompost (T_4), metalaxyl-M @ 0.05% (T_5), copper hydroxide 0.2% (T_6) and control (T_7) in RBD with three replications (Fig. 39). Sree Kiran was the variety of taro used for the study. The treatments were applied thrice at an interval of 15 days from the onset of disease occurrence. The disease incidence was recorded five times and PDI was calculated. At all occasions, the least PDI was noticed with metalaxyl-M with PDI 8.13, 15.90, 10.80, 14.80 and 15.90 followed by the treatment, borax + *Bacillus subtilis* + vermicompost with PDI of 10.70, 27.60, 19.30, 20.20 and 22.30 as against 22.90, 42.10, 32.70, 39.90 and 45.40 in the control (Fig. 39). The highest yield was also noticed in metalaxyl-M (15.70 t ha^{-1}) followed by borax + *Bacillus subtilis* + vermicompost (9.05 t ha^{-1}) as against 4.72 t ha^{-1} in the control.

Fig. 39. Field view showing the disease suppression by Metalaxyl- M (left) over control (right)

Field experiment to evaluate various strategies to manage collar rot incidence in elephant foot yam

The experiment was laid out with seven treatments viz., *Bacillus subtilis* (T_1), *B. subtilis* + vermicompost (T_2), healthy planting material (T_3), mancozeb + carbendazim (Sprint) @ 0.2% (T_4), *Trichoderma asperellum* (T_5), *T. asperellum* + vermicompost (T_6) and control (T_7) in RBD with three replications. Gajendra was the variety used for the study (Fig. 40). The treatments were applied twice at an interval of one month from the onset of disease occurrence. The disease incidence was monitored at frequent intervals. The least collar rot incidence was noticed in the treatment, mancozeb + carbendazim 0.2% (4%) followed by *T. asperellum*+ vermicompost (5.3%) as against 16% in control. However, the yield in the treatments, mancozeb + carbendazim (Sprint) 0.2% (13.60 t ha^{-1}), *Trichoderma asperellum* (14.00 t ha^{-1}) and *T. asperellum*+ vermicompost (14.30 t ha^{-1}) were on par.

Fig. 40. Field view of elephant foot yam with various management strategies

Isolation of organisms causing post-harvest diseases in elephant foot yam and screening of fungicides and bio-pesticides against the pathogens

Diseased corms were collected from different storage yards, the organisms were isolated, the cultures were purified and Koch's postulates were established with nine organisms (Fig. 41).

Fig. 41. Elephant foot yam corms with post-harvest infection

The fungicides, carbendazim (bavistin), mancozeb + carbendazim (Sprint and Saaf), copper hydroxide (Kocide), bio-pesticide (*Nanma*) and neem oil were tested against the mycelial growth of the nine pathogens under *in vitro* condition. The fungicides were tested at concentrations of 100, 200, 400, 800, 1600 and 3200 ppm. The biopesticide and neem oil were tested at 2500, 5000, 10000 ppm concentrations. The fungicide, mancozeb + carbendazim (Sprint) could completely arrest the growth of all the pathogens at 100 ppm. This was followed by mancozeb + carbendazim (Saaf), which could completely arrest the growth of all the pathogens at 400 ppm. *Nanma* could inhibit the growth of the pathogens ranging from 55- 94% at the recommended dose (0.70%).

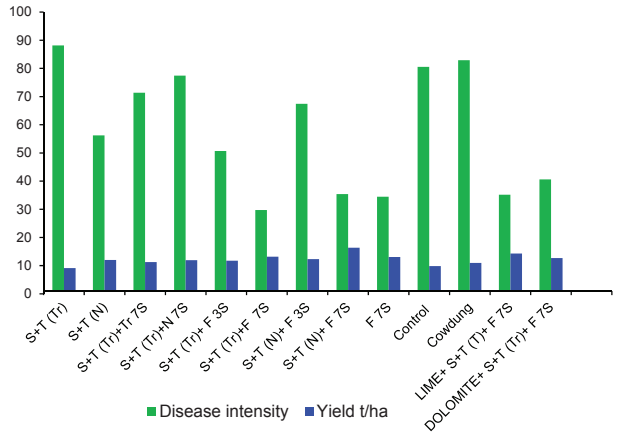
Greater yam anthracnose

Management

The efficiency of different combinations of soil and tuber treatment with *Trichoderma asperellum*, ICAR-CTCRI developed biopesticide, *Nanma* and spraying of carbendazim, *Nanma* and *T. asperellum* were tested in the field for the second season (2016-2017) against anthracnose in greater yam. Lime and dolomite also were used separately. Soil treatment with *T. asperellum* @ 50 g of 10^7 cfu g^{-1} and tuber treatment @ 5 g in fresh cow dung slurry per kg of cut tubers along with foliar spraying of carbendazim (0.05%) seven times, first three at fortnightly intervals and further monthly after symptom initiation (T_6), was the best treatment, which significantly reduced the disease intensity (63%). Even though the yield was not significantly different among treatments, the maximum increase (32%) in yield was observed in the above treatment compared to the absolute control. It was followed

by soil and tuber treatment with *Nanma* 1% @ one litre per plant along with spraying of carbendazim seven times and spraying of carbendazim seven times alone (Fig. 42).

The pooled analysis of two seasons 2015-2016 and 2016-2017 also indicated that T_6 was the best treatment, which reduced the disease significantly, but on par with spraying of carbendazim seven times alone (T_9) and soil and tuber treatment with *Nanma* 1% @ one litre per plant along with spraying of carbendazim seven times (T_8) and T_6 with lime and dolomite application separately. The yield was also significantly high and on par in the above treatments compared to control.

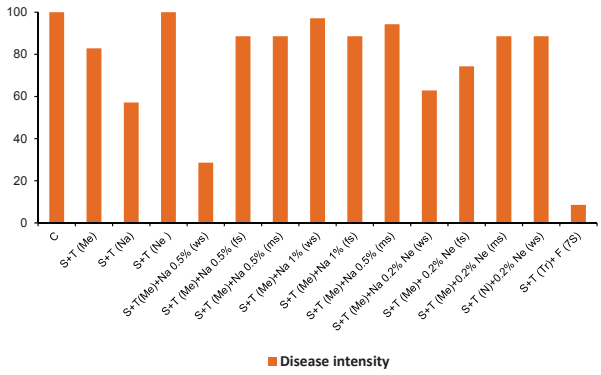


C: Control; S: Soil treatment; T: Tuber treatment; Tr: *Trichoderma*; N: *Nanma*; F: Fungicide (carbendazim); 7S: seven sprays; 3S: three sprays

Fig. 42. Effect of bio-control agent, bio-formulation and carbendazim on the intensity of anthracnose and yield in greater yam, var. Orissa Elite

Bio-intensive management of greater yam anthracnose

Pot trial to study the effect of cassava based biopesticides and neem oil on greater yam anthracnose has been conducted using soil and tuber treatment with *Menma* @ 1% and spraying N*anma* @ 0.5% and 1% and neem oil @ 0.2%. The observation on disease intensity indicated that soil and tuber treatment with *Menma* @ 1% and spraying *Nanma* @ 0.7% weekly resulted in maximum reduction in PDI (71%) compared to control. This is followed by soil and tuber treatment with *Nanma* @ 0.7 % (43%) and also soil and tuber treatment with *Menma* @ 1% and spraying neem oil @ 0.2% weekly (37%) (Fig.43). The effective treatments will be evaluated under field condition during 2017-2018.

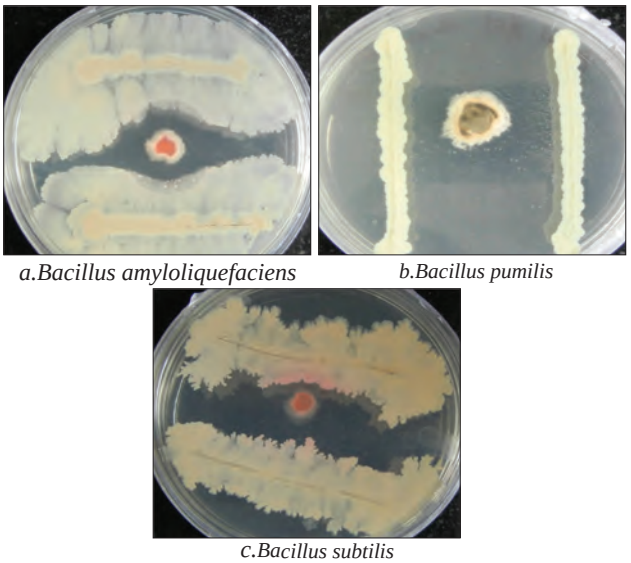


C: Control; S: Soil treatment; T: Tuber treatment; Me: Menma; Na: Nanma; Ne: Neem oil; F: Fungicide (carbendazim 0.05%; Tr: Trichoderma: ws; weekly spray; fs: fortnightly spray; ms: monthly spray;7S: seven sprays

Fig.43. Effect of *Menma* and *Nanma* (cassava based biopesticides) and neem oil on the intensity of anthracnose and yield in greater yam var. Orissa Elite

Isolation and evaluation of endophytes against *Colletotrichum gloeosporioides* causing greater yam anthracnose

Fungal and bacterial endophytes were isolated from the leaves and roots of arrowroot, Chinese potato, taro and greater yam using standard procedures. One fungal and three bacterial isolates showed inhibition of the growth of *Colletotrichum gloeosporioides*. DNA was isolated and were identified through PCR as *Trichoderma* sp using TEF gene primers and as *Bacillus subtilis*, *B. amyloliquefaciens* and *B. pumilus using* 16 S r DNA primers (Fig. 44)



a.Bacillus amyloliquefaciens *b.Bacillus pumilis*

c.Bacillus subtilis

Fig.44. Inhibition of *C. gloeosporioides* by endophytes isolated from taro (a) arrowroot (b) and Chinese potato (c)

Epidemiology

A field experiment was laid out for the third year during 2016-2017 with an aim of developing decision support system to advise the farmers for managing anthracnose based on weather parameters. For this three released varieties of greater yam, viz., Orissa Elite (highly susceptible), Sree Karthika and Sree Keerthi (tolerant) were used and the disease severity was observed at weekly intervals till 8th month of planting, December. The maximum disease intensity was observed with Orissa Elite (100%) followed by Sree Karthika and Sree Keerthi. The intensity of anthracnose in greater yam was generally less in highly tolerant varieties, Sree Karthika, Sree Keerthi as well as susceptible variety, Orissa Elite, because of low rainfall during 2016-2017. However, the disease advances in August after rainfall at the end of July and it was almost static in September in all the varieties. Again after rainfall in October the intensity increased. Orissa Elite attained the maximum intensity (100%) during November after 7 months of planting. This indicated that rainfall plays a major role in the development of the disease through inoculum dispersal by rain splash.

Mining of resistance genes in greater yam

Cloning and sequencing of the identified NBS-type sequences called resistance gene analogues (RGAs) during 2015-2016 using degenerate primers, showed similarity to the other RGA sequences in the database and the presence of conserved domains, viz. P-loop, RNBS-B, RNBS-C, Kinase-2 and GLPL, categorising them with the NBS–leucine-rich repeat class gene family. Amino acid sequence alignment of the *Dioscorea* RGAs with RGAs of the other plant species grouped them with the non-toll interleukin receptor subclasses of the NBS sequences. The expression profiles of RGAs determined using semi quantitative Reverse Transcriptase polymerase chain-reaction in Sree Keerthi (tolerant) and Orissa Elite (susceptible) genotypes in response to anthracnose infection demonstrated that *Dioscorea alata* RGAs were upregulated three days after disease inoculation in the tolerant genotype, whereas in the susceptible genotype it was on the 5th day. In contrast, RGAs were found to be expressed in both resistant and susceptible control plants, but the level was increased upon pathogen inoculation. The reverse transcription product was normalized and the efficiency was evaluated using actin primers, which serves as reference gene. The result suggests the role of Resistance Genes Anologs in the early pathogen recognition of Sree Keerthi against *C. gloeosporioides*, which may be one of the reasons for its tolerance to anthracnose disease. These genes could be a good start point for further studies such as candidate gene mapping or understand the bases for resistance in greater yam. The isolation and expression analysis of *D. alata* RGAs have been reported for the first time in this study

Characterisation, diagnosis and management of viruses of tuber crops

Identification of new virus

The presence of *Badna virus* was detected in taro leaves using genus specific Haf primer and virus specific PNG badna primers, which amplify RT/RNaseH-coding region. The approximate amplicon size were 530 and 250 bp respectively. Based on this, new primers will be designed for further routine diagnosis.

Virus indexing of lesser yam tubers

Detection of *Yam mild mosaic virus* (YMMV) from lesser yam tuber was standardized. Among different parts of the tuber, viz., peel, skin flesh, flesh alone, top, middle and bottom portion of the tuber, the tuber flesh is good for sampling tubers.

Multiplication of virus free elephant foot yam

Around 90 kg of virus free tissue cultured elephant foot yam tubers were planted in farmers' field during 2016-2017, which gave around 13 fold yield (~1196 kg) (Fig. 45). Tuber samples collected from the farmer's field were indexed for DsMV and found free from infection. Indexing of field grown elephant foot yam tubers has also been done for DsMV infection using DAS-ELISA. Among 37 samples tested, only three (8%) showed positive. The healthy tubers are being multiplied at ICAR-CTCRI and also in farmer's field.

Fig. 45. Elephant foot yam tubers from tissue cultured plants

Elephant foot yam callus culture has also been done. The calli were regenerated and multiplied *in vitro*. Putative transgenic elephant foot yam plants are being maintained *in vitro*.

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

Prevalence and phylogeography of cassava mosaic disease and its diagnosis

The survey conducted across all districts in Kerala revealed that cassava mosaic disease (CMD) is widespread having high symptom severity and increased aggressiveness as compared to earlier years. Maximum intensity of CMD was observed in Wayanad (4.00) followed by Malappuram (3.40), Alappuzha (3.28) and Ernakulam (3.00). Studies using multiplex PCR with all the samples collected during survey showed that *Sri Lankan cassava mosaic virus* (SLCMV) was widespread in all districts of Kerala, while *Indian cassava mosaic virus* (ICMV) infection was seen solely as well as combined with SLCMV (mixed infection) in nine districts namely Thiruvananthapuram, Kollam, Alappuzha, Kottayam, Idukki, Ernakulam, Palakkad, Malappuram and Kasargod (Fig.46 and Fig.47). Beta satellite molecules were identified from the Thiruvananthapuram sample having mixed infection and this needs to be further confirmed. By restriction analysis and sequence analysis, high variability was detected within and between the cassava mosaic viruses in Kerala. High sequence variability was found within and between the ICMV and SLCMV samples collected during this survey and this attributes to a large number of single nuclear polymorphisms (SNPs) found within the conserved regions.

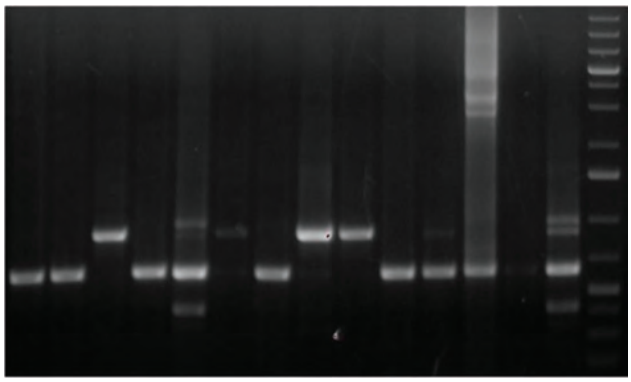


Fig.46. Differentiation of ICMV and SLCMV from infected samples using multiplex PCR. Lanes 1 to 7-Kottayam samples; 8 to 14-Idukki samples; Lanes 1, 2, 3, 7, 10 and 12 shows SLCMV infection, Lanes 3, 8 and 9 shows ICMV infection and lanes 5, 11 and 14 shows mixed infection; L- 1 kb plus DNA ladder (fermentas)

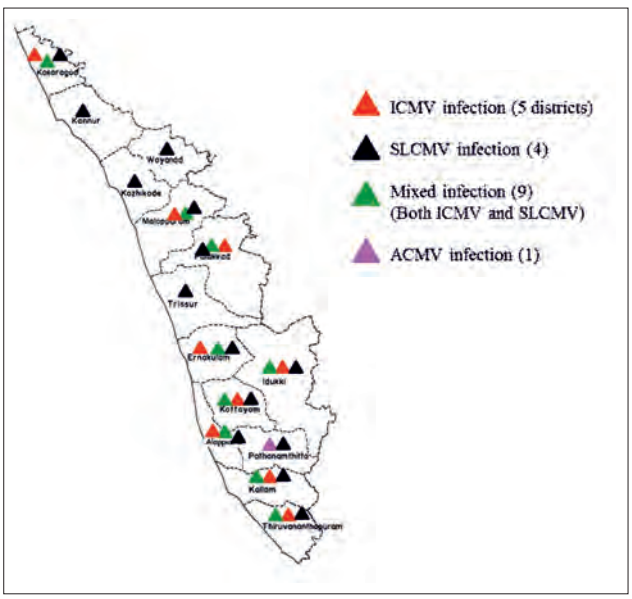
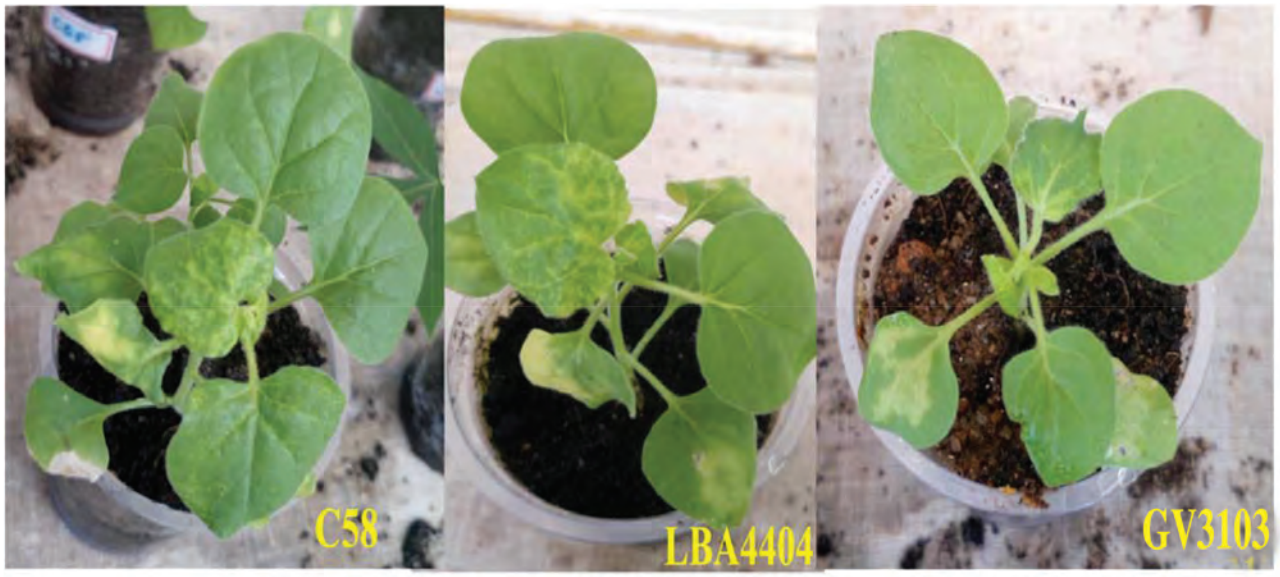


Fig. 47. Distribution pattern of ICMV, SLCMV and ACMV in survey conducted in Kerala

Molecular mechanism of cassava mosaic virus infection

Standardisation of agro-inoculation of cassava with ICMV infectious clones was attempted. However this was not successful. But the infectious nature of clones was confirmed in *Nicotiana benthamiana* (Fig. 48).

a. Nicotiana benthamiana



b. Cassava

Fig. 48. Agro-inoculation of *Nicotiana benthamiana* (a) and cassava var. H-226 (b) with SLCMV infectious clones in different *Agrobacterium* strains (C58, LBA4404 and GV3103)

Management of cassava mosaic disease through resistant varieties

Four hundred first clonal CMD resistant hybrids were evaluated for high yield, starch and cooking quality. Among the hybrids, 15S-140 produced the highest tuber yield (12.90 kg plant^{-1}) followed by 15S-165 (11.50 kg plant^{-1}) and 15S-117 (8.00 kg plant^{-1}). Ten hybrids that recorded high yield (>5.00 kg plant^{-1}), CMD resistance and having good plant type were selected and planted in replicated evaluation trial for identifying CMD resistant varieties suitable for industrial use. Eight hybrids with high yield and cooking quality were selected and planted in replicated evaluation trial for identifying CMD resistant varieties suitable for culinary purpose. Among the hybrids selected with good cooking quality, 15S-409 (6.30 kg plant^{-1}) was the highest yielder followed by 15S-59. The CMD resistance of all these clones was confirmed through artificial screening. Based on AYT, six CMD resistant clones (7th clonal) that recorded high yield (>50 t ha^{-1}) viz. 9S-73, 9S-132, 9S-164, 9S-172, 9S-174 and 9S-286 were selected for

on-farm trial and also for conducting agronomic trial. A total of 90 cassava lines with resistance, recovery and susceptibility to CMD disease were selected from the breeding program. The selected lines were grown for CMD phenotypic scoring and DNA isolation. The 15 CMD associated markers are under screening with the selected cassava lines to see whether there is any clear variation in the population.

Cassava mosaic virus-vector relationship and vector management

Morphometric studies on whiteflies (*Bemisia tabaci*) collected from different parts of Kerala in cassava growing regions using 23 characters revealed that there were variations in morphometry (most of the characters) among populations collected from Sulthan Bathery and other 12 agro-ecological zones. Molecular level variability of cassava whitefly populations from 13 agro-ecological zones using ISSR and mtCOI gene sequencing showed that the population from Sultan Bathery mainly belonged to Asia I biotype and the rest of them belonged to Asia II 5 biotype. *Bemisia tabaci* specific 10 ISSR primers were screened and were used to find genetic variations among whitefly populations. Biotypes specific banding patterns were identified using ISSR primers for whitefly biotypes Asia I and Asia II-5.

Integrated management of cassava mosaic disease

A field trial was conducted to study the effect of nutrients on cassava mosaic disease. The nutrients Zn, Si, P, Ca and B were selected for the study based on preliminary screening. They were given both as foliar (6 times at monthly intervals) and soil (twice). Statistical analysis of the data on growth characters and visual observation on disease infection at 3, 6 and 9 MAP indicated significant effect of treatments in the case of retained leaves at 3 and 9 MAP, fallen leaves and total leaves at 9 MAP, infection at 3, 6 and 9 MAP. Infection was lesser with Si, Zn and Ca during 3, 6, 9 MAP respectively.

Production of cassava mosaic virus free synthetic seed

Different concentrations of sodium alginate and calcium chloride solutions were tested in order to optimize the shape, texture and germination frequency of synthetic seeds of cassava. The nodes containing axillary buds from *in vitro* grown cassava variety, H-226 were encapsulated with 2%, 3% and 4% sodium alginate (w/v) along with Murashige and Skoog (MS) salts without calcium salt and exposed to 75mM, 100mM and 125mM calcium chloride solution ($CaCl_2.2H_2O$). Round and sufficiently hard beads/synthetic seeds were observed by the encapsulation with sodium alginate 3% and exposed to 100mM $CaCl_2.2H_2O$ combination (Fig.49A). Encapsulation at 2% and 3% sodium alginate concentrations and exposure to $CaCl_2.2H_2O$ at 75mM and 100mM concentrations gave high germination frequency under *in vitro* condition (Fig. 49B). The effect of number of days of storage of the synthetic seeds on sprouting was also studied. Up to seven days of storage, the encapsulated cassava explants under room temperature gave 73% sprouting. Drastic reduction of sprouting (16.67%) was observed after 21 days of storage under room temperature. The synthetic seeds have the possibility of being an efficient way for germplasm storage, exchange and propagation of pathogen-free planting material.

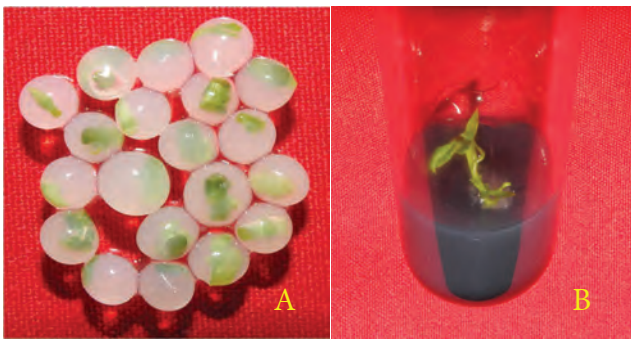


Fig. 49. Cassava synthetic seeds (shoot buds of var. H-226) encapsulated in 3% sodium alginate and 100 mM calcium chloride (A) Synthetic seed germinating *in vitro* (B)

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

Multi-grain functional cookies using *Curcuma angustifolia* starch along with pulses and millets

The study was conducted with the objective of utilizing the starch from the under exploited tuber crop popular among the tribal communities, *Curcuma angustifolia*, by processing it into protein-energy rich, calcium rich and fibre rich multi-grain functional cookies, which are highly suitable for tribals in order to combat protein-energy malnutrition and micronutrient deficiency (Fig. 50). The proximate composition and physico-chemical and sensory properties of multi-grain functional cookies was evaluated. The protein-energy rich functional cookies have been developed using curcuma starch (25%) along with pearl millet flour. The protein sources utilized were soy flour, Bengal gram flour and whey protein concentrate. It provides protein 8.24%, fibre 3.33%, carbohydrate 57.30% and energy 481.37 kcal. The calcium rich functional cookies were developed using curcuma starch (25%) with pearl millet flour and finger millet flour as sources of calcium. It provides calcium 42.64 mg $100g^{-1}$, protein 3.45%, fibre 2.40%, carbohydrate 62.08% and energy 466.04 kcal. Similarly, the fibre rich functional cookies have been developed using curcuma starch with pearl millet flour and wheat bran and oat bran flours were used as sources of dietary fibre. It provides fibre 6.79%, protein 3.79%, carbohydrate 62.27% and energy 446.02 kcal.

Fig. 50. Multi-grain functional cookies using *Curcuma angustifolia* starch along with pulses and millets

Refinement of machineries for cultivation and processing of tuber crops

Evaluation of cassava harvester

A two row cassava harvester was purchased from Tamil Nadu Agricultural University and evaluated at ICAR-CTCRI farm (Fig. 51). During evaluation it was found that the tractor was slipping due to heavy draft. So tynes from one row was removed and the harvester was converted into single row harvester. The harvesting efficiency was influenced by the width between the tynes of harvester. Three width of operations viz., 60, 65 and 70 cm were selected. The time taken for harvesting 21-22 plants were found to be 30-43 seconds and the total number of tubers harvested in a trial was 153-183. The number of broken tubers was 18-28 and the percentage of damage was 11.40-13.50%. The harvester was compared with the manual method of harvesting. The time taken for harvesting 21 plants manually was 90 sec and the number of tubers was 130. The number of broken tubers was 11 and the percentage of damage was 8.40%. The capacity of the harvester ranged between 1800-2580 cassava plants per hour, whereas only 840 plants could be harvested in an hour manually.

Fig. 51. Cassava harvester

Particle boards and adhesives from cassava by-products and starch

Particle board using starch as binder

The fresh cassava stems from mature plants of about 9-10 months were cut into small pieces using a chaff cutter and sundried for 3-4 days and milled in a hammer mill using a 5 mm sieve plate and the powdered samples were used for making particle boards (Fig. 52). Cassava starch from the tubers was extracted by employing wet processing method using a mobile starch extraction plant. The variables used in the manufacturing of particle board from cassava stems were amount of starch (5, 10 and 15% to stem powder), amount of glycerol (5, 10 and 15% to starch), pressure of moulding (40, 60 and 80 bar) and press time (5, 10 and 15 min). Weight of dry powder and temperature of die plates were kept constant as 150 g and 100°C respectively. In order to facilitate quick and easy gelatinization of starch, water was also added. The experiments were designed using response surface methodology by Box-Behnken design. The various physico-mechanical and functional properties of the particle boards viz., thickness, density, moisture content, modulus of rupture, thickness swelling, and water absorption after 2 and 24 h were analyzed.

As the starch content in the particle board increased, density decreased, whereas it increased with pressing time and pressure. The influence of pressure and time was found to be more significant. Maximum density of 987.90 kg m^{-3} was obtained for the board made with 15% starch and 15 min press time, whereas the minimum of 694.29 kg m^{-3} for the board made with 5% starch and 5 min press time, both were made with a pressure of 60 bar and 10% glycerol. It was found that maximum moisture content of 23.91% was obtained for the board made with 10% starch, 15% glycerol at a pressure of 80 bar and pressed for 10 minute, whereas the minimum moisture content of 13.02% was obtained for the board made with 5% starch, 10% glycerol at a pressure of 60 bar and pressed for 15 minute. Maximum thickness swelling of 77.90% was obtained for the board made with 5% starch, 5% glycerol at a pressure of 60 bar and pressed for 10 minute, whereas the minimum thickness swelling of 22.57% was obtained for the board made with 15% starch, 15% glycerol at a pressure of 60 bar and pressed for 10 minute. Maximum water absorption after 2 hours of soaking of 99.28% was obtained for the board made with 10% starch, 15% glycerol at a pressure of 60 bar and pressed for 5 minute, whereas the minimum water absorption of 13.46% was obtained for the board made with 10% starch, 15% glycerol at a pressure of 80 bar and pressed for 10 minute. Maximum water absorption after 24 hours of soaking of 127.70% was obtained for the board made with 5% starch, 5% glycerol at a pressure of 60 bar and pressed for 10 minute, whereas the minimum water absorption of 42.80% was obtained for the board made with 5% starch, 15% glycerol at a pressure of 60 bar and pressed for 10 minute.

The maximum compressive strength of 0.186 N mm^{-2} was obtained for the board made with 15% starch, 10% glycerol made at a pressure of 60 bar and 15 minute press time, whereas the minimum compressive strength of 0.029 N mm^{-2} was obtained for the boards made with 5% starch, 10% glycerol at a pressure of 60 bar and pressed for 5 min. Maximum rupture modulus of 1373.35 MPa was obtained for the board made with 10% starch, 5% glycerol at a pressure of 80 bar and pressed for 10 minute, whereas the minimum rupture modulus of 191.79 MPa was obtained for the board made

Fig. 52. Particle board from cassava stalks

with 5% starch, 10% glycerol at a pressure of 60 bar and pressed for 15 minute. Flexural strength almost linearly increased with increase in starch content and pressure, whereas quadratic effect with press time and glycerol. Among these parameters, only time had significant effect. It was found that maximum flexural strength of 4.55 MPa was obtained for the board made with 15% starch, 10% glycerol at a pressure of 60 bar and pressed for 15 minute, whereas the minimum flexural strength of 0.47 MPa was obtained for the board made with 5% starch, 10% glycerol at a pressure of 60 bar and pressed for 5 minute.

Particle board using plasticisers

Cassava stem contains about 10-18% starch and hence particle boards were prepared by adding the generally available plasticisers viz., water from 2 to 10%, glycerol from 2 to 10% and dextrin from 2 to 10% and their physico-mechanical properties were analysed. Density of the particle board reduced from 957 to 815 kg m^{-3}as the concentration of the water increased from 2 to 10%. By mixing glycerol, the density decreased from 917 to 867 kg m^{-3}. Addition of dextrin increased the density of particle board, from 921 to 964 kg m^{-3}. By the addition of water, glycerol or dextrin, there was not much variation in the moisture content of the resulting particle board. Water absorption properties decreased as the amount of water, glycerol and dextrin increased in the particle board formulation. Thickness swelling also decreased as the concentration of the plasticisers increased. Compressive strength of the board varied from 0.304 N mm^{-2} to 0.078 N mm^{-2} for the board prepared by adding water. For glycerol added boards it ranged from 0.147 to 0.108 N mm^{-2} and for those with dextrin the compressive strength ranged from 0.118 to 0.255 N mm^{-2}. Modulus of rupture varied from 1.46 to 3.48 MPa for water, 4.14 to 2.70 MPa for glycerol and 3.37 to 7.75 MPa for dextrin boards. The maximum modulus values were obtained for the boards made with dextrin.

Particle board using synthetic resins

The particle boards were also produced from dried cassava stems using urea formaldehyde and melamine urea formaldehyde as binders by varying the feed weight (150-300g), temperature (120-140°C) and press time (5-10 min). The various physico-mechanical properties of the particle boards analyzed were density, moisture content, modulus of rupture, thickness swelling, water absorption after 2 and 24 hours by BIS method. It was found that as the sample weight and temperature increased, density also increased; and a maximum density of 1062 kg m^{-3} was obtained for the melamine urea formaldehyde incorporated board (150 g) made at 130°C and minimum of 863 kg m^{-3} for the urea formaldehyde mixed board (300 g) made at 130°C. Maximum moisture content of 20.48% was obtained for the melamine urea formaldehyde incorporated board (225 g) made at 130°C and the minimum moisture content of 7.44 % was obtained for the urea formaldehyde mixed board (225 g) made at 130°C. It was found that maximum rupture force of 23.7 MPa was obtained for the urea formaldehyde incorporated board (225 g) made at 140°C and minimum of 8.74 MPa for the melamine urea formaldehyde (150 g) mixed board made at 140°C.

Maximum thickness swelling was 20.03% for the urea formaldehyde incorporated board (150 g) made at 130°C and minimum of 3.47% for the urea formaldehyde mixed board (300 g) at 120°C. Maximum water absorption after 2 h soaking was 18.05% for the melamine urea formaldehyde incorporated board (150 g) made at 130°C and minimum was 0.51% for the urea formaldehyde mixed board (150 g) made at 130°C. Maximum water absorption after 24 h soaking was 22.95% for the urea formaldehyde incorporated board (150 g) made at 130°C and minimum of 5.04% for the melamine urea formaldehyde mixed board (225 g) made at 120°C. It was found that maximum volume swelling was 21.53% obtained for the urea formaldehyde incorporated board (150 g) made at 130°C and minimum of 5.04% for the melamine urea formaldehyde mixed board (225 g) at 120°C.

Corrugating adhesive from modified cassava starch

Cassava starch was chemically modified by partial acid hydrolysis. Single phase corrugating adhesive formulations were developed from the acid thinned

starch. A Box-Behnken design was used to optimize the process parameters. The variables used were: starch solid content (20, 30 and 40%), sodium hydroxide (2, 4, and 6% based on starch dry wt.) and sodium tetraborate (1, 3 and 5%). The carboxyl content in the acid modified starch was 0.2±0.05 milli equivalents per 100g starch. The samples made under the following conditions showed good consistency and performed well in application to paper boards and formed fairly strong bonds:

Starch content – 30%, NaOH – 6% and borax content – 1% (solid content- 24.21%)

Starch content – 20%, NaOH – 4% and borax content – 1% (solid content- 17.36%)

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

Fresh cassava roots undergo post-harvest physiological deterioration (PPD) and become unfit for consumption within 2-3 days after harvest. Modified storage of cassava roots and tuber treatments such as waxing were tried to increase the shelf-life as well as to reduce the PPD intensity. Modified atmospheric storage of cassava roots (Fig. 53) was carried out with high CO_2 in storage container with five varieties of cassava (Sree Jaya, Sree Vijaya, Vellayani Hraswa, Kalpaka and Sree Swarna) to delay PPD. Shelf-life was extended up to one week for the fresh tubers; however, high transpiration of tubers increased the relative humidity, which resulted in fungal growth. Desiccants such as $CaCl_2$ were used to reduce the relative humidity inside the container and reduce the condensation of water and prevent microbial and fungal growth. The results were encouraging as there was a reduction in relative humidity and fungal growth in stored tubers. The experiment is in progress.

Fig. 53. Modified atmospheric storage unit for increasing shelf-life of cassava roots

Wax coating of cassava tubers (Fig. 54) after selected pre-treatment techniques was developed for increasing shelf-life for one month or more periods for retail sale or export. The tubers were successfully stored for a month without any loss in quality. The method is being standardized for commercialization.

Fig. 54. Paraffin wax coated cassava roots with increased shelf-life of one month

Screening tool for PPD using Near Infrared Spectroscopy (NIRS) was developed to analyse root samples for PPD and the spectral data were

analyzed through Principal Component Analysis (PCA) and chemometric tools to group the different PPD category in root tissues of cassava. A FT-NIR technique has been developed for analysing the quality changes in tubers under storage. NIRS was applied to characterize the cassava roots with varying PPD symptom levels. The results showed that spectral features of fresh and deteriorated root tissue differed in the NIR regions of wave numbers from 5300, 5200-5100, 4600-4400, 4240-4150 cm^{-1} in the first principal component, wave numbers such as 5450, 5250, 4700 and 4400 cm^{-1} for the second principal component. The third component belonged to 4800 cm^{-1}.

Development of robust FT-NIRS calibration model for functional pigments in sweet potato and appropriate value addition technologies to retain pigments

Vacuum frying is a promising technology for the production of healthy and nutritional snacks. The optimization of vacuum frying technology was carried out using orange and purple-fleshed sweet potato chips by using response surface methodology. A three-level Box–Behnken design was employed to study the effects and optimize the process parameters by taking frying temperature, vacuum pressure and frying time as critical factors. The vacuum fried samples were compared with atmospheric fried samples. The oil retention was 50.30% lower in the vacuum fried chips of orange-fleshed sweet potatoes, where the retention of carotenoids was also higher (6.81 mg g^{-1}) (Fig. 55). In purple-fleshed sweet potato vacuum fried chips, the oil retention was 60% lower than that of normal chips and retention of anthocyanins was higher (58.42 mg $100g^{-1}$) (Fig. 56). Sensory evaluation results showed acceptability of the vacuum fried samples for all the sensory attributes investigated. The optimized conditions for vacuum fried chips of orange-fleshed sweet potato are frying temperature, 110°C, vacuum pressure, 16.12 Kpa and frying time, 7 min.

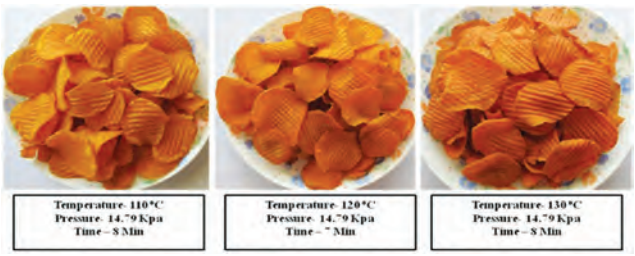


Fig.55. Vacuum fried chips of orange-fleshed sweet potato

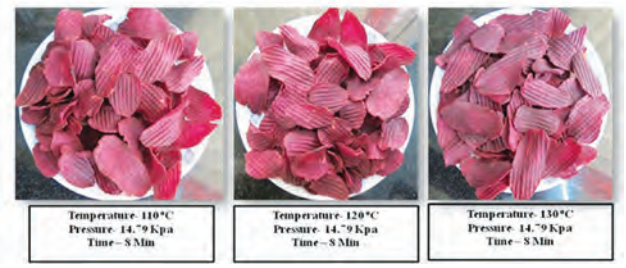


Fig.56. Vacuum fried chips of purple-fleshed sweet potato

Development of multigrain tuber crops based ready to cook/ready to eat extruded/snack products

Development of flour and ready to fry/ roast papad from elephant foot yam

Aroids such as elephant foot yam are not exploited for industrial uses as it is cultivated in small pockets and used only as vegetables. Browning (discoloration) and acridity are the major problems in utilizing these tubers. Different treatments were used for the prevention of browning and acridity in selected tubers. Among the pre-treatments, soaking in 1% citric acid for 2 h was the best method to avoid browning and acridity in the tubers. Chips were made from pre-treated tubers and milled to obtain the fine flour (Fig. 57). The flour for papad making was standardized as 30% elephant foot yam flour + 40% black gram flour + 20% green gram flour. Other ingredients were water, salt, papad masala and oil.

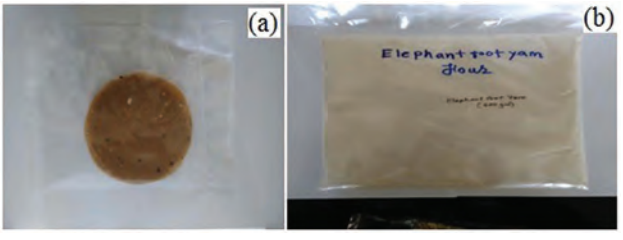


Fig.57. *Jimikand* papad (a) and flour (b)

Development of ready to fry *Jimikand* shorts

Elephant foot yam tuber was cleaned with tap water and made into shreds by shredder. Then shreds were kept in 1% citric acid for 2 h to avoid the browning and acridity problems. After pre-treatment the shreds were cleaned with tap water and blanched for 10 min to kill harmful microorganisms and to prevent undesirable odour. Further shade drying was carried out (10-12 h) and the shorts were packaged in HDPE. These shorts were used as ready to fry snacks whenever required (Fig. 58).

Fig.58. *Jimikand* shorts

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

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

Thermoplastic starch is a kind of modified starch produced by mixing starch with additives and undergoing further processing. Thermoplastic starch sheets are often developed as cushioning material, because they have excellent energy absorbent characteristics and play a significant role in the protection of the produce during transit and storage. Hence much focus was given for the development of thermoplastic starch based material to replace petroleum based commodity plastics, in a cost effective manner, with biodegradable materials offering competitive mechanical properties. The present study was undertaken to produce thermoplastic sheets (TPS) from cassava starch with glycerol/fibre blends by thermo pressing method employing response surface methodology for process optimization.

Thermoplastic starch sheets (TPS) were made using cassava starch-glycerol blends. The experiment was performed by a Box- Behnken response surface design and the variables used were: glycerol-30, 40 and 50% based on starch dry weight, temperature of die plate-130, 140 and 150°C and pressure of the die plate-120,130 and 140 bar. The time of pressing was fixed as 5 min. The physico-mechanical and functional properties of the sheets viz., moisture content, density, total colour difference, yellowness index, diametrical expansion index, solubility, moisture adsorption isotherms, mechanical properties viz., ultimate tensile strength and per cent elongation at break were measured. The rheological properties such as storage modulus (G′), loss modulus (G″), complex viscosity and phase angle of the gelated starch sheet were also analysed.

The glycerol content in the mix had a positive quadratic effect, whereas temperature and pressure had no effect on the moisture content of the TPS. Density decreased linearly with respect to temperature, whereas glycerol content had a positive linear effect. Maximum tensile strength of 1.08 N mm^{-2} was obtained for the sample made at 140°C and 140 bar with 50% glycerol, whereas the minimum of 0.16 N mm^{-2} was obtained for the TPS made at 150°C and 130 bar with 30% glycerol. Percent elongation increased linearly with temperature of pressing and decreased with glycerol content, whereas pressure had no effect. The highest solubility of 35.83% was obtained for the sheets made at 150°C and 120 bar with 40% glycerol, while the lowest (7.70%) was obtained for the sheets made at 150°C and 130 bar with 30% glycerol. In most of the treatments after 75 min of hydration, the expansion index was almost same showing that hydration was almost completed at 75 min itself. The highest expansion of 70% was found to be for the sheets made at 150°C with 130 bar and 50% glycerol and the lowest expansion of

25% was observed for the sheets made at 140°C and 140 bar with 30% glycerol. The hygroscopicity of the thermoplastic sheets were analysed by observing the variations in absorption of moisture by the sheet exposed to 85% relative humidity. The maximum moisture absorption (0.262 g g^{-1}) was exhibited by the sheets made at 140°C, 140 bar with 50% glycerol and minimum of 0.012 g g^{-1} for the sheets made at 140°C, 130 bar with 40% glycerol.

The rheological properties of the sheets hydrated in water for about 20 min was analyzed by measuring the mechanical spectra of the hydrated sheet. The pressure and glycerol content had no influence on the storage and loss modulus, whereas temperature had a negative quadratic effect on these parameters. For phase angle, temperature had a positive quadratic effect, whereas pressure and glycerol content had negative quadratic effect. Complex viscosity quadratically decreased with both temperature and pressure, whereas glycerol had positive quadratic effect.

Thermoplastic sheets with cassava starch-cassava stem powder-glycerol blends were prepared by adding 20% cassava stem fibre in the above combinations as explained for the cassava starch-glycerol blends and the following results were obtained. The moisture content of the TPS varied from 19.21% (50% glycerol, 140°C and 120 bar) to 8.81% (30 % glycerol, 140°C and 140 bar); density from 1552 kg m^{-3}(140°C, 130 bar and 40% glycerol) to 799 kg m^{-3} (140°C, 120 bar with 30% glycerol); total colour difference from 64.36 (150°C, 120 bar with 40% glycerol) to 50.59 (130°C, 120 bar with 40% glycerol); yellowness index from 64.28 (150°C, 130 bar with 30% glycerol) to 30.89 (130°C, 130 bar with 30% glycerol); maximum ultimate tensile strength from 1.65 N mm^{-2} (130°C, 130 bar with 30% glycerol) to 0.16 N mm^{-2} (150°C, 130 bar with 50% glycerol); % elongation from 42.18% (150°C, 130 bar with 30% glycerol) to 10.99% (130°C, 130 bar with 50% glycerol). The highest % of solubility was observed as 33.27% for the sheets made at 140°C and 140 bar with 50% glycerol, while the lowest % of solubility was observed as 7.21% for the sheets made at 130°C and 120 bar with 40% glycerol.

Thermoplastic sheets with cassava starch-coconut pith-glycerol blends were made by adding 20% coconut pith in the above combinations as explained for the cassava starch-glycerol blends and resulting sheets had the following properties: moisture content ranged from 18.24% (50% glycerol, 130°C, 130 bar) to 793 kg m^{-3} (150°C, 130 bar with 30% glycerol), total colour difference from 73.54 (150°C, 140 bar with 40% glycerol) to 48.65 (150°C, 130 bar and 30% glycerol); yellowness index from 31.70 (130°C, 120 bar with 40% glycerol) to 15.70 (140°C, 130 bar with 40% glycerol); tensile strength from 1.37 N mm^{-2} (150°C, 130 bar with 30% glycerol) to 0.16 N mm^{-2} (140°C, 130 bar with 40% glycerol); % elongation from 44.61% (140°C, 130 bar with 40% glycerol) to 5.69 % (150°C, 130 bar with 30% glycerol). The highest % of solubility was observed as 32.79% for the sheets made at 140°C and 140 bar with 30% glycerol, while the lowest % of solubility was observed as 16.80% for the sheets made at 150°C and140 bar with 40% glycerol.

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

Synthesis and characterization of resistant starch of cassava and sweet potato by dual modification

Cassava and sweet potato starches were subjected to dual modification viz., esterification followed by retrogradation to synthesize resistant starch (RS), which resulted in significant increase in resistant starch and slowly digestible starch with lowering of glyceamic index. The scanning electron micrograph (SEM) of native and modified starches are shown in Fig. 59. Starch was subjected to octenyl succinylation followed by retrogradation. The RS content increased from 1.5±0.39% for native cassava starch to 33.1±0.68% for octenyl succinylated and subsequently retrograded cassava starch. The estimated glyceamic index (EGI) of cassava starch decreased from 91.2±1.34 to 58.4±0.68. In the case of native sweet potato starch, RS content was 3.4±0.39% and it increased to 36.6±0.68% for retrograded octenyl succinylated sweet potato starch. The EGI reduced from

86.3±1.34 for the native starch to 55.8±0.68 for the modified starches. In the second experiment, resistant starch has been prepared by esterification of cassava and sweet potato starches with citric acid and the subsequent retrogradation. The RS content increased from 1.5±0.39% for native cassava starch to 39.5±0.72% for retrograded cassava starch citrates. The increase in resistant starch and slowly digestible starch led to a decrease in digestibility and lower glyceamic index for the modified starches. The EGI of native cassava starch was 91.2±1.34, whereas it reduced to 55.4±0.22 for the modified starch. For retrograded sweet potato starch citrates, there was an increase in RS content from 3.4±0.39% for native sweet potato starch to 47.0±0.60% for the treated starch.

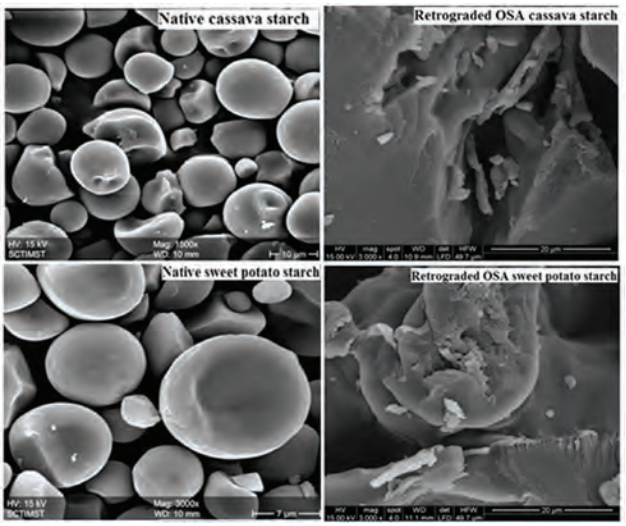


Fig.59. SEM of native and modified cassava and sweet potato starches

Synthesis and characterization of RS5 type resistant starch by lipid complexation

Treatment of starch with long chain fatty acid resulted in complexation of the amylose with fatty acid resulting in reduction in digestibility and formation of RS5 type resistant starches. There was a reduction in rapidly digestible starch for the complexed starches (45.9±0.41%) in comparison to native cassava starch (78.1±0.26 %). The RS content increased from 1.5±0.39% to 33.6±0.32%, whereas the EGI reduced from 91.2±1.34 to 61.2±0.76. Complexation of sweet potato starch with long chain fatty acid resulted in reduction in rapidly digestible starch (42.2±2.57%), when compared to native starch (82.4±0.37%). The RS content increased from 3.4±0.50% to 33.2±1.29% and the EGI decreased from 86.3±3.12 to 59.9±1.83.

Cassava starch hydrogels as slow release matrices for therapeutic drugs

Hydrogels prepared from native cassava starch, starch citrate, octenyl succinylated starch and composites of cassava starch with poly vinyl alcohol (PVA) as well as konjac glucomannan (KGM) have been evaluated *in vitro* as matrices for incorporating the antibiotic drug, ampicillin for obtaining controlled release property. Among the different hydrogels, starch-konjac glucomannan gel showed more sustained release of ampicillin from it (77% and 59% respectively, at pH 2.1 and 7.4 after 6 h of incubation). *In vitro* release at stimulated gastric and intestinal fluids (pH 2.1 and 7.4, respectively) showed that the release of drug was in the order ST-KGM<ST-PVA<OSA starch< starch citrate<native starch hydrogels. Starch-konjac glucomannan gel showed more sustained release of ampicillin from it (77% and 59% respectively, at pH 2.1 and 7.4 after 6 h of incubation) compared to other hydrogels. The release data were fitted to Higuchi model, zero order and first order to study the release kinetics. The drug release kinetics was more fitted to Higuchi model with $r^2 = 0.99$. From the K and r^2 values for different kinetic models, the mechanism of drug release was found to be a combination of diffusion and erosion of gels.

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

Development of lacto pickle from yam tubers

Yam (var. Orissa Elite) tuber matrices (in the form of cubes of 1.5× 1.5 ×1.5 cm^3) were pickled by lactic fermentation by brining the cut and blanching the de-skinned tubers in brine (2-10%). Preliminary sensory studies have shown that the lacto-pickles prepared with 2-6% brine were not palatable; hence further studies were taken up with only 8-10% brine. The matrices were inoculated with a mixed starter cultures of *Lactobacillus plantarum*, and *L. acidophilus* and incubated for 21 days. The lacto-pickle with 8-10% brine had a pH

of 3.04-3.30 and the titratable acidity of 2.8-3.0 g kg^{-1}. The composition of the pickle was as follows: starch 38-54 g kg^{-1}, total sugar 13-18 g kg^{-1}, lactic acid 2.8-3.2 g kg^{-1} and ascorbic acid 31- 46 mg kg^{-1} on fresh weight basis. *Lactobacilli* counts varied from 2.2×10^6 to 4.7×10^5 during a period of about 30 days.

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

Development of pasta from cassava-millet based composite flours

Cassava flour (45%) blended with different millet flours viz. proso, foxtail and finger millets 20% each were made into pasta by adding maida (20%), tapioca starch (5%) and whey protein concentrate (10%) (Fig. 60). They were compared with that of the pasta made from cassava and cassava-maida blend. Maximum starch content was obtained for proso millet (49%) and minimum for foxtail (40%). The sugar content of 7, 6, 6%, was obtained for the millet flours of proso, foxtail and ragi respectively. There was not much variation in the protein content of the flours 10.10-11.50%. The fat content in the millet was negligibly small i.e. 0.10-0.30%. The moisture content in the millet flour was in the range of 7.20-7.90%. The ash content in the millet flour ranged from 1.40% for proso millet and 2.30% for foxtail millet. Moisture content of the pasta ranged from 8.44% for ragi based pasta to 7.20% for foxtail based pasta. The values were almost on par with that of tapioca based pasta (tapioca 70% and maida 30%) and were higher than that of maida (100%) pasta, for which the moisture content was 5.38%. Minimum starch content was observed in foxtail flour based pasta (42.82%), whereas maximum of 48.60% for proso millet incorporated pasta and these values very much lower than that of cassava based pasta (60.88%) and maida pasta (64.04%) . The sugar content of 5.73, 6.30 and 7.08% was obtained for the pasta produced from the composite flour containing proso millet, foxtail millet and ragi, respectively. Protein content was 11.50% for proso millet based pasta, 11.36% for foxtail millet and 10.15% for ragi based pasta. It was observed that fat content in millet based pasta was comparatively lower, 0.15% for foxtail millets, 0.25% for ragi millet and 0.35% for proso millet. The ash content of the pasta made from proso millet was 1.49%, foxtail millet was 2.38% and ragi was 2.04%.

Fig.60. Finger millet pasta (a), foxtail pasta (b) and prosomillet pasta (c)

When the pasta was cooked, maximum swelling index of 1.35 was obtained for the pasta containing foxtail millet followed by 1.28% for proso millet and 1.16% for ragi millet. Cassava-maida based pasta had about 1.32 swelling, which was on par with that of the foxtail millet based pasta. Cooking loss of the millet based pasta was comparatively lower than that of cassava-maida pasta. The lowest value of cooking loss was observed for proso millet based pasta (6.20%) followed by 7.15% for foxtail millet and 7.75% for ragi millet. The cooking time of proso millet based samples were 5.10 min, foxtail millet based pasta, 5.47 min and ragi millet based pasta, 6.56 min. These values were higher than that of the cassava-maida pasta (3 min) and lower than that of maida pasta (7 min). Sensory analysis showed that among the millet based pasta, the overall acceptability score was highest (7.5) for proso millet based pasta followed by foxtail (7.25) and ragi (6). However, these values were slightly smaller than that of cassava-maida pasta and maida pasta (8.5).

Development of sweet potato based composite food bars

A ready-to eat (RTE) nutri bar fortified with sweet potato flour was developed using sweet potato flour (20-30%), Bengal gram (10-15%), green gram (10-15%) with oats, nuts etc for adult/child and geriatric groups and their properties were analysed (Fig. 61). It contained 6.40% protein, 51.80% carbohydrates, 494.78 kcal, 4.52 mg $100g^{-1}$ Fe, 30 mg $100g^{-1}$ Ca and 6.06 mg $100g^{-1}$ Mg. A study was also undertaken to develop composite

food bar from sweet potato using locally available proso millet for adult/child and geriatric groups. Two varieties of sweet potato flour (SPF) viz., Thiruvananthapuram local (TVML) and Kollam local (KML) under two processing conditions viz., cooked and dried (CD) and cooked, frozen and dried (CFD) were used for the production of composite food bars. The formulations were made for adult or child with 30% sweet potato flour and geriatric with 35% sweet potato flour along with other ingredients.

Fig. 61. A ready-to-eat nutri bar fortified with sweet potato flour

Moisture content of the composite food bar prepared with the flour from TVML variety ranged from 10.15 to 12.40% and of KML variety, it varied from 10.00 to 12.5%. Starch content in the food bars prepared using TVML varied from 18.72 to 23.68%, whereas for KML variety the starch content ranged from 18.74 to 22.25%, showing not much variation among the two varieties. Among the different formulation, the sugar content in the adult or child formula was almost double than that of geriatric formula. The variations in protein content in the food bars prepared using different varieties were not significant.

Among the different methods of making flours, the fat content in the bars prepared using cooked, frozen and dried sample was lower than that of the cooked and dried samples i.e., ranged from 0.30 to 0.55% for cooked, frozen and dried sample and from 0.50 to 0.75% for cooked and dried samples. The amount of fibre content in the food bars prepared from the flour of TVML variety ranged from 2.01% to 2.1%, whereas for KML variety, the values ranged from 2.0% to 2.11. The ash content in the food bars did not change with varieties, method of preparation of flour and the formula for different age group. Water activity of the food bars prepared from the flour of TVML variety ranged from 0.682 to 0.786, whereas for KML variety it ranged from 0.648 to 0.705. The water activity of the food bars prepared using flour from KML variety was comparatively lower. For the food bars from TVML variety, the energy value ranged between 214 kcal to 307 kcal, whereas for KML variety, it ranged from 214 kcal to 315 kcal. The energy value of the food bar prepared for adult or child group was higher than that of geriatric formula. Sensory evaluation was carried out on a 9 point hedonic scale and among the different samples, the food bars prepared from the sweet potato flours of Thiruvananthapuram local variety after cooking and drying had the highest overall acceptability of 8.

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

Indigenous knowledge of tuber crops among *Kunbi* indigenous people

The *Kunbi* indigenous people of Joida, Karnataka, are efficient conservators of variety of taro and yam diversity. Dasheen taro is an essential part of their food basket and integral component of their social and cultural life. *Kunbi*'s are migrated from Goa and they survived the transition period by consuming taro tubers before settling down with organised cultivation of cereals and other vegetables. *Kunbi* women are considered as "Chief conservators" of Dasheen taro and they maintain the crop mostly in homesteads. Few Indigenous Technical Knowledge (ITKs) and practices documented from Kunbii people are as follows:

(i) During *Janmashtami* (Lord Krishna's birthday), the *Kunbi's* create a symbolic Krishna design using Dasheen taro leaves and place them in the field and worship it by following rituals.

(ii) Wild elephant foot yam tubers are collected from forests and are placed in the running river water with a belief that the water movement reduces the anti-nutritional components in those tubers.

(iii) Indigenous seed storage bins – The *Kunbi* are storing taro and yam tubers in the pits carved on the sandy loam mounds adjourning to their homes (Fig. 62). Before storing tubers inside the bins, they are treated with ash to prevent any damage. After filling the bins, it is closed with a stone. In this method, the tubers can be stored profitably for 3-4 months.

Fig.62. Indigenous seed storage mechanism followed by *Kunbi*

(iv) Dasheen taro are integral part of *Kunbi* ethnic food basket. The dasheen taro is consumed as fried chips, curry, Bonda etc. (Fig. 63)

Fig.63. Ethnic foods prepared from taro

Sweet potato front line demonstrations (FLD) in Belagavi, Karnataka

Under the FLDs conducted at Belagavi under commercial sweet potato systems, average yield obtained from sweet potato varieties were 20.15 t ha^{-1} from ST-14, 36 t ha^{-1} from Sree Arun and 16.12 t ha^{-1} from Sree Kanaka. Commercial system of cultivation was followed with application of fertilisers and irrigation with sprinklers (Fig. 64).

Sweet potato production and marketing system in Belagavi, Karnataka

In Belgaum district, sweet potato is cultivated commercially in 1221 ha with an annual production of 16720 tonnes. The sweet potato tubers are sold in the Agricultural Produce Marketing Committee

Fig.64. Co-operating farmer with ST-14 tuber harvested from his field

(APMC) located in Belgaum. The year-wise sweet potato transactions conducted at APMC, Belgaum is given in Fig. 65.

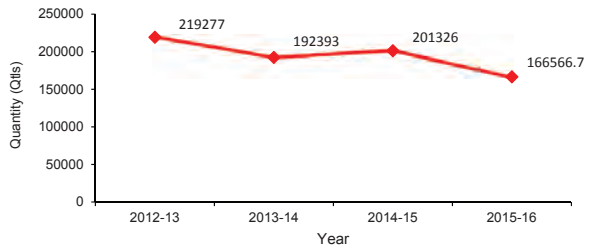


Fig. 65. Year wise arrival of sweet potato at APMC, Belgaum

The sweet potato tubers are sold in "open auction" mode at APMC to traders from Delhi and Gujarat (Fig. 66). The collected tubers are transported to wholesale markets located in cities.

Fig. 66. Sweet potato trade at APMC, Belgaum

Strategic market analysis for commercializing tuber crops based food products

Development of cassava commodity model

A cassava commodity model is developed with the help of scientists from NCAP, which is under validation. This model is being developed with Partial equilibrium approach with the primary objective of generating medium-and long-term outlooks on demand, supply, trade and prices of cassava. Various data included in the model are area, production and productivity, consumption (per capita consumption - NSSO survey) and prices. Sago and starch predictions for 2020, 2030 will be made after validation.

Willingness-to-pay for cassava pasta

An experiment containing 100 pasta consumers was conducted in Hyderabad to assess the impact of health information on the consumers' willingness-to-pay for cassava pasta. In this test, cassava pasta was evaluated against commercial pasta product (Del Monte). After blind test sensory evaluation, the consumers were provided with information on the crop (first information) followed by the ingredients (second information).

(i) Consumer acceptability of cassava pasta

Results displayed in Fig. 67 indicated that respondents slightly liked the aroma or odour (mean = 6.06) and taste (mean = 6.10) of cassava pasta, whereas for the other three components (general appearance, colour and texture) respondents chose mid-point (mean = 5). Whereas for sample-II (Del Monte Branded wheat Pasta), respondents moderately liked the general appearance (mean = 7.03), colour (mean = 6.9) and texture (mean = 6.7) than the aroma/odour and taste (mean = 5).

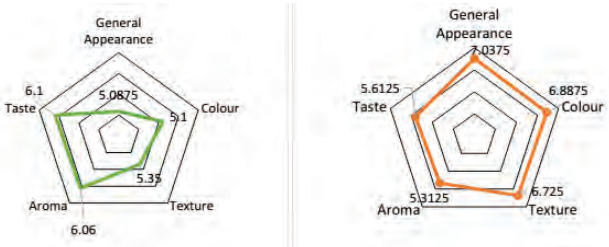


Fig .67. Consumer acceptance of cassava pasta (left) and commercial pasta (right)

(ii) Willingness to pay for the pasta using experimental auctioning

In case of cassava pasta in blind test, respondent's average willingness to pay was Rs 146.50, which

increased to Rs 188.00 (increase by 28%) in case when first information was provided. In case of second information, the willingness-to-pay increased to Rs. 191 (Fig. 68). This increase was higher than commercial pasta. These results proved that health information has significantly increased the conceptual price of pasta.

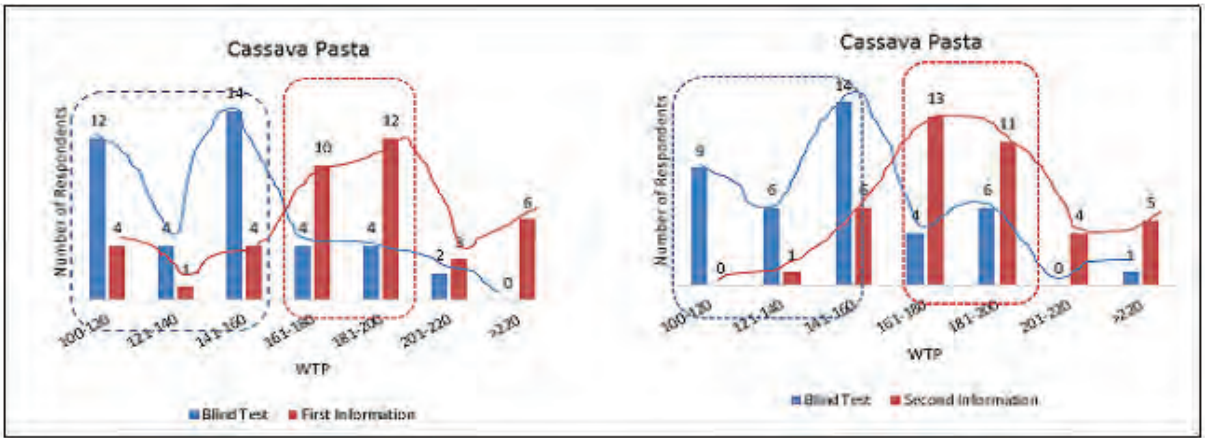


Fig.68. Changes in the willingness-to-pay under three information conditions

Sustainable livelihood analysis of tuber crops farmers

The study was conducted among 60 tuber crops and 60 rice farmers selected from Kanya Kumari and Tirunelveli districts in Tamil Nadu. The data were collected on five capitals namely human capital, physical capital, natural capital, financial capital and social capital. A well structured interview schedule was used for data collection. As a part of data collection key informant techniques and discussions were held with the villagers.

Human capital index: It included the parameters namely education level of farmers, training undergone, labour availability, health facilities and experience of the farmers. Data revealed that the human index was more for rice farmers (0.56) when compared to tuber crops farmers (0.45). The training index was very less for tuber crops farmers (0.06), whereas for the rice farmers it was (0.34). Experience was more in the case of rice farmers (0.62), when compared to tuber crops farmers (0.42).

The Physical capital included components like transport facilities available in the village, housing type, drinking water facilities, electricity and cooking fuel available to the farmers. As far as physical capital is concerned it was somewhat more for rice farmers (0.71) as compared to tuber crops farmers (0.68). Housing type for rice farmers was 0.88 and for tuber crops farmers it was 0.82, which was more or less similar. All the selected villages were electrified and hence the index value was 1.

Natural capital included the land area owned by the farmers, ownership status of cultivable land, type of land and also the number of crops grown by the farmer. The index for the land area available with the rice farmers was more (0.69), when compared to tuber crops farmers (0.58). The index for ownership status of land was similar for both the farmers.

Under financial capital, the components included were annual income of the farmers, access to credit by the farmers, savings available with the farmers and the borrowed capital. It was found that the index for annual income was more for rice farmers (0.48), whereas it was 0.36 for the tuber crops farmers. Saving was more for tuber crops farmers (0.41) and for rice farmers it was 0.21.

The components under social capital were relationship within the communities, membership in organisations, access to society, access to agricultural information and communication facilities available in the village. Access to agricultural information was more for rice famers (0.62) and for tuber crop farmers it was 0.33.

It could be observed that the human capital index

was more for rice farmers (0.61) when compared to tuber crops farmers (0.49). Physical capital was also high for rice farmers (0.71). Natural capital was marginally high for rice farmers (0.70) and for tuber crops farmers it was 0.66. Financial capital was also more for rice farmers (0.56) but in the case of tuber crops farmers it was 0.45. Social capital was same for both the farmers (0.57).

The rural sustainable livelihood index for rice farmers was more (0.63) than tuber crops farmers (0.52). The t test revealed that there exists significant differences between the rice and tuber crops farmers in the variables namely experience in farming (t= 3.87), farm size (2.26), annual income (2.57) and access to agricultural institutions (3.57). The sources of livelihood as reported by both the farmers were agriculture, employment in government/private sector and petty business. The vulnerability factors were rampant inflation, price fluctuation, crop failure and labour cost. The trends observed were migration of young people, relative's migration, price rise, drought and climate change.

Development of ICT applications in tuber crops

Validation of electronic crop

Electronic crop (E-Crop) was installed in sweet potato field for validation. Crop was planted on 15 March 2016 and harvested on 25 June 2016. Weather data and soil moisture content was collected by the device with the help of the sensors connected to it. The weather data was collected at 15 minutes interval and uploaded to the website of the institute. At 7.30 pm all these data get downloaded to the local machine automatically. Once the data is downloaded, the sweet potato model SPOTCOMS runs using the data files downloaded and computes the dry matter produced by the crop till date and calculates the potential yield the crop can achieve as per the growth the crop has already attained. In addition, it calculates the amount of water, nitrogen and potassium, which should be applied to achieve the re-calculated potential yield. All these information will be sent to the mobile of the farmer in the form of advisory. Fig. 69 shows values of potential and actual yield, which are predicted on different dates during the crop season. The data shows that the gap between the potential yield and actual yield narrowed down as the crop growth neared maturity. In this trial, actual yield predicted and observed were 12.97 t ha^{-1} and 12.15 t ha^{-1} respectively with 93.25% accuracy.

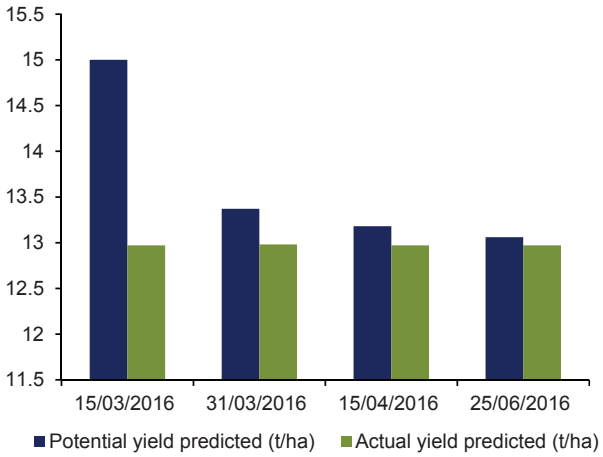


Fig. 69. Potential and actual yield predicted by E-Crop on different dates of sweet potato growth period

Development of variety Identifier

Mobile app version of variety identifier is in the final stage of development (Fig. 70). The app is named VIT i.e. Variety Identification Tool. It can be used in any android phone for identifying

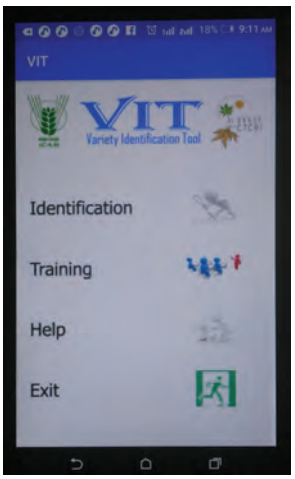


Fig. 70. Main activity page of VIT

tuber crops varieties from their morphological features. The software uses the camera inbuilt in the phone for taking images of the plant parts and the software recognizes the varieties using image analysis algorithm used in the app.

The activity pages of the app and the module to capture images have been completed. The module to recognise images and the module to update and retrieve image from online database are nearing completion. The most important modules of the app are the training module and the image recognition module. The algorithms used in the modules are:

Training algorithm

1. Choose the crop and plant part from the options
2. Take the snap of the selected plant part of the crop
3. Choose the name of the variety from the combo box, if the selected variety is already available in the database
4. If the name of the variety is not in the database write the name of the variety and update the database
5. The software compares the snap with the representative image in the database and if the variation is above a threshold value, that snap will not be considered at all

Identification algorithm

1. Choose the crop and plant part from the options
2. Take the snap of the selected plant part of the crop
3. Click on "Identify the variety"
4. If the image is similar to the representative image in the database the app identifies the variety
5. If the image could not be identified the Training activity will be loaded and the user can update the information of the new variety

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

Quantitative structure activity relationship of anthocyanins of greater yam and sweet potato were studied using the descriptors and experimental Trolex Equivalent Antioxidant Capacity (TEAC) of anthocyanins from egg plant and radish as the training dataset.

Six anthocyanins from greater yam and nine from sweet potato tubers isolated at ICAR-CTCRI were considered as test set (Tables 3 & 4). SMILES (simplified molecular input line entry system) of the training set were obtained from PubChem database. Using chemical structure of test set data, SMILES were generated. SMILES of the test molecule were created using ChemDraw software. Descriptors are the numerical representation of chemical information encoded within a molecular structure via mathematical procedure, calculated using ChemDes, a free integrated web based platform. SMILES generated for each molecule in test set were converted to sdf file by online smile translator and structure file generator tool, for visualization of molecules using free version of Pymol. For model development multivariate linear regression was used. KNIME platform was used for QSAR studies. The following tables show the predicted TEAC values of training as well as test datasets (Tables 3 & 4). The results show significantly higher predicted activity of anthocyanins from sweet potato.

Table 3. Descriptors, experimental and predicted activity of traning dataset

Name of the compounds in training dataset	TPSA	LogP2	Hy	UI	LogP	TEAC Exp	Prediction (TEAC Exp)
Cyanidin	112.45	8.462	-3.137	4.17	2.909	6.764	6.855
Delphinidin	130.61	1.567	-3.041	3.7	1.252	3.084	3.084
Cyanidin-3-glucoside	191.6	6.833	-3.21	4.17	-2.614	4.723	3.121
Cyanidin-3-sophoroside	270.75	3.218	-3.407	4.17	-1.794	5.809	4.595
Delphidin-3,5-diglucoside	290.98	5.95	-3.35	4.17	-2.439	3.223	4.510
Delphinidin-3-sambubioside	270.75	2.1	-3.338	4.17	-1.449	5.101	4.554
Delphinidin-3-rutinoside	270.75	1.125	-3.407	4.17	-1.061	4.098	4.908
Cyanidin-3-arabinoside	171.37	3.9	-3.196	4.17	-1.975	1.289	2.999
Delphinidin-3-glucoside	211.83	0.008	-3.21	4.17	0.088	5.137	4.602

Table 4. Predicted values of descriptors and activity of test dataset

Name of the compounds in test dataset	TPSA	LogP2	Hy	UI	LogP	TEAC Prediction for test set
Cy-3-O-[(6-O-β-D-glucopyranosyl)-β-D-glucopyranosyl]	270.75	3.218	-3.407	4.17	-1.794	4.6001
Cy-3-O-[(6-O-β-D-glucopyranosyl)-β-D-glucopyranoside]-7-O-β-D-glucopyranoside	349.9	18.668	-3.517	4.17	-4.321	5.732018
Cy-3-O-[(6-O-(6-O-(E)-sinapoyl-β-D-glucopyranosyl)-β-D-glucopyranosyl]-7-O-β-D-glucopyranoside	394.66	5.446	-3.895	4.7	-2.334	8.552555
Cy-3,7-di-O-[(6-O-(6-O-(E)-sinapoyl-β-D-glucopyranosyl)-β-D-glucopyranosyl]	518.57	6.362	-4.219	5.087	-2.522	11.77468
Cy-3-O-[(6-O-(6-O-(E)-sinapoyl-β-D-glucopyranosyl)-β-D-glucopyranosyl]	315.51	0.037	-3.838	4.7	0.193	8.920715
Cy-3-O-[(6-O-(6-O-(E)-feruloyl-β-D-glucopyranosyl)-β-D-glucopyranosyl]-7-O-β-D-glucopyranoside	385.43	5.486	-3.893	4.7	-2.342	8.451492
cy-3-(6”-p-hydroxybenzoylsoph)-5-glc	364.9	6.888	-3.89	4.644	-2.624	8.023567
Peo-3-(6”-p-hydroxybenzoylsoph)-5-glc	353.9	5.389	-3.938	4.644	-2.321	8.071167
cy-3-(6”,6”’-dicaffeoylsoph)-5-glc	431.66	0.712	-4.19	5.087	-0.844	11.40637
Cy-3-(6”-caffeoyl-6”’-p-hydroxybenzoylsoph)-5-glc	411.43	0.901	-4.153	5.044	-0.949	10.91629
Cy-3-(6”-caffeoyl-6”’-feruolylsoph)-5-glc	420.66	0.292	-4.229	5.087	-0.541	11.57898
Peo-3-(6”, 6”’-dicaffeoylsoph)-5-glc	420.66	0.292	-4.229	5.087	-0.541	11.57898
Peo-3-(6”-caffeoylsoph)-5-glc	374.13	4.912	-3.984	4.7	-2.216	8.583641
Peo-3-(6”-caffeoyl-6”’-p-hydroxybenzoylsoph soph)-5-glc	400.43	0.417	-4.193	5.044	-0.646	11.08264
peo-3-(6”-caffeoyl-6”’-feruolylsoph)-5-glc	409.66	0.057	-4.267	5.087	-0.238	11.77437

Docking studies

Twenty two polyphenolic compounds from greater yam, sweet potato and Chinese potato were used for docking studies. Considering the drug testability and minimum binding energy required, polyphenolic compounds of greater yam and Chinese potato, kaemferol and rosmarinic acid was found to act as a promising, which can inhibit activity of Angiotensin Converting Enzyme (ACE) thereby reducing cardiovascular and neurological disorders. The polyphenolic compounds of sweet potato, pelargonidin and peonidin act as promising, which can inhibit Acetylcholinesterase and Angiotensin converting enzyme.

EXTERNALLY AIDED PROJECTS

1. **Adapting clonally prop agated 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, the 50 exotic taro genotypes received under INEA program were maintained *in vitro* as well as in field. Out of these, 32 lines were multiplied and distributed to farmers' of seven different locations of Odisha (Khorda-2, Cuttack-3, Puri-2), where the crop established well. Morphotypes were identified amongst the 50 lines, such as eddoes-10 lines, dasheens-35 lines and intermediate-5 lines. Of the 50 exotics, 11 lines were stoloniferous, showing slender, elongated, short stolons. All the 50 exotic lines and indigenous lines were grouped into six based on key petiole colour characters**.** Flowering was recorded in 22 exotic accessions during 2016. The lines identified as tolerant and resistant to TLB in 2012 continued to show the same reactions till 2016, confirming the stability of this character. All the breeding lines from Samoa continued to show the disease tolerance character. BL/SM/116, 151 (Samoa), BL/PNG/09, 11 (Papua New Guinea) and CE/MAL/12 (Malaysia) showed better expression of tolerance with no symptom development till date. Under participatory evaluation for yield and other quality attributes, 32 INEA lines and seven local varieties showed higher yield potential (18-25 t ha^{-1}) as in the previous year. Planned hybridization can be achieved conventionally by maintaining perennial plot to synchronize flowering and non-conventionally by cryo-stored pollen. Hybrid seeds of desirable lines were developed both by maintenance of perennial plants and also using cryostored pollen (Fig. 71). The fruiting, seed characteristic of cryostored hybridized pollen was observed to be on par with conventionally bred fruits, seeds. *In vitro* germination of cryopreserved pollen hybridized seeds (Fig. 72) was statistically on par with conventionally bred seeds. The *in vitro* seedlings obtained through conventional-nonconventional means were transplanted from screen house to field for further observations and evaluation.

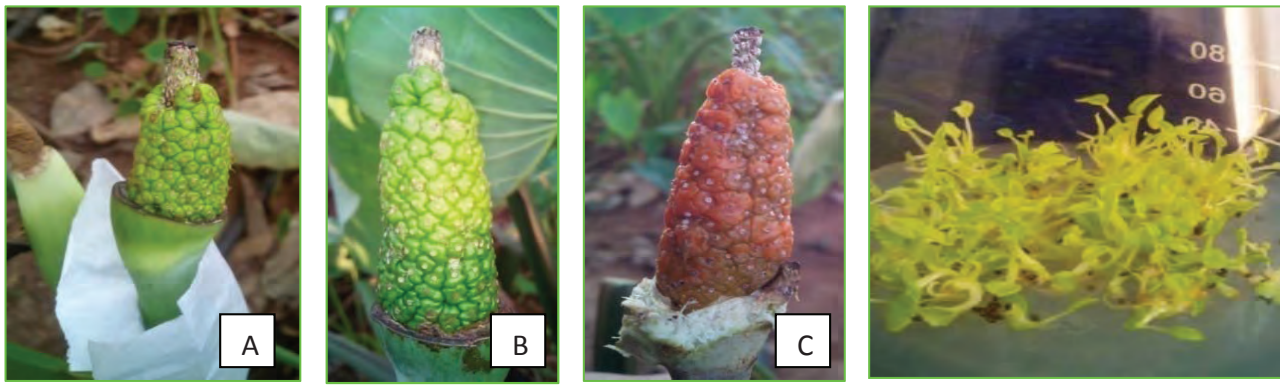


Fig. 71. Successful hybridization with cryopreserved pollen. 10 days after pollination (A), 20 days after pollination (B) and 1 month mature fruit (C)

Fig. 72. *In vitro* germination of cryopreserved pollen hybridized seeds

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

Under the DUS project on elephant foot yam and taro, varietal gene bank was established at the nodal and co-nodal centers for 21 varieties of taro and 18 varieties of elephant foot yam. The DUS guidelines of taro and elephant foot yam was developed. For this, 29 pre-harvest morphological characters were recorded to identify distinctiveness among 21 taro varieties viz., position of leaf - a. cup-shaped and b. erect-apex down; leaf blade margin pattern - a. sinuate and b. undulate; petiole junction colour - a. purple and b. yellow; sap colour of leaf blade tip - a. yellow, b. pink, c. whitish (transparent) and

d. brownish; leaf blade colour - a. dark green, b. yellow/yellow green and c. green and also leaf blade margin and petiole basal ring colour - a. yellow, b. green and c. purple (Fig. 73). The reference varieties were also identified for these traits and its variants.

Similarly, 28 pre-harvest morphological and post-harvest characters were recorded for 18 varieties of elephant foot yam and the following traits and variants were identified for the guidelines along with reference varieties for these traits (Fig. 74). Stem colour (a. dark green with white patches, b. green with white patches); rachis colour (a. green with white patches and purple spots, b. green with white patches); rachis junction colour (a. green with white patches and purple spots, b. green with white patches); main stem texture (a. smooth, b. rough); leaflet colour (a. yellow/yellow green, b. green with yellow spots); leaflet vein colour (a. green, b. white) and leaf waxiness (a. low, b. medium).

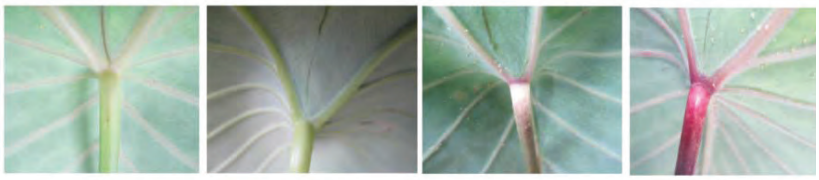


Fig.73. Petiole basal ring colour in taro

Fig.74. Rough and smooth skin texture in elephant foot yam corms

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: Dr. Archana Mukherjee)

For the development of draft DUS guidelines in greater yam, 31 pre-harvest characters were recorded, of which the following were found to be common in all the varieties viz., plant type: climber, twining to right; density of spines: few; emerging leaf color: light green; young leaf color: green; petiole color (young leaf): green and first leaf emergence: 1 month. Other variable traits like stem colour (a. green, b. light green); emerging stem colour (a. purplish green, b. light green); young stem colour (a. green, b. dark green) and mature stem colour (a. purplish green, b. green) were recorded along with reference varieties. The post-harvest characteristics were also recorded.

In the case of yam bean, 16 pre-harvest characters were recorded for the development of draft DUS guidelines (Fig. 75). Amongst these, the following were found to be constant, viz., stem color (tender):

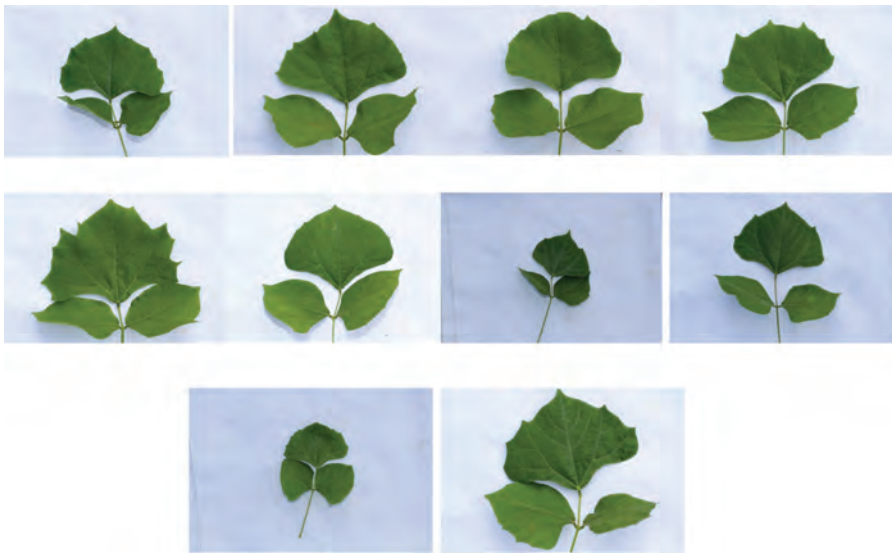


Fig. 75. Leaf architecture in yam bean

green; stem color (mature): light green; leaf color: green; lateral leaflet type: lobed; flower formation: present and flower color of standard and wing: purple with white patches.

4. **Consortium research platform on agro-biodiversity** (ICAR, New Delhi; PI: Dr. M.N. Sheela)

Characterization and evaluation of 278 accessions of cassava for seven qualitative (two plant and five tuber) traits and six quantitative (tuber) traits was done during the period under report. Fifty two sweet potato accessions were screened for 17 vegetative characters and seven tuber characters (IPGRI descriptors). Documentation of 75 greater yam and 30 wild yams accessions was carried out. Morphological cha racterization of underground tuber characters was recorded from 12 wild elephant foot yam accessions using 12 traits as per NBPGR descriptors. Eighteen above ground traits was recorded in 30 elephant foot yam accessions. Cultivars with unique characteristic features have been identified and will be utilized for registration.

5. **Tuber crops development project, Kerala: Area expansion of tuber crops using quality planting materials** (Department of Agriculture, Govt. of Kerala; PI: Dr. James George)

The third phase of the project was initiated during April, 2016. The objectives of the project are large scale production of clean and disease free planting materials of improved varieties of cassava, yams and elephant foot yam through micropropagation and minisett techniques (Table 5), 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 (Table 5 and Fig.76).

Physical achievements

District covered	:	3 (Kollam, Malappuram, Kasaragod)
Tuber crops covered	:	Cassava, Elephant foot yam, Greater yam
Total area covered	:	3.6 ha
Cassava	:	1.2 ha (30 units of 10 cents; Kootilangadi, Malappuram)
Elephant foot yam	:	1.2 ha (30 units of 10 cents; Elamad, Kollam)
Greater yam	:	1.2 ha (30 units of 10 cents; West Eleri, Kasaragod)
No. of beneficiaries	:	90

Varieties distributed

Cassava	:	Sree Jaya, Sree Vijaya, Sree Swarna, Sree Raksha
Elephant foot yam	:	Gajendra
Greater yam	:	Sree Keerthi, Sree Karthika, Sree Shilpa, Sree Neelima, Sree Swathi, DA 234, 293, 810, 820, 821, DR 1047, TCR 66
Training programmes conducted	:	12

Table 5. Quality planting material produced and projected area expansion

Panchayat/District	Crop	Area covered (ha)	Total production	Projected area expansion (ha)
Kootilangadi (Malappuram)	Cassava	1.2	30000 stems	12
Elamad (Kollam)	Elephant foot yam	1.2	62 tons	10
West Eleri (Kasargod)	Greater yam	1.2	32 tons	10

Fig.76. Harvest festival of greater yam at west Eleri

6. Network Project on Organic Horticulture (NPOH) (ICAR-Indian Institute of Spices Research 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; yield under organic management (13.94 t ha^{-1}) was 10.50% higher over conventional system (12.61 t ha^{-1}). In Chinese potato, organic practice resulted in higher net income (Rs. 413,000 ha^{-1}) and added profit of Rs. 26,686 ha^{-1} over conventional practice due to production of 10.50% higher yield. The pH (by +1.14 unit over conventional), organic C (+15%), available N and P increased significantly under organic management. In tubers, K content was significantly higher and dry matter, starch, crude protein, P, Mg, Fe, Mn, Zn and Cu contents were enhanced under organic management. Organic management also resulted in significantly higher P and Zn uptake.

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

On-station developed (at ICAR-CTCRI) organic production technologies for cassava and yams were validated in an organically raised 48 yr old coconut plantation at ICAR-CPCRI, Kasaragod, for the second season (Fig. 77). Yield under organic mode (0.76 and 0.98 respectively of conventional) was on a par with chemical system in both cassava (8.14 and 10.71 t ha^{-1}) and yams (*Dioscorea* spp.) (6.81 and 6.91 t ha^{-1}) intercropped in coconut garden based

Coconut + cassava

Coconut + greater yam

Coconut + lesser yam

Fig. 77. Validation trials on organic farming of yams and cassava at ICAR-CPCRI, Kasaragod under Network Project on Organic Horticulture

on average yield data of two years. The three species of *Dioscorea* (*D. alata*, *D. esculenta* and *D. roundata*) and three varieties of cassava responded similarly to organic and conventional management. Of the three species of *Dioscorea*, *D. alata* and *D. esculenta* were more responsive (+8-10%) to organic management, but organic management lowered yield by 30% in dwarf white yam (*D. roundata*). The three varieties of cassava, Sree Vijaya, Vellayani Hraswa and H-165, exhibited similar yield reduction (-22%, -27%, -23% respectively) under organic management over conventional system.

Development of technology for organic production in arrowroot

Based on two years' experimentation at ICAR-CTCRI in arrowroot, organic production technologies involving FYM @ 10 t ha^{-1}, green manure @ 10-15 t ha^{-1} and biofertilizers (*Azospirillum*, P solubilizer and K solubilizer @ 3 kg ha^{-1} each) were developed; yield under organic management (12.81 t ha^{-1}) was 2% lower than conventional (13.05 t ha^{-1}) and integrated (12.93 t ha^{-1}) practices. In arrowroot, conventional practice resulted in higher net returns and B:C ratio (Rs. 215, 017 ha^{-1}; 2.22 respectively) due to production of higher yield.

7. **Network Project on Organic Farming (NPOF)** (ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, as Lead Centre; PI: Dr. G. Suja)

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

Four cropping systems, cassava-vegetable cowpea, cassava-groundnut, taro-black gram and taro-green gram, were evaluated under six management options, 100% organic, 75% organic, 100% inorganic, state recommendation (POP), 50% organic + 50% inorganic, 75% organic + 25% inorganic in large plots (18 m x 5.4 m) in strip plot design (unreplicated) with border fences of subabul between plots, border rows of lemon grass, karonda and lemon surrounding the experimental area and cowpea buffer strips in between plots as per the technical programme suggested by the lead centre (Fig. 78).


Taro-green gram

Taro-black gram


Cassava-vegetable cowpea


Cassava-groundnut

Cormel yield of taro under 100% organic

Cormel yield of taro under 75% organic + 25% inorganic

Fig.78. Evaluation of organic, inorganic and integrated management practices in cropping systems involving tuber crops under Network Project on Organic Farming

In cassava, the tuber yield was highest under 100% inorganic practice, followed by 75% organic + 25% inorganic and 100% organic. The yield under 100% organic was +22.72% of POP, -1.25% of 75% organic + 25% inorganic and -6.55% of 100% inorganic. In taro, the cormel yield was highest under 75% organic + 25% inorganic, followed by 50% organic + 50% inorganic and 100% organic. The yield under 100% organic was -28.37% of 75% organic + 25% inorganic and +107% of POP.

In cassava, the net returns was the highest under 100% inorganic (Rs. 3,76,144 ha^{-1}; B:C ratio: 4.13) followed by 100% organic (Rs. 3,04,520 ha^{-1}; B:C ratio: 2.91), computed without premium price. 100% organic (Rs. 4,59,098 ha^{-1}; B:C ratio: 3.88) followed by 75% organic resulted (Rs. 3,82,443 ha^{-1}; B:C ratio: 3.28) in higher returns when computed with premium price. In taro, 50% organic + 50% inorganic (Rs. 3,49,709 ha^{-1}; B:C ratio: 2.29) was the most profitable followed by 75% organic + 25% inorganic (Rs. 3,21,347 ha^{-1}; B:C ratio: 2.06), calculated with and without premium price for organic produce.

In green gram, the highest yield was obtained in 100% organic (766.46 kg ha^{-1}) followed by 75% organic + 25% inorganic. In blackgram, 100% inorganic (936.21 kg ha^{-1}) resulted in the highest yield followed by 75% organic + innovative practices. In groundnut, 100% inorganic practice (1887.56 kg ha^{-1}) produced highest yield closely followed by 75% organic + innovative practices and 100% organic. In vegetable cowpea, the highest yield was obtained in the case of 75% organic + innovative practices (4064.81 kg ha^{-1}), closely followed by 100% organic.

In taro-green gram and taro-black gram system, the production efficiency was highest for 50% organic + 50% inorganic (60.56 kg ha^{-1} day^{-1}) and 75% organic + 25% inorganic (68.47 kg ha^{-1} day^{-1}) respectively. In cassava-groundnut system, 100% inorganic followed (141.43 kg ha^{-1} day^{-1}) by 100% organic and in cassava-vegetable cowpea system, 100% organic (112.99 kg ha^{-1} day^{-1}) closely followed by 100% inorganic resulted in higher system productivity.

Geo-referenced on-farm characterization of organic growers

Nineteen organic farmers were surveyed as per the schedule from *Kazhakoottam*, *Neyyattinkara*, *Parassala*, *Vamanapuram* and *Pallichal* blocks of Thiruvananthapuram district. The basic objective of this survey was to study the common organic farming practices adopted by the farmers, to identify the relative share of farmers involved in organic farming either individually or in clusters and constraints in organic production. Among the organic farmers surveyed, 94% belonged to small and marginal group with an average land holding size less than 2 ha and the farms were uncertified. Farm animals were an integral part of the organic system. Majority of farmers (79%) practise organic farming mainly for sustenance to provide safe food to their family rather than marketing and making profit. Among the respondents, 42% deployed the on-farm generated organic manures for crop production. Cultural and eco-friendly techniques were mainly adopted for pest management. Among the market centred enterprises, piggery, ornamental fishes and organically produced cut flowers received premium prices with high B:C ratios.

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

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

The objectives of the project are development of best management practices (BMP) with emphasis on surface and subsoil acidity, soil available macro, 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 intercropped in coconut garden for better profit, soil and tuber quality for the two agro-ecological units of Kerala (AEU-3, AEU-9).

Field trials conducted at three locations in AEU 3 and four locations in AEU 9, each for cassava and elephant foot yam under intercropping in coconut to develop BMP taking into account the subsoil acidity revealed no significant effect of BMP comprising of organic manures, NPK fertilizers, liming materials (viz., lime, gypsum and dolomite) and secondary and micronutrients (viz., Zn and B) on tuber yield of elephant foot yam compared to POP, farmers practice, NPK+FYM along with liming materials and NPK+FYM along with secondary and micronutrients (Fig. 79). Evolved

Fig. 79. Field experiment on best management practice in elephant foot yam

three custom mixed fertilizer grades comprising of major, secondary and micronutrients for elephant foot yam intercropped in coconut gardens based on STCR approach (targeted yield of 45 t ha^{-1}) and response curve approach and developed three custom mixed formulations for AEU 3 and AEU 9. Field testing of these three formulations at two rates viz., 500 and 625 kg ha^{-1} in one location in AEU 3 and three locations in AEU 9 indicated significantly higher yield with 625 kg ha^{-1}, but the tuber yield was on par under the three grades (Fig. 80).

Fig. 80. Field experiment on custom mixed fertilizer experiment in elephant foot yam

9. Assessment of soil fertility and preparation of soil fertility maps for various agro-ecosystems of Odisha

(Rashtriya Krishi Vikas Yojana; PI: Dr. K. Laxminarayana)

Received 6236 profile soil samples at three depths viz., 0-30, 30-60 and 60-100 cm at Gram Panchayat level representing 30 districts About 10,000 soil

samples have been analyzed for pH, EC, organic C, available N, P, K, exchangeable Ca and Mg. About 3000 profile soil samples were estimated for available Fe, Cu, Mn and Zn and 1000 profile samples were analyzed for B and S. The analytical work is in progress.

Infrastructure facilities were improved in the Soil Science laboratory with Digital pH meter, Conductivity meter, Environmental shaker, UV-VIS Double beam spectrophotometer, Double distillation unit, Single distillation units, magnetic stirrer, GPS, Camera, Refrigerator, Electronic Balance, Mechanical Stirrer. During 2016-2017, the instruments like Nitrogen Dual Distillation unit, Flame Photometer, BOD Incubator, Hot Air Oven, Muffle Furnace, Autoclave, Digital Burette, Turbidity meter, Water bath, Air Conditioner were installed in the Soil Science laboratory.

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 building of Techno-Incubation Centre has been constructed and the required equipments have been purchased.

11. **Outreach programme on the management of sucking pests in horticultural crops** (ICAR Network Project; PI: Dr. C. A. Jayaprakas)

The ICAR-CTCRI developed biopesticide was standardised for the management of mealy bugs in tomato, brinjal and gooseberry. Spray interval was standardized and field trials were conducted in farmers' field. Trials were conducted in poly houses for the management of sucking pests. A short video film in Malayalam and English was produced on the use of biopesticide among farmers.

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

ICAR-CTCRI developed biopesticides were field tested in the farmers' fields against pseudostem weevil and rhizome weevil in Thiruvananthapuram and Kasaragod districts. A dispenser for the application of biopesticide was designed and developed. The technology was transferred to six KVKs in Kerala. Also, training programmes were conducted at different KVKs and Krishi Bhavans.

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

Genetic diversity analysis of 40 *Phytophthora colocasiae* isolates was performed using Sequence Related Amplified Polymorphism (SRAP) markers with nine primer combinations. Hundred percent polymorphism was observed and there was considerable genetic diversity among isolates. The clustering was not correlated with phenotypic/ geographical origin. It may be due to mutation or somatic variation. Suitable SSR markers were identified for characterizing *P. colocasiae* from reported SSR markers for *Phytophthora* spp. The Resistant Gene Analogues (RGAs) were identified from resistant (Muktakeshi) and susceptible (Sree Kiran) taro cultivars, sequenced and characterized.

14. **Indo–Swiss cassava network project** (Indo-Swiss Collaboration in Biotechnology, (ISCB), Swiss Agency for Development & Co-operation, Bern and New Delhi and Department of Biotechnology, Govt. of India, New Delhi; PIs: Dr. M. N. Sheela and Dr. T. Makeshkumar)

Development of transgenic cassava resistant to cassava mosaic disease: Friable embryogenic callus (FEC) production was optimized for Indian cassava varieties, H-165 and Sree Athulya. Meristem derived virus free plants of cassava var. *Mulluvadi*, Sree Raksha-1, Sree Raksha-2 were achieved, and that of var. *Kumkumarose* is in progress and these lines will be included in FEC production. Genetic transformation of cassava var. H-165 with SLCMV RNAi construct was done, but putative transformants failed to regenerate (shoot elongation) into plants as compared to control. Imported ACMV resistant transgenic lines were tested against SLCMV

through whitefly transmission and all of them were completely susceptible (Fig. 81). Screening procedure for virus resistance in cassava was standardised with graft, whitefly transmission and limited success was obtained with agro-inoculation using infectious clones.

Fig. 81. Response of ACMV resistant transgenic cassava plants to SLCMV inoculation through whitefly

Exchange of plant materials: Cassava mosaic disease (CMD) resistant varieties from ETH were introduced to ICAR-CTCRI for multiplication and evaluation. The CMD resistant clones viz., UMUCAS-33 (EC879925), KBH-18 (EC879926), KBH-26 (EC879927), TME-3 (EC879928), TME-7 (EC879929) and TME-4 (EC879930) were multiplied and hardened and established in the field at ICAR-CTCRI for evaluation.

Standardisation of tissue culture media for micropropagation: For standardization of micropropagation protocol, explants from *in vitro* grown plants were inoculated in MS media supplemented with different combinations of NAA, BAP and $CuSO_4$. Among the media evaluated, MS media with NAA - 0.5 μml^{-1}, BAP - 2 μml^{-1} and $CuSO_4$ - 2μml^{-1} were found to be the best for micropropagation of cassava.

Introgression of transgenes into popular varieties of cassava: Natural flowering in cassava will take eight to ten months and also some popular varieties including TMS-60444 are very erratic in flowering under Indian conditions. Hence, an experiment on hormonal manipulation for flowering was initiated. Application of ascorbic acid @100 ppm resulted in initiation of flowering at the fifth month followed by the treatment NAA @ 50 ppm. Ascorbic acid @ 100 ppm resulted in the induction of higher number of flowers (36) in sparsely flowering cassava varieties.

Field trial on cassava mosaic disease resistant varieties: Six CMD resistant clones viz., 8W5, 9S-127, 43-11, 8S-501-2, CR-24-4, CR-43-2 were selected and planted along with the newly released varieties viz., Sree Apoorva, Sree Athulya and local control (H-226, *Kumkumarose*) in farmers fields in Salem at Pethanaickenpalayam and Rajapalayam (Fig. 82). Most of the farmers

Fig. 82. Field evaluation of CMD resistant lines in Salem district and farmers selection of preferred varieties

ranked 8S-501-2 as the best variety followed by CR-24-4 and CR-43-11.The farmers preferred 8S-501-2 owing to its high yield, CMD resistance and close similarity to the locally preferred variety, H-226. Farmers also selected CR-24-2 and CR-43-11 for CMD resistance, higher tuber yield and number of tubers per plant. Virus load was quantified in the non transgenic CMD resistant lines and they were completely free from virus (SLCMV & ICMV) infection.

15. CRP on Vaccines and Diagnostics (ICAR, PI: Dr. T. Makeshkumar)

Dasheen mosaic virus

An immunocapture reverse transcription loop-mediated isothermal amplification (IC-RT-LAMP) was developed for the rapid detection of *Dasheen mosaic virus* (DsMV) from elephant foot yam and taro. To optimize the IC-RT-LAMP reaction condition, DsMV genomic RNA could be amplified under isothermal (63°C) conditions within 1 h. The resulting amplicons were detected by the visual observation of the colour change of the reaction mixture without gel electrophoresis (Fig. 83). The ethidium bromide nucleic acid stain could produce long stable colour change and brightness in a close tube-based approach to prevent cross-contamination risk. Time required for some popular diagnostic techniques of RNA plant viruses including reverse transcription PCR (RT-PCR), reverse transcription loop-mediated isothermal amplification (RT-LAMP) and DAS-ELISA was 36-48 hours to complete the protocol. Whereas IC-RT-PCR, could successfully detect the presence of virus within 7 hours with more accuracy and high sensitivity. IC–RT-LAMP assay could successfully detect positive infected plant samples in very short time with high sensitivity, very less cost and simplicity.

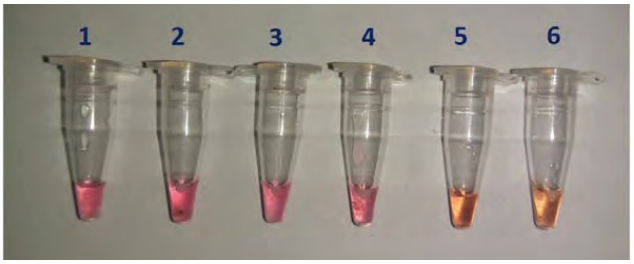


Fig. 83. Visualization of DsMV LAMP product using nucleic acid stain (ethidium bromide). Tube 1-3: DsMV infected elephant foot yam leaf sample, 4: Positive sample, 5 & 6: Healthy elephant foot yam leaf sample

Sri Lankan cassava mosaic virus

A loop-mediated isothermal amplification (LAMP) technique was employed to develop a simple and rapid method for the detection of *Sri Lankan cassava mosaic virus* (SLCMV) in diseased plants of cassava. Six sets of primers were designed for targeting the conserved CP region and SLCMV were successfully detected in the LAMP technique. No reaction was observed in the tissues of healthy plants by either LAMP or PCR. The LAMP products can be visualized by the presence or absence of turbidity. Staining directly in the tube with nucleic acid stain dye allowed easy detection, which was similar to the analysis by gel electrophoresis (Fig. 84). Although both the LAMP and the PCR methods were capable of detecting SLCMV in infected tissues of cassava, the LAMP method would be more useful than the PCR method for the detection of SLCMV infection in cassava plants because it was more rapid, simple and accurate method. Further validation of LAMP assay will be carried out with field samples for detection of SLCMV.

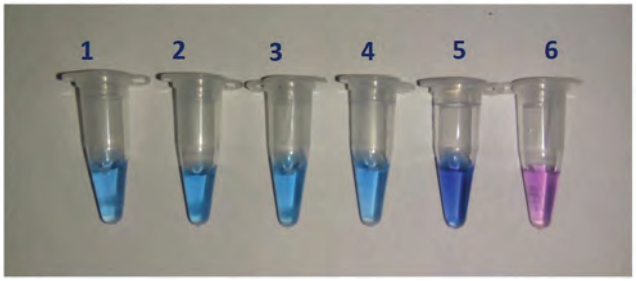


Fig. 84. Visualization of SLCMV LAMP product using nucleic acid stain (hydroxynapthol blue). Tube 1-3: SLCMV infected cassava leaf sample, 4: Positive sample, 5: Healthy cassava leaf and 6: Water

16. 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, New Delhi, PI: Dr. J.T. Sheriff)

Spectral properties of cassava tubers such as absorbance and transmittance were measured over a wave number range from 4000 cm^{-1} to 700 cm^{-1}

using FT-NIR spectrometer for 21 varieties of cassava viz., Sree Swarna, Sree Athulya, 5-12-84, 17-5, 9S-127, 43-7, CR-43-3, W-19, CMR-15, Sree Pavithra, Vellayani Hraswa, CR-24-4, Sree Visakham, Kumkumarose, Sree Rekha, Sree Jaya, H-226, 4-2, 5-3 and CR-59.

A cassava slicer for the preparation of sample was developed. The slicer comprised of two components viz., a fixed platform and a movable plate. By keeping the cassava tuber on the fixed platform and moving the movable plate downwards, the slices of desired thickness can be obtained.

Three sensors were developed and 21 varieties of tubers were measured at proximal, middle and distal portions. Based on evaluation, sensor 2 and sensor 3 were selected and through statistical analysis, the revised sensor 3 was rejected and the sensor 2 was selected and further improved with 3 mm gap between the parallel plates.

The developed cassava starch meter mainly consists of three units viz., sensor unit, microcontroller unit and a display unit (Fig. 85). The sliced sample cassava is placed between the sensor plates. PIC16F877A microcontroller and LM016L LCD are used in the equipment.

The gadget was evaluated at SAGOSERVE, Salem and a high level of correlation was established between the gadget and chemical readings ($P<2.96\times10^{-9}$). During the demonstration, the gadget received good acceptability among the cassava farmers, traders, starch and sago manufacturers. A MoU has been signed with the industrial partner M/s Environmental Measurements and Controls (EMCON), Cochin, for commercializing the gadget.

Fig. 85. Cassava starch meter

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

Process production of high quality cassava flour studies was 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 and flour from crushed and pressed gratings). The size of the polycarbonated roofed yard is 18 m × 12 m. An automatic weather station has been fixed in the solar yard to note the process weather parameters (Fig. 86). The best sample was obtained from crushed and pressed gratings dried in the polycarbonated roofed yard with a loading density of 3 kg m^{-2}.

Fig. 86. Polycarbonated roofed yard for cassava flour production

18. Consultancy project on Integration of sweet potato production and processing in Belgaum (M/s Belgaum Minerals, Belgaum, Karnataka, PI: Dr. J.T.Sheriff)

Five varieties of sweet potato, viz., local, Sree Kanaka, Sree Arun, ST-13 and ST-14 were planted (in 15 acres in the first season and 25 acres in the second season) in the mining areas of Belgaum in RBD. Among the five varieties, ST-14 was grown

in 10 and 12 acres respectively. With the help of a ridger, ridges of 45 cm height were made for sweet potato planting with row to row spacing of 100 cm. The average tuber yield per plant was more in Sree Arun (250 g plant^{-1}) followed by ST-14 (150-200 g plant^{-1}), local check (*Kanhangad*) (150 g plant^{-1}) and Sree Kanaka (100-150 g plant^{-1}). The lowest tuber yield was in ST-13 (75-100 g plant^{-1}). In the next season, two acres of sweet potato nursery of Sree Arun, Sree Kanaka, ST-14 and ST-13 were maintained. No pests and disease incidence was noticed and the nursery crop was very healthy. The incidence of sweet potato weevil was found in certain plots, where soil was dry due to moisture stress. Advice was given for irrigation immediately and also to spray Imidacloprid (3 ml per 10 litres of water) in infected fields. Belgaum Minerals has established a sweet potato processing unit, comprising sweet potato peeler cum slicer, electrical tray driers, pulveriser and sieving machine. Sweet potato flour prepared from the Kharif harvest of sweet potato tubers was stored in the godown. The flour retained orange colour in ST-14 variety and purple colour in ST-13 variety.

The biochemical and micronutrient properties of five varieties of sweet potato were analysed. The moisture, protein, fat, carbohydrate, ash and total sugars were estimated as 71.1, 1.3, 0.3, 26.4, 0.9 and <0.5% in sweet potato fresh tubers, whereas in the sweet potato flour the corresponding values were 6.4, 4.6, 0.9, 86.5, 1.6 and 13.4%. The Ca, Mg, Na, K, Fe and Zn contents of sweet potato tubers were 0.08%, 9.21ppm, 0.20%, 0.07%, 9.20 ppm and 2.60% respectively, whereas in the sweet potato flour, the corresponding values were 0.10%, 23.37 ppm, 0.10%, 0.40%, 25.87 ppm and 2.21% respectively. The vitamin A, C and B12 of sweet potato tubers were estimated as 197.08, 49.20 and 49.20 ppm and in sweet potato flour the values were 227.96, 14.83 and 14.83 ppm respectively. The saturated fatty acid, mono unsaturated fatty acid and poly unsaturated fatty acid in sweet potato tubers were estimated as 35.98, 5.86 and 64.00 ppm respectively, whereas in the sweet potato flour, the corresponding values were 27.26, 2.69 and 70.06 ppm. The cholesterol and gluten content in both sweet potato tubers and flour was less than 0.1ppm and 0.1% respectively. The fibre content in both sweet potato tubers and flour was less than 0.1%.

The formulation for the development of sweet potato based weaning food mix powder was standardized (Fig. 87). The level of sweet potato flour used was 40-70%, along with cowpea flour (5-10%), soybean flour (5-15%), peanut flour and milk powder. It provides starch 29.79-37.41%, sugar 26.07-32.01%, fat 10.72-15.41%, protein 8.63-18.46% and fiber 1.66-1.78%.

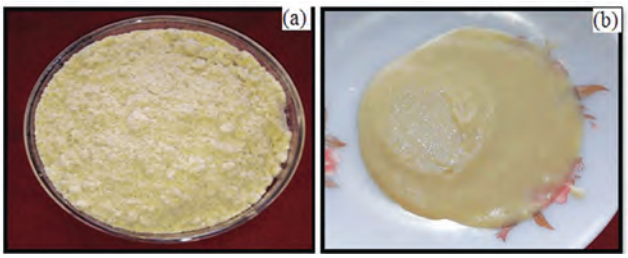


Fig. 87. Sweet potato based weaning food mix powder (a) and paste (b)

19. ICAR-EMR project on establishment of mechanized cassava and sweet potato model farms (ICAR, PI: Dr. J. T. Sheriff)

A factorial experiment in RBD was laid with three replications and six treatments to decide the method of planting suitable for mechanisation. Two cassava varieties, H-165 and M*ulluvadi* were selected as Factor I and three methods of planting viz., manual mound method, manual ridge method and tractor drawn ridge method were adopted as Factor II. The planting was done in October 2016. A high power tractor (75 hp) was purchased under the project.

20. High value compounds/phytochemicals

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

Structural studies of anthocyanins in sweet potato and greater yam

Structure of anthocyanins present in purple-fleshed tubers of the variety, ST-13 and leaves of accession S-1467 of sweet potato and the purple tubers of greater yam (Acc. Da-340) were determined by HPLC, High Resolution Mass Spectrometry and NMR analysis. Same number and kind of anthocyanins were present in tubers of ST-13 as well as in the leaves of S-1467, and only difference

was in their quantities. A total of nine anthocyanins were identified- five peonidin derivatives and four cyanidin derivatives, all were acylated and six were in diacylated form. The major anthocyanin was Peo-3-O-(6"-caffeoyl-6"'-p-hydroxybenzoyl soph)-5-O-glc.

Four new anthocyanins along with the other two earlier reported anthocyanins (total of six anthocyanins) were identified in the tubers of purple-fleshed greater yam (Acc. Da-340). All anthocyanins were cyanidin derivatives. The major anthocyanin was in diacylated form and it contributed up to 70.50% of the total anthocyanins.

The morphological changes induced by the anthocyanins (100, 200 and 400 µg ml^{-1}) in human mammarian epithelial cell line (MCF 10A) were studied using Hoechst staining to assess the extent of cytotoxicity to normal cells. At all the doses studied, the samples did not cause any substantial morphological changes to the cells as evidenced by reduced fluorescence. The anthocyanins were non-toxic to normal cells even at concentration as high as 400 µg ml^{-1}. Anticancer property of anthocyanins isolated from the purple-fleshed tubers of sweet potato (ST-13) and greater yam (Acc.Da-340) was evaluated by studying apoptosis using FRET-based caspase sensor probe and cell cycle analysis with propidium iodide staining followed by fluorescence-activated cell sorting. These anthocyanins inhibited cell cycle and induced apoptosis in human cervical cancer, breast cancer and colon cancer cell lines at a dose of 200 µg ml^{-1} or below, proving their potential anticancer properties (Fig. 88). The percentage of cells in G_1, S, G_2 and sub G_0 phases of the cell cycle was calculated and treatment with anthocyanins caused a mild arrest in cell cycle and induced apoptosis. In all studies, anthocyanins from Da-340 tubers exhibited significantly higher activity than that from the sweet potato, highlighting the comparatively higher potential of purple-fleshed greater yam as an antioxidant and chemo-preventive agent.

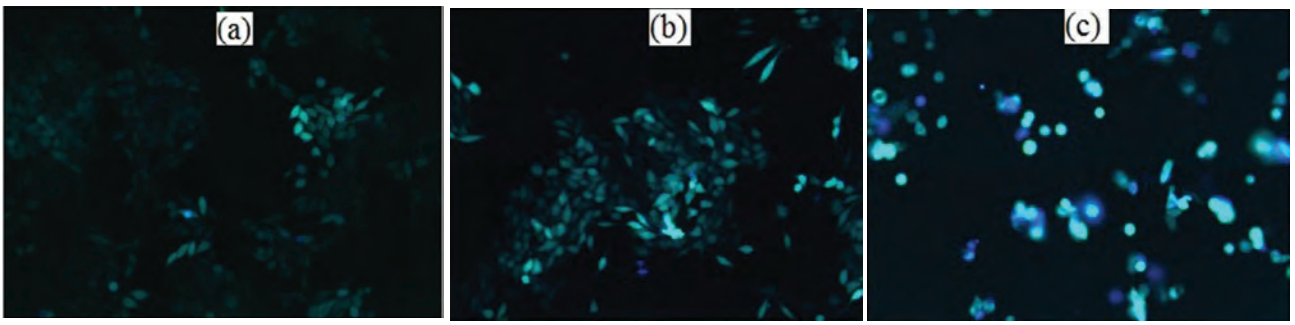


Fig. 88. Caspase activation of human colon cancer cells. Control (a), Cells treated with sweet potato (var. ST-13) tuber anthocyanins (b) and Cells treated with greater yam (Acc. Da-340) tuber anthocyanins (c) (Nuclear chromatin condensation is visible in the cells treated with 200 µg ml^{-1} of anthocyanins)

Anthocyanins from sweet potato and greater yam tubers were encapsulated with maltodextrin and the encapsulated anthocyanins showed a significant reduction in pigment degradation compared to pure anthocyanins. The percentage retention of anthocyanins in encapsulated pigments of greater yam tubers (74.70% and 40.60% after 15 days and 30 days of storage, respectively) was greater on storage in comparison to the encapsulated sweet potato tuber (71.20 and 37.60% after 15 days and 30 days of storage, respectively) and leaf (63.70 and 36.70% after 15 days and 30 days of storage, respectively) anthocyanins. Storage stability was also evaluated in a model sugar-citrate solution having a brix of 13° at three different storage conditions, viz., T_1 (8°C in refrigerator), T_2 (30°C in dark) and T_3 (30°C in light). After 30 days of storage, anthocyanin stability decreased in the order $T_1 > T_2 > T_3$.

The solvent system was optimized for the extraction of phytochemicals from Chinese potato tubers. Primary phytochemical analysis revealed that these tubers are rich sources of flavonoids, phenols, terpenes, tannins, glycosides, alkaloids, saponins, steroids and carbohydrates. The phenolic

content was about 4.42 mg g^{-1}, flavonoids, 1.06 mg g^{-1} and terpenoids, 12.32 mg g^{-1}.

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

The N release behaviour of coated urea in soil and the effect of soil type

The N release behaviour of urea coated with grafted cassava starch was studied. Neem coated urea and uncoated urea were used as controls. The N release from the coated urea samples were more sustained. After 108 days of incubation, about 70-78% N release was observed from different samples. The coated urea samples showed significant water retention capacities in the range of 74.20 to 405.60%. In all cases, the available N content was lower in the soils treated with neem-coated urea. Soil type affected the release pattern of urea. The release of N was slowest in red soil, but fastest in laterite soil from all fertilizer samples. In laterite soil and black soil, the release of N from the grafted starch coated urea was more sustained than that from uncoated urea. However, in red soil and Kari soil, the available N content was slightly higher during the initial 15-30 days, in coated urea treated soils than that in uncoated urea treated soils.

Urea has been incorporated in cassava starch-montmorillonite (MMT), a layered silicate (native as well as citric acid modified forms) composites. The urea incorporated samples were tested for N-release in four different types of soils for different incubation periods. The release of N was slowest in red soil, but fastest in laterite soil for all the samples. The citric acid modified MMT composite showed higher release of N from incorporated urea than native MMT composite. It was especially higher in black soil. In laterite soil, the release of N from MMT-starch incorporated urea was lower than that of normal urea but higher than that of neem-coated urea. The sustained release property of N from composite incorporated urea was better than that of neem-coated urea in Kari soil and back soil.

Incorporation of urea in starch based superabsorbent hydrogel

Starch based superabsorbent polymer (SAP) has been synthesized by graft-copolymerization and subsequent alkali saponification of the grafted starch. The SAP swollen in urea solution was applied to the soil and the release of water as well as urea from the hydrogel was determined at regular intervals. The hydrogel could absorb, retain and slowly release the N along with water to its surroundings and thus served the dual function of water retention as well as slow release of fertilizer nutrient.

22. **Techno-Incubation Centre** (Kerala State Council for Science, Technology and Environment, Govt. of Kerala; PI: Dr. M.S. Sajeev)

Techno-Incubation Centre under the Division of Crop Utilization organized 21 training programmes on value addition and entrepreneurship development in tuber crops. It was attended by 358 people (182 male and 176 female) including farmers and young entrepreneurs from different districts of the state. An amount of Rs.63,600 was collected as training fees. The incubation centre was used by 30 entrepreneurs for the production of snack foods like pakkavada, crisps, nutrichips, murukku, sweet fry and pasta amounting to 1560 kg and Rs.11,273 was collected as user fee. Apart from training and providing incubator facility, different products were manufactured and sold in various exhibitions and to people visiting the centre, by which Rs. 46,110 could be collected. The total revenue generated from the Incubation Centre was Rs.1,20,980. Shri. Sudarshan Bagath, Hon'ble Minister of State for Agriculture and Farmer's Welfare launched the products of the incubatees (Fig. 89).

Fig. 89. Launching of products of the incubatees by Shri. Sudarshan Bagath, Hon'ble Minister of State for Agriculture and Farmer's Welfare on 28th January 2017

23. Developing models for predicting commercialisation potential of functional foods from starchy staples
(ICAR Extramural Extension; PI: Dr. P. Sethuraman Sivakumar)

During 2016-2017, six agricultural start-ups were surveyed to document the product pricing strategies followed. Majority of the start-ups (57%) are using competitive pricing strategies based on the competitor price. No pricing algorithm or software was used. The pricing algorithms were developed based on cost incurred in developing technologies, revenue based pricing and market demand based pricing.

24. Livelihood improvement of tribal farmers through tuber crops technologies (ICAR -CTCRI-Tribal Sub Plan; PI: Dr. M. Nedunchezhiyan)

During the reporting period, Nuaguda village (39 household), Potangi block, Koraput district; Kenjaguda village (49 household), Chakapada block, Kandhamal district; Burahkocha village (57 household), Angara block, Ranchi district were adopted for demonstration of farming systems involving tuber crops (Figs. 90 to 97) . Planting material of tuber crops was provided to the farmers along with the improved varieties of the major crops grown by them. Two trainings were organized to up-grade the skill of tribal farmers before and after the interventions in these villages. The data on cropping pattern and socio-economic conditions of the farmers before and after the interventions were collected and are presented here.

In Nuaguda village, Koraput district, the farmers belonged to Khanda tribes. Rice, ragi, maize and vegetables (brinjal and potato) were cultivated. Farmers practiced traditional method of cultivation, especially traditional variety of sweet potato. In each farmer's field, 0.4 ha model farming system involving tuber crops was demonstrated (Fig. 90). The crop and other components were as follows: rice (0.2 ha), maize (0.03 ha), ragi (0.02 ha), red gram (0.02 ha), sweet potato (0.04 ha), yam bean (0.02 ha), greater yam (0.02 ha), taro (0.02 ha), elephant foot yam (0.008 ha), cassava (0.002 ha) and vegetables (brinjal, tomato, ridge gourd and potato) (0.01 ha). Prior to the interventions, the gross income of the farmer was Rs 92,850 ha^{-1} with B:C ratio of 1.91. The employment generation was 232 man days ha^{-1}. After the intervention of 0.4 ha farming system involving tuber crops model, gross

Fig. 90. Greater yam + maize intercropping in Nuaguda village

Fig.91.Tuber crops cultivation at Kenjaguda village

Fig.92. Paddy line transplanting at Kenjaguda village

Fig.93. Raikya bean cultivation at Kenjaguda village

income of the farmer was raised to Rs 1, 88,680 ha^{-1} with B:C ratio of 2.73. The employment generation was 344 man days ha^{-1}. Farming system involving tuber crops (0.4 ha model) generated additional 112 man days ha^{-1} over the existing system.

In Kenjaguda village, Kandhamal district, rice, ragi, maize and vegetables (brinjal, tomato and beans) were cultivated. In each farmer's field, 0.4 ha model farming system involving tuber crops was demonstrated (Figs. 91, 92, 93). Each farmer was provided 50 kg of aluminum fencing materials to protect the crops from wild animals. All the farmers were also given small tools (one each of hand-hoe (khurpa), sickle (datri), crow bar, pick axe, spade, garden weeder, hand trowel and hand cultivator to reduce drudgery of planting, weeding and harvesting. Three knapsack sprayers were given to the three SHG groups to spray organic Handikatha (a local preparation using cow urine and dung) against pests and diseases. Prior to the interventions, the gross income of the farmer was Rs 93,470 ha^{-1} with B: C ratio of 1.90. The employment generation was 242 man days ha^{-1}. After the intervention of 0.4 ha farming system involving tuber crops model, gross income of the farmer was Rs 1, 87,910 ha^{-1} with B:C ratio of 2.73. The employment generation was 331 man days ha^{-1}. Thus farming system involving tuber crops (0.4 ha model) generated additional man days of 89 after the intervention.

In Burahkocha village, Ranchi district, rice and vegetables (brinjal and tomato) were cultivated (Figs. 94 & 95). To improve the goat breeds, 10 Black Bengal Bucks were given to the tribal farmers of the village. Further to prevent diseases to goats, cemented raised floor was constructed in all the farm households (Fig. 96). A solar pumpset was installed to irrigate the crops during dry spells and rabi season (Fig. 97). Prior to the interventions, the gross income of the rice farmer was Rs 66,000 ha^{-1} with B: C ratio of 1.50. Whereas, the gross income of vegetable farmer was Rs 2, 58,000 ha^{-1} with B:C ratio of 2.04. The employment generation was 228 man days ha^{-1}. After intervention of 0.4 ha farming system involving tuber crops model, gross income of the farmer was Rs 1, 87, 860 ha^{-1} with B:C ratio of 2.75. The employment generation was 325 man days ha^{-1}. Farming system involving tuber crops (0.4 ha model) generated additional 97 man days ha^{-1}.

Fig.94. Tuber crops cultivation at Burahkocha village

Fig.95. Tomato cultivation in Burahkocha village

Fig. 96. Cemented raised floor for goat keeping at Burahkocha village

Fig. 97. Solar pump-set at Burahkocha village

Technologies Assessed, Transferred, Consultancy and Patent Services

The Institute Technology Management Unit (ITMU) of the Institute has been active in carrying out the following IP activities during the period 2016-2017. The unit had engaged with public/ private parties for the commercialization of the following technologies:

Technologies commercialized

Name of the technology/innovation/ material	Contracting party	Mode of technology transfer	Year	Revenue earned (₹)
Technology for fried snack foods and fried chips from cassava	Shri. N. P. Suneer, M/s KV Food Products Ltd., Kannur 670 613	Consultancy	September 2016	25,000
Technology for value addition of cassava products	Kudumbashree-State Eradication Mission under the Department of Local Self Government, Govt. of Kerala, Thiruvananthapuram	Consultancy	November 2016	As per the prevailing rate of Techno-Incubation Centre
Electronic gadget for measuring starch content of cassava tubers	Shri. Sreejith M/s Environmental Measurements & Control, Kochi	Licensing	January 2017	10,000
Technology for fried snack foods and fried chips from cassava	Shri. C. Manoj, Thottumkal House, Thengali, Thiruvalla	Consultancy	January 2017	25,000
Production of high quality cassava flour from cassava	M/s VERDS FAB PRODUCTS, No. 535 Ponnamallee High Road, Arumbakkam, Chennai 600 106	Contract research	March 2017	3,00,000
Developing jackfruit – cassava gluten free pasta	M/s Artocarpus Foods Pvt. Ltd, Plot No. F, Kinfra Park, Nadukani, Kannur	Contract research	March 2017	48,000
Technology for fried snack foods and fried chips from cassava	Shri. Santosh Kumar, Kerala	Consultancy	March 2017	25,000

Consultancy and patents

- Saravanan, R., Gajbhiye, N. A. and Maiti, S. 2016. Method of Preparing Aloin. Indian Patent. No. 277501. Application Number 1261/ MUM/2008, Publication Number 52/2009.

Technologies transferred

The following technologies were included in Package of Practices Recommendations, Crops (2016), Kerala Agricultural University

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

Technologies developed/pipeline

Potential tuber crop genotypes

- Two CMD resistant high yielding cassava varieties, CR24-4, CR43-7 identified for release.
- Developed two CMD resistant hybrids with short-duration (6 months) 16S-203 (7.81 kg plant^{-1}) and 16S-330 (7.21 kg plant^{-1}).
- Identified triploid cassava TR 44-7 with very high yield of 64.20 t ha$^{-1.}$
- PPD tolerant cassava varieties/accessions, Sree Sahya, Kalpaka, CO-1, CR-43-2, CR-20A (2), CR-24-4, free of PPD symptoms even after 20 days of harvest, identified.
- Sweet potato accessions, S 30/16, Baster-45 and acc. No. 527 with 75 days maturity and 526/7 with high yield (0.7 to 1.07 kg plant^{-1}) identified.
- High yielding white yam hybrid, Drh-1150 (46.90 t ha^{-1}) developed.
- A wild yam accession, CTDf-1 (*Dioscorea floribunda*) with high protein content of 14% (on dry weight basis) identified.

Preservation of crop genotypes

- Protocol for cassava pollen cryo-preservation.
- Protocol for synthetic seed production in cassava.

Production technologies

- Three grades of custom made fertilizer mixtures comprising of secondary and micronutrients for elephant foot yam intercropped in coconut gardens.
- Nutrient requirement of cassava for fertigation, N @ 75 kg nitrogen and K_2O @ 100 kg ha^{-1}.
- Nutrient requirement of sweet potato under Island ecosystem of Andaman, N, P_2O_5 and K_2O@ 50:40:50 kg ha^{-1}.
- Drip irrigation for greater yam + maize intercropping system: Drip irrigation at 100% CPE 1-90 DAP (days after planting) + 80% CPE 91-270 DAP along with fertigation of N:$P_2O_{5:}K_2O$ @ 140:90:140 kg ha^{-1}.
- Cassava as a benign crop for continuous cultivation in the same field.
- Organic production technology for arrowroot ready for on-farm testing: FYM @ 10 t ha^{-1}, green manure @ 10-15 t ha^{-1} and biofertilizers (*Azospirillum*, P solubilizer and K solubilizer @ 3 kg ha^{-1} each).
- Methodology for climate suitability studies of cassava using AR5 data and geoinformatics tools.

Collaborative (contractual)/license agreement

- Production and dissemination of quality and disease free planting material of elephant foot yam (230 tonnes) and greater yam (30 tonnes) to farmer under license agreement.

Protection technologies

- A biopesticide formulation for management of thrips in vegetable crops.
- Ten *Bemisia tabaci* specific ISSR primers for studying genetic variations among whitefly populations.
- Application of mefenoxam for the management of taro leaf blight incidence.
- Application of 0.2% sprint (combination of carbendazim and mancozeb) or *Trichoderma* + vermicompost for the management of collar rot incidence in elephant foot yam.
- Soil application and tuber treatment with *Trichoderma* along with seven sprays of carbendazim (0.05%), first three at fortnight interval and further monthly for efficient management of greater yam anthracnose.
- LAMP based diagnosis of Sri Lankan Cassava mosaic virus (SLCMV) and Dasheen mosaic virus (DsMV).
- Protocol to diagnose *Yam mild mosaic virus* from lesser yam tubers through DAS- ELISA.
- Protocol to diagnose *Dasheen mosaic virus* from elephant foot yam yam tubers through DAS- ELISA.
- Identified six CMD resistant clones on the basis of performance in AYT.

Technologies for value added food products

- Sweet potato based gluten free cookies.
- Sweet potato flour fortified RTE nutri bar.
- Vacuum frying technology for orange-fleshed and purple-fleshed sweet potato chips.
- Sweet potato based functional bars enriched with resistant starch.
- *Jimikand* papad.
- RTE *jimikand* shorts.
- Taro flour based gluten free cookies.
- Encapsulated anthocyanin pigments from sweet potato leaves, tubers and greater yam tubers.
- Protein rich, calcium rich and fibre rich functional cookies containing *Curcuma angustifolia* starch.
- Lacto-pickling of greater yam.

Technologies for industrial products

- Particle board using dried cassava stem. "Green" particle boards from cassava stems using cassava starch as bio-adhesives.
- Thermoplastic cassava starch sheet (TPS) using cassava starch-glycerol based composites.
- Resistant starches with medium to low glyceamic index.
- Refined process for the production of high quality cassava flour.
- Hydrogels suitable for incorporation of therapeutic drugs.
- FT-IR spectroscopy for prediction of carotene content in sweet potato germplasm.
- Electronic gadget for measuring starch content in cassava tubers.
- Wax coating of cassava tubers for extended shelf-life.
- Laboratory scale process for a single phase corrugating adhesive with acid thinned cassava starch.

Post-harvest machineries

- Sold eight hand operated cassava chipping machines and 14 harvesting tools.

Decision Support Systems/Bioinformatics Tools

- CASSNUM version 1.1: Cassava Site Specific Nutrient Management (in CD). Released by ICAR-CTCRI on 23 May 2016 at BCKV, Kalyani.
- NRRPUP: Nutrient Recommendation for Raising Potato in Uttar Pradesh (V.K. Dua, Prince Kumar, Shashi Rawat, Shefali Sood, G. Byju, Jagdev Sharma and S.K. Chakrabarti. Developed by ICAR-CPRI, Shimla).
- A Database of predicted SNPs and SSRs of cassava in cassava and elephant foot yam.
- A database of predicted miRNA of cassava and elephant foot yam.
- Model for QSAR prediction of anthocyanins.

Education and Training

Education

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

Particulars of the programme	Number of students
B.Sc. project work of students	67
M.Sc. project work of students	4
M.Sc. course on Integrated Biotechnology	10
Ph.D. Programmes	33
PDF Programme	1

- Post Doctoral Fellow (2016-2018): Dr. G.L. Sreelatha, has registered as post-doctoral fellow to work on the topic "Management of taro leaf blight through integrated approach using ZnO nanoparticles and antagonistic microbes" (Under Kerala Biotechnology Mission, KSCSTE (January to March 2017) and SERB, DST (From April 2017) under the guide ship of Dr. M. L. Jeeva.
- Dr. T. Makeshkumar handled one course for B.Sc.-M.Sc. Integrated Biotechnology-Biot.3116, Basics of Virology and Oncology (2+1) at KAU, College of Agriculture, Vellayani.
- Dr. Vivek Hegde and Dr. C. Visalakshi Chandra successfully completed the distance learning course on Intellectual Property, conducted by World Intellectual Property Organization (WIPO) academy.

Trainings organized by ICAR-CTCRI

- During this period, 282 farmers, 1446 students and 161 department officials from different parts of the country visited the institute. They were made aware about the institute activities and also on the various research achievements of the institute.
- National Technology Day 2016 - KSCSTE sponsored Workshop on "Creative Strategies for Generating Innovative Agricultural Technologies" at ICAR-CTCRI, Thiruvananthapuram on 11 May 2016.
- Workshop on "Tuber Crops Technology Transfer and Commercialisation" held at ICAR-CTCRI, Thiruvananthapuram on 25 June 2016.
- One day National Workshop on "Horticulture for East Coast" was organized at the Regional Centre, ICAR-CTCRI, Bhubaneswar on 1 July 2016. Fifty delegates from different institutes participated in this workshop.

Horticulture for East Coast

Valedictory function of the Training Program on Soil Analysis

- Seventy five trainees belonging to officers and technical staff category from Department of Agriculture, Govt. of Kerala, representing nine districts were trained in five batches of "Orientation Training Program on Soil Analysis" during July-November 2016. The training program was co-ordinated by Dr. V. Ramesh, Principal Scientist, Division of Crop

Production. The program was funded by Dept. of Agriculture, Govt. of Kerala under National Mission for Sustainable Agriculture scheme of Govt. of India.

- Training on "Production and Processing of Tuber Crops" was imparted to 10 farmers and two officials from Salem at ICAR-CTCRI, Thiruvananthapuram on 11 August 2016.
- Training on "Production and Value Addition in Tuber Crops" was organized for 20 farmers from Ariyalur at ICAR-CTCRI, Thiruvananthapuram during 29-31 August 2016.
- ICAR sponsored Short Course on "Processing Machineries, Value addition and Entrepreneurship Development in Tuber Crops" was organized during 31 August-9 September 2016 at ICAR-CTCRI, Thiruvananthapuram and 18 participants attended the same.
- A Model Training Course entitled "Root and Tuber Crops based Integrated Farming System: A Way Forward to Address Climate Change and Livelihood Improvement" was organized at ICAR-CTCRI, Regional Centre, Bhubaneswar during 19-26 September 2016. The training programme was conducted with the objectives to provide advance training to the state agricultural officers and scientists of ICAR/ SAUs/KVKs and improve their skills in the area of Root and Tuber Crops Based Integrated Farming System (IFS), to show the trainees live demonstrations/experiments on IFS to improve resource-use efficiency and to provide an opportunity to discuss and exchange ideas/ knowledge sharing between the academics and with the experts/resource persons. Nineteen officials from State Departments and Scientists from KVKs/ICAR Institutes in the areas of Agricultural Sciences from six states viz., Andhra Pradesh, Himachal Pradesh, Karnataka, Kerala, New Delhi and Odisha participated in the programme. The course was organized by Dr. M. Nedunchezhiyan, Principal Scientist & Course Director and Mr. V.V. Bansode and Dr. V.B.S. Chauhan, Scientists & Course Coordinators. Certificate of Participation was distributed to the participants by Dr. Archana Mukherjee, Head, ICAR-CTCRI, Regional Centre, Bhubaneswar.




Participants of the Short Course on Root and Tuber Crops based Integrated Farming System: A Way Forward to Address Climate Change and Livelihood Improvement at ICAR-CTCRI, Regional Centre, Bhubaneswar

- CTCRI-SAMETI capacity building programme on "Preparation of Bankable Project Profiles for Agri-business" at SAMETI, Thiruvananthapuram during 3-5 November 2016.

CTCRI-SAMETI collaborative training on bankable agribusiness projects

- Training was conducted on "Production and Processing of Tuber Crops Technology" for 20 farmers and three officials from Namakkal under ATMA at ICAR-CTCRI, Thiruvananthapuram on 11 November 2016.
- NAARM-MANAGE-CTCRI-CRISP collaborative workshop on "Good Practices in Extension Research and Evaluation" at ICAR-NAARM, Hyderabad during 29 November 2016 to 2 December 2016.

NAARM-MANAGE-CTCRI-CRISP workshop

- Training was conducted on "Tuber Crops Production and Processing" to 60 farmers under the PMKY scheme of ATMA at ICAR-CTCRI, Thiruvananthapuram on 20 January 2017.
- One day brainstorming session on "Management of Sweet potato Weevil: Present Status and Future Directions" was held at the Regional Centre, ICAR-CTCRI, Bhubaneswar on 4 February 2017. About 25 delegates from OUAT, AICRP centers and ICAR sister institutes participated in this.
- Training programme on "Entrepreneurship Development Programme for Agriculture Students" was jointly organized by ICAR-CTCRI and KAU at Vellayani, Thiruvananthapuram during16-18 February 2017.
- Training on "Preparation of Bankable Projects (AC & ABC scheme)" was jointly organized by ICAR-CTCRI and KAU at ICAR-CTCRI Thiruvanathapuram during 15-17 March 2017.

Participants of the Training Programme on Bankable projects

- **Trainings organized by Techno-Incubation Centre, ICAR-CTCRI**

Incampus: Training on practical demonstration, value addition and entrepreneurship development in tuber crops at Techno Incubation Centre, ICAR-CTCRI: 1 March 2016, 5 March 2016, 14 March 2016, 6 April 2016, 8 April 2016, 3 May 2016, 3 June 2016, 24 June 2016, 23 July 2016, 3 August 2016, 9 August 2016, 12 August 2016, 30 August 2016, 8 November 2016, 10 November 2016, 8 December 2016, 27 December 2016, 4 January 2017, 31 January 2017, 10 February 2017, 14 February 2017 and 3 March 2017.

- **Off campus:** Value addition in tuber crops, Krishibhavan, Muthukulam, Allappuzha, 10 May 2016; Novel food products from tuber crops for small scale industries, Green Agri Club, Kuruvikadu, Marthandam, Tamil Nadu, 4 October 2016; Value addition technologies in tuber crops. VAIGA 2016, International Conference on Value Addition for Income Generation in Agriculture. Department of Agriculture, Kerala, 5 December 2016; Processing and product diversification in tuber crops, Agmark, Department of Agriculture, Panthalam, Pathanamthita, 7 December 2016;Value added products and facilities of CTCRI for entrepreneurship developments, Technology Clinic, District Industries Centre, Kollam, 16 December 2016; Value added products and facilities of CTCRI for entrepreneurship development, District Industries Centre, Thiruvananthapuram, 25 January 2017; Small scale processing of tuber crops for micro level entrepreneurship developments, Kerala Agricultural University, Vellayani, 4 February 2017; Processing machineries and value addition in tuber crops, Agricultural Engineers Day, Wadakanchery, 10 February 2017; Value addition and entrepreneurship development in tuber crops, VFPCK, Thiruvananthapuram, 13 February 2017; Small scale processing of tuber crops for micro level entrepreneurship development, Kerala Agricultural University, Vellayani, 15 February 2017; Value addition and entrepreneurship development in tuber crops. Department of Agriculture, Vytilla, Ernakulam, 16 February 2017.
- **Orientation Training for Probationers:** Seven scientists (On Probation) who had joined ICAR-CTCRI were given one month orientation training (10 April-10 May 2016) in the institute. The training included interaction with the scientists of the various divisions of the institute. They were also given a wider exposure on the research activities done in the institute. The Scientists were taken to fields and they interacted with the farmers. Visits were also arranged to KVK, Farmers Cooperative Society and other institutions. Dr. Sheela Immanuel, Principal Scientist & Head, Section of Social Sciences coordinated the training.
- **In-house Training for Skilled Support Staff:** A two days training for knowledge and skill enhancement was conducted for 22 Skilled Support Staff (SSS) at ICAR-CTCRI from 28 February 2017 to 01 March 2017. The classes were handled by the scientists and other staff of the institute. Exposure was given to them in all the activities undertaken by the Institute.
- More than 142 classes on production, protection, processing and value addition aspects were handled by scientists of various divisions under different programmes within and outside the institute beneficial to department officials, subject matter specialists, students and farmers all over the country. The specific topics covered were improved varieties, tissue culture, agro-techniques with special focus on organic management, INM, IPM, vermi-composting, bio-pesticides and bio-control strategies, post-harvest management and value addition.

Training Programmes organized under Tribal Sub Plan Scheme at Regional Centre, ICAR-CTCRI

- Training on micro propagation of elephant foot yam was conducted at VIBSRAN, Nimpith, Kolkata during 15-16 April 2016. Thirty progressive farmers and technical persons attended the training.
- Training on production techniques of sweet potato was conducted at MSSRF, Jaypore, Odisha during 20-22 July 2016. Thirty farmers attended the training programme.
- Six training programmes were organized on farming systems involving tuber crops at Hatibadi (village), Kandhamal (dist.), Odisha, Burhakocha (village), Ranchi (dist.), Jharkhand, Kenjaguda (village), Kandhamal (dist.), Odisha, Nuaguda (village), Koraput (dist), Odisha, on 26 July, 10 August, 18 August, 29 December 2016, 4 January, 2 February 2017 under AICRPTC-TSP. About 289 farmers attended the training programme.

Trainings attended by ICAR-CTCRI staff

a. Scientists

Sl. No.	Name	Particulars of the training	Period
1.	Dr. A.V.V. Koundinya	Professional Attachment Training on PCR based DNA Fingerprinting Techniques at ICAR-NBPGR, New Delhi	12 May to 11 August 2016
2.	Mr. J. Suresh Kumar Dr. P. Arun Kumar	Professional Attachment Training on Conservation Studies on Early Growth of Brinjal (under the guidance of Dr. A. Gopalkrishna Reddy) and Abiotic Stress Tolerance Studies in Tomato, respectively, at ICAR–CRIDA, Hyderabad	13 May to 12 August 2016
3.	Mr. P. Prakash	Attachment Training under the guidance of Dr. Avinash Kishore and Dr. Devesh Roy, Senior Research Fellow at IFPRI, South Asia Office, New Delhi	13 May to 12 August 2016
4.	Mr. R. Arutselvan	Professional Attachment Training at ICAR-IIHR, Bengaluru, under the mentorship of Dr. M. Krishna Reddy	13 May to 12 August 2016
5.	Dr. Sanket J. More	Professional Attachment Training on Characterization of Water Stress and Identification of Crops in Orchards through Hyper Spectral Remote Sensing under the guidance of Dr. S.K. Bal at ICAR – NIASM, Baramati, Maharashtra	13 May to 18 August 2016
6.	Dr. K. Susan John	Management Development Training Programme on Leadership Development at ICAR-NAARM, Hyderabad	7 - 18 June 2016
7.	Dr. Vivek Hegde	Summer School Training Programme (21 days) on Contemporary Methods of Conservation and Management of Horticultural Genetic Resources at ICAR-IIHR, Bengaluru	7 - 27 June 2016
8.	Ms. Namrata Ankush Giri	ICAR sponsored Summer School Training Programme (21 days) on Engineering and Technology Innovation in Developing Health Foods at ICAR-CIPHET, Ludhiana, Punjab	8 - 28 June 2016
9.	Mr. V. Bansode	Summer School Training Programme (21 days) on Approaches to Identification, Quantification and Reduction of Post-harvest Losses in India at ICAR-CIPHET, Ludhiana, Punjab	17 August to 6 September 2016
10.	Dr. P.S. Sivakumar	Scale Development Workshop at IIT Madras, Chennai	7 - 12 September 2016
11.	Dr. Sanket J. More Mr. J. Suresh Kumar	Model Training Course on Root and Tuber Crops based Integrated Farming System: A Way Forward to Address Climate Change and Livelihood Improvement at ICAR-CTCRI Regional Centre, Bhubaneswar	19 - 26 September 2016
12.	Mr. J. Suresh Kumar	Geospatial Analysis for Natural Resource Management, ICAR-NAARM, Hyderabad	18 - 27 October 2016
13.	Dr. V.B.S. Chauhan	ICAR Short Course on Integrated Farming System: An Approach Towards Livelihood Improvement of Farm Women and Natural Resource Conservation at ICAR-CIWA, Bhubaneswar	14 - 23 December 2016
14.	Mr. P. Prakash	Winter School Training Programme (21 days) on Impact Assessment of Agricultural Technology at ICAR-IARI, New Delhi	14 December 2016 to 3 January 2017
15.	Dr. Saravanan Raju	Training on Introduction to Climate Change for climate change focal team members at Apollo Dimora, Thiruvananthapuram, organised by Directorate of Environment & Climate Change (DoECC)	19 - 20 January 2017
16.	Dr. Kalidas Pati Mr. R. Arutselvan	CAFT Training Programme (21 days) on Computational Approaches for Next Generation Sequencing (NGS) Data Analysis in Agriculture at ICAR-IASRI, New Delhi	8 - 28 February 2017
17.	Dr. Vivek Hegde	Training Programme on Competency Enhancement Programme for Effective Implementation of Training Functions by HRD Nodal Officers of ICAR at ICAR-NAARM, Hyderabad	13 - 15 February 2017
18.	Dr. Sanket J. More	Training Programme on Physiological and Molecular Aspects of Improving Crop Adaptation to Drought at UAS, Bengaluru	27 February to 11 March 2017

b. Technical Staff

Sl. No.	Name	Particulars of the training	Period
1.	Shri. V.R. Sasankan, Senior Technical Officer & Farm Superintendent Shri. B. Renjith Kishor T-6, Senior Technical Officer	Competence Enhancement Programme on Soft Skills and Personality Development for Technical Officers of ICAR at ICAR-NAARM, Hyderabad	1-10 June 2016
2.	Dr. S. Karthikeyan, Technical Assistant	Training Programme on Microbial Culture Handling and Maintenance at ICAR-NBAIM, Bhanjan, Uttar Pradesh	2-11 August 2016
3.	Dr. L.S. Rajeswari, Assistant Chief Technical Officer	Training Programme on Statistical Techniques for Agricultural Data Analysis for the Technical Personnel of ICAR at ICAR-IASRI, New Delhi	2-11 November 2016
4.	Shri. B.B. Das, Technical Officer, Regional Centre, ICAR-CTCRI, Bhubaneswar	Workshop on MS-Powerpoint for Officers and Staff at ISTM, New Delhi	28-30 December 2016
5.	Shri. C.S. Salimon, Senior Technical Officer	Professional Training on Operational and Maintenanace of Improved Implements and Machinery for Technical Officers of ICAR Institutes at ICAR-CIAE, Bhopal	12-17 December 2016
6.	Shri.V. Ganesh, Technical Officer	Training Programme on Fundamental Concepts and Methodologies for Agricultural Water Management for the Technical Personnel of ICAR at ICAR-IARI, New Delhi	19-24 December 2016
7.	Shri. V.R. Sasankan, Senior Technical Officer, & Farm Superintendent Shri. D.T. Rejin, Senior Technician	Training Programme on Good Agricultural Practices for Enhancing Resource Use Efficiency and Farm Productivity at ICAR-IARI, New Delhi	14 -27 February 2017
8.	Shri. G. Shaji Kumar, Technical Assistant (Driver)	Training Programme on Automobile Maintenance, Road Safety and Behavioural Skills at ICAR-CIAE, Bhopal	20-24 February 2017

c. Administrative Staff

Sl. No.	Name	Particulars of the training	Period
1.	Shri. T. Jayakumar, AAO Shri. S. Hareendrakumar, Assistant	Implementation of NIC's e-Procurement through CPP Portal at ICAR-NAARM, Hyderabad	25-26 April 2016
2.	Shri. P.C. Noble, AAO, Regional Centre	Establishment Rules at ISTM, New Delhi	23-27 May 2016
3.	Shri. S. Hareendrakumar, Assistant Shri. N. Jayachandran, LDC	Knowledge Enhancement Training Programme on Supply Chain Management at ICAR-IASRI, New Delhi	16-17 June 2016
4.	Ms. K. Padmini Nair, Personal Assistant	Enhancing Efficiency and Behavioural Skills for Stenographer Grade III, PA, PS of ICAR at ICAR-NAARM, Hyderabad	24-30 November 2016

Awards and Recognitions

Awards

- Dr. C. Visalakshi Chandra was awarded the Young Scientist Award for the Best Oral Presentation titled "Characterization and identification of genotypes for tolerance to post-harvest physiological deterioration in cassava" (authored by C. Visalakshi Chandra, M.N. Sheela, Saravanan Raju, C. Mohan, Vivek Hegde, S. Darshan and A. Vijayan) in the National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016) held at ICAR-CTCRI during 20 - 22 October 2016.

Dr. C. Visalakshi Chandra receiving the Young Scientist Award of NCTTC-2016

- Ms. P. Lakshmipriya bagged the Young Scientist Award (Runner up-I) for the oral research paper titled "*Piriformospora indica*, a cultivable endophyte for growth promotion and disease management in taro" (authored by P. Lakshmipriya, Vishnu S. Nath, S.S. Veena, K.N. Anith, J. Sreekumar and M. L. Jeeva) in the National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016) held at ICAR-CTCRI during 20 - 22 October 2016.
- Ms. G. Saranya, received the Young Scientist Award (Runner up-II) for the oral research paper titled "Mining of resistance genes associated with anthracnose infection in greater yam (*Dioscorea alata* L.)" (authored by G. Saranya, Vishnu, S. Nath, M.L. Jeeva, and T. Makeshkumar) in the National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016) held at ICAR-CTCRI during 20 - 22 October 2016.
- Dr. K. Susan John won the second place in the International Plant Nutrition Institute (IPNI) photo contest 2016 in the other category for B deficiency in cassava. The award carried US Dollars 100, a certificate and a USB with nutrient disorder archives.
- Irfa Anwar, M.N. Sheela, K.I. Asha, Athira Jyothi, B.S. Prakash Krishnan and P.V. Abhilash bagged the Best Poster Presentation award for the research paper on "Genetic diversity analysis of wild yams in India", in Session IV on Crop Wild Relatives at the 1st International Agrobiodiversity Congress at New Delhi held during 6 - 9 November 2016.


1st INTERNATIONAL AGROBIODIVERSITY CONGRESS
Best Poster Presentation
Awarded to
Irfa Anwar, M.N. Sheela, ... P.V. Abhilash
Session Name : 4: Crop wild Relatives: Back to the wild to save future
Dr. R. S. Paroda
Co-Chair
Dr. M. S. Swaminathan
Chair

Best poster award received by Ms. Irfa Anwar during the 1st International Agrobiodiversity Congress held at New Delhi on 6-9 November 2016

Certificate of the IPNI photo contest award received by Dr. K. Susan John

Awards received in the National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016) held at ICAR-CTCRI during 20 - 22 October 2016

Sl. No.	Name of the awardee	Award and category	Title of the paper	Authors
1.	Dr. M.N. Sheela	Best Oral Paper in Session II on Genetic Resources of Tuber Crops	Breeding for varieties resistant to cassava mosaic disease using different sources of resistance	M.N. Sheela, P.V. Abhilash, S. Darshan, B.S. Prakash Krishnan, P. Arunkumar, T. Makeshkumar, K.I. Asha, C. Mohan, S. Sunitha, N. Krishna Radhika, A. Asha Devi and James George
2.	Dr. G. Suja	Best Oral Paper Award in Session III on Sustainable Management of Tuber Crops for Livelihood Security	Is organic production sustainable? Insights from tuber crops	G. Suja, A.N. Jyothi, V.S. Santhosh Mithra and J. Sreekumar
3.	Dr. S.S. Veena	Best Oral Paper in Session IV on Plant Protection: Concerns and Care	Progress and prospects of collar rot management in elephant foot yam	S.S. Veena, R.S. Misra and M.L. Jeeva
4.	Ms. R. Remya	Best Oral Paper in Session V on Processing and Product Diversification	Octenyl succinylation as a method for developing slowly digestible starch and resistant starch in stem and root tuber starches	R. Remya and A.N. Jyothi
5.	Mr. P. Prakash	Best Oral Paper in Session VI on Indigenous Technical Knowledge and Transfer of Technology	Analysis of sweet potato value chain and determinants of market options choice in selected districts of Odisha in India	P. Prakash, A. Kishore, D. Roy and D. Behura
6.	Mr. P.V. Abhilash	Best Poster Paper Award in Session II on Genetic Resources of Tuber Crops	Genetic diversity among released varieties of cassava in India	A.S. Shersha, S. Athulya Dev and M.N. Sheela
7.	Dr. V. Ramesh	Best Poster Award in Session III on Sustainable Management of Tuber Crops for Livelihood Security	Response of cassava under integrated soil water and nutrient conservation measures in hill soils	V. Ramesh, C.S. Ravindran, G. Byju and J. Sreekumar
8.	Dr. R. Muthuraj	Best Poster Award in Session III on Sustainable Management of Tuber Crops for Livelihood Security	Quality planting material production of cassava through farmers participatory approach in the Attapadi and Wayanad tribal area of Kerala	R. Muthuraj, James George, S. Sunitha, M.N. Sheela and T. Makeshkumar
9.	Mr. E.R. Harish	Best Poster Award in Session IV on Plant Protection: Concerns and Care	Characterization of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) for vector-virus interactions in cassava	E. R. Harish, Mani Chellappan, T. Makeshkumar and M.T. Ranjith

Mr. Prakash receiving the best oral presentation award in NCTTC-2016 from Director, ICAR-CTCRI

- Dr. Kalidas Pati, Scientist was selected for the prestigious Endeavour Research Fellowship 2017 for post-doctoral research at The University of Western Australia, Perth, Australia under 'Australia Awards' of Australian Government Department of Education and Training.
- Ms. Pradeepika Chintha has been awarded the Netaji Subhas-ICAR International Fellowship for the year 2016 for pursuing higher education in university abroad.
- Drs. Archana Mukherjee, Vivek Hegde and P. Sethuraman Sivakumar visited Joida to get GI registration of taro and the Joida dasheen taro. Received GI registration and the community got "Plant Genome Saviour Award".
- Dr. Sanket J. More bagged the ASPEE Foundation Gold Plated Silver Medal in Ph.D. for securing highest overall C.G.P.A. and conducting quality research.
- Basketball team consisting of Dr. Sanket J. More, Dr. J. Sreekumar, Shri. V. R. Sasankan, Shri. P.C. Noble, Shri. R. Bharathan, Dr. S. Shanavas, Shri. C. Chandru, Shri. A. Chandran bagged the first prize in the ICAR – Inter Institutional Tournament (South Zone) held at Hyderabad during 22-26 August 2016.

Award of Ph. D

- A.V.V. Koundinya, Scientist, Crop Improvement was awarded Ph. D. in Vegetable Science on 26 October 2016 from Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal under the guide ship of Dr. (Prof.) Manas Kumar Pandit on the topic, "Profiling of quality parameters as a function of cropping season, character associationship, stability analysis and screening against fruit and shoot borer infestation in brinjal".
- Ms. C.S. Suchithra was awarded Ph. D. in Environmental Science from the University of Kerala for the thesis titled "Soil phosphorus management for sustainable cassava production and environmental health in Ultisols" done under the guidance of Dr. G. Byju.
- Ms. A.C. Hridya was awarded Ph. D. in Environmental Science from the University of Kerala for the thesis titled "Soil related constraints and site specific nutrient management in cassava (*Manihot esculenta* Crantz)" done under the guidance of Dr. G. Byju.
- Ms. Sabitha Soman was awarded Ph. D. in Environmental Science from the University of Kerala for the thesis titled "GIS based nutrient decision support system for sustainable cassava production in Thiruvananthapuram district, Kerala" done under the guidance of Dr. G. Byju.

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

- Ms. Nimmi Simon was awarded M. Sc. Biotechnology from Cochin University of Science and Technology. The project work was done on the topic "Molecular characterization of cassava (*Manihot esculenta* Crantz) germplasm using SSR markers" under the guidance of Dr. K.I. Asha at ICAR-CTCRI.
- Ms. K.U. Jincy Raj was awarded M.Sc. Biotechnology from Cochin University of Science and Technology. The project work was done on the topic, "Cloning and transformation of genes in starch synthesis pathway of cassava (*Manihot esculenta* Crantz)" under the guidance of Ms. N. Krishna Radhika at ICAR-CTCRI.
- Mr. S. Krishnaraj was awarded B.Sc.-M.Sc. (Integrated) Biotechnology from Kerala Agricultural University. The project work was done on the topic "Genetic diversity analysis of elephant foot yam (*Amorphophallus*

paeoniifolius (Dennst.) Nicolson)" under the guidance of Dr. A. Asha Devi at ICAR-CTCRI.

- Ms. Ann P. George was awarded M.Sc. in Biotechnology from Cochin University of Science and Technology. The project work was done on the topic "Usefulness of inter simple sequence repeat markers in differentiating between species of important aroids" under the guidance of Dr. A. Asha Devi at ICAR-CTCRI.
- Ms. G. Saranya was awarded B.Sc.–M.Sc. (Integrated) Biotechnology from Kerala Agricultural University. The project work was done on the topic "Mining of resistance genes associated with anthracnose infection in greater yam (*Dioscorea alata* Linn.) under the guidance of Dr. M. L. Jeeva at ICAR-CTCRI. Dr. T. Makeshkumar was a member in the advisory committee.
- Ms. P. Lakshmipriya was awarded B.Sc.–M. Sc. (Integrated) Biotechnology from Kerala Agricultural University. The project work was done on the topic "*Piriformospora indica*, a cultivable endophyte for growth promotion and disease management in taro" at ICAR-CTCRI under the guidance of Dr. S. S. Veena. Dr. M. L. Jeeva was a member in the advisory committee.
- Ms. Geethu S. Nair was awarded B.Sc.–M. Sc. (Integrated) Biotechnology from Kerala Agricultural University. The project work was done on the topic "Standardization of virus inoculation method for cassava mosaic disease" at ICAR-CTCRI under the guidance of Dr. T. Makeshkumar. Dr. M. L. Jeeva was a member in the advisory committee.
- Shri. J. T. Jeyakrishnan was awarded B.Sc.–M.Sc. (Integrated) Biotechnology from Kerala Agricultural University. The project work was done on the topic "Molecular analysis of phylogeography of cassava mosaic disease" at ICAR-CTCRI under the guidance of Dr. T. Makeshkumar. Dr. J. Sreekumar was a member in the advisory committee.

Award of PGDMA

- Shri. Ayush Bhandari was awarded Post Graduate Diploma in Management – Agriculture (PGDMA) by ICAR-National Academy of Agricultural Research Management (NAARM), Hyderabad on the topic "Estimation of consumers' willingness to pay for "Functional Pasta" using experimental auction approach". This work was done at ICAR-CTCRI under the guidance of Dr. P. Sethuraman Sivakumar.

Institute Awards

- The Sardar Patel Outstanding Agricultural Institute Award for 2005 was won by this Institute. The Award money was received in 2006. The interest from the money was utilized to award the following best technical, administrative and skilled support staff of ICAR-CTCRI for 2016.

Administrative	Technical	Skilled support staff
Smt. S. Geetha Nair	Shri. G. Venukumaran Shri. V.L. Mathew	Smt. C.T. Chellamma

Recognitions

Dr. J.T. Sheriff

- Principal member in the Committee of FAD 16 Committee Food Grains, Starches and Ready-to-eat foods, Sectional Committee, Bureau of Indian Standards, New Delhi.
- Member, FASSI Scientific Panel (Food Additives, Flavourings, Processing Aids and Materials); Alternate member in the Committee of FAD 20 Agricultural and Food Processing Equipments, BIS, New Delhi.
- Member, Research Advisory Committee, Indian Institute of Crop Processing Technology, Thanjavur; Member, IMC, ICAR-CIAE, Bhopal; Technical committee member, Sagoserve, Salem.
- External examiner for Ph.D. programmes, Tamil Nadu Agricultural University.

Dr. M.N. Sheela

- Invited as resource person to deliver a lecture on "Conservation methodologies for medicinal tuber Crops" in the UGC sponsored National Seminar on Rescue and Restoration of Selected Medicinal Plants of Western Ghats at Iqbal College, Peringammala, Thiruvananthapuram, during 15 - 16 March 2017.
- External examiner for the evaluation of thesis and conduct of viva voce of M.Sc. / Ph.D. Plant Breeding and Genetics (1 Ph.D and 4 M.Sc.)

College of Agriculture, Vellayani and College of Horticulture, Vellanikkara, Kerala Agricultural University.

- External examiner for the evaluation of thesis of Mr. Vipin Mohan, B.Sc-M.Sc (Integrated) Biotechnology, College of Agriculture, Vellayani.

Dr. Sheela Immanuel

- External examiner to evaluate thesis and conduct final viva voce of Ms. K.K. Anju, M.Sc. (Ag.) (Agricultural Extension), Kerala Agricultural University.

Dr. G. Byju

- Subject expert in the discipline of Soil Science for Career Advance Scheme (CAS) Promotions under UGC 2006, Kerala Agricultural University.
- External examiner for Ph.D. thesis evaluation of the thesis titled, "Understanding the productivity of cassava in West Africa using QUEFTS model", Wageningen University, The Netherlands.
- External examiner for thesis evaluation and viva of 1 Ph.D. student and 5 M. Sc. students and qualifying viva voce examination of 5 Ph. D. students of Kerala Agricultural University.
- Reviewer of a research paper in the International Journal, Nutrient Cycling in Agroecosystems, published by the Springer.

Dr. G. Suja

- Subject expert in the discipline Agronomy for Career Advance Scheme (CAS) Promotions under UGC 2006, Kerala Agricultural University.
- External examiner of Ph. D. and M.Sc. Agronomy/Environmental Sciences students (4 nos.) of Kerala Agricultural University and Kerala University.
- 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 3 February 2017.

Dr. K. Susan John

- External examiner for 3 PG students at College of Horticulture, Vellanikkara (Soil Science and Agricultural Chemistry), Kerala Agricultural University, Kerala.
- External examiner for setting up of question papers for University of Horticultural Sciences (UHS, Bagalkot) on "Soil and Plant Analysis" (SAC-201) and evaluation of answer sheets.
- Panel expert for tuber crops in the discussion at pre-rabi-scientist-extension-farmer interface at Kerala Agricultural University, Thrissur on 7 October 2016.

Dr. K. Laxminarayana

- External member for selection of Senior Research Fellow and Skilled Assistant under the Extramural Project at CHES (IIHR), Bhubaneswar on 25 April 2016.
- Tuber crop expert by Habitat Research Institute and LAYA (NGO), Visakhapatnam, to explore the consumption of wild tuber crop species by the tribal families in Rampachodavaram Mandal of East Godavari district and Paderu division of Visakhapatnam district, Andhra Pradesh during 9-11 July 2016.

Dr. K.I. Asha

- External examiner for the conduct of the Ph. D thesis pre-submission seminar of Ms. S.L. Soumya, full-time research scholar, Department of Botany, University of Kerala, Kariavattom, Thiruvananthapuram on 13 June 2016.
- Chairperson of the Committee for Preparation of the Academic Audit Report 2016, Department of Botany, University of Kerala, Kariyavattom.

Dr. A. Asha Devi

- External examiner for the evaluation of thesis and conduct of viva voce for the Ph. D thesis of Mr. M. K. Chandraprakash in the Faculty of Biotechnology, Jawaharlal Nehru Technological University, Hyderabad on 11 April 2016.
- External examiner for the evaluation of thesis and conduct of viva voce for the M.Sc. thesis of Mr. Hembede Vivekanand Laxman of the Department of Biotechnology, College of Agriculture, Vellayani on 14 October 2016.
- Member to evaluate the technical papers in Life Sciences at the 29th Kerala Science Congress at Sasthra Bhavan, Pattom, Thiruvanathapuram on 22 December 2016.
- External examiner for the conduct of the

pre-submission viva of Smt. M. Lakshmi, Department of Botany, University of Kerala, Karyavattom, Thiruvanathapuram on 30 March 2017.

Dr. Shirly Raichal Anil

- Subject expert to conduct the pre-submission seminar of Mr. R.P. Praveen, full time Ph. D research scholar, Department of Botany, University of Kerala, Kariavattom on 18 June 2016.
- External examiner for M. Phil. viva voce examination and evaluation of thesis at the Department of Botany, University of Kerala, Kariavattom on 27 October 2016.
- Resource person to deliver a lecture and conduct practical training on short term conservation of germplasm in the National Workshop on Plant Tissue Culture, Cell Culture and Cryopreservation Technology held at Department of Botany, University of Kerala, Kariavattom during 14-23 November 2016.
- Member of expert committee for discussing on issues in the field of tissue culture and floriculture in the Department of Agriculture, Govt. of Kerala on 6 December 2016.

Dr. T. Makeshkumar

- External examiner for the evaluation of theses of 4 Ph. D. students at Madurai Kamaraj University, Jawaharlal Nehru Technological University, Kerala Agricultural University and Amity University, Haryana.
- Expert for Ph. D thesis pre-submission seminar of Ms. Mallika, Rajiv Gandhi Centre for Biotechnology (University of Kerala) on 1 September 2016.
- External expert for the assessment of Ms. Anusree Thampi, CSIR Fellow, Division of Crop Protection, ICAR-IISR, Kozhikode.
- Expert for evaluation of research proposal submitted to Kerala Biotechnology Commission for financial assistance under Young Investigators Programme in Biotechnology (YIPB).
- Member, National Organising Committee of 8th International Geminivirus Symposium and 6th International ssDNA Comparative Virology Workshop, 7-10 November 2016, Hotel Vivanta by Taj, New Delhi.
- Convener, Plant virology session and Member, National Organising Committee of International Conference on Global Perspectives in Virus Disease Management (VIROCON 2016).

Dr. A.N. Jyothi

- Member of the technical committee for the purchase of FTIR and GC instruments at the State Pesticide Testing Laboratory, Department of Agriculture, Govt. of Kerala, Parottukonam, Thiruvananthapuram, Kerala.

Dr. P. Sethuraman Sivakumar

- Expert member of the State level Award Committee for the selection of State Farmer Awards 2015 and felicitated by Shri. Adv. V. S. Sunil Kumar. Minister for Agriculture, Govt of Kerala for his contribution for the same.
- External subject expert at the Departmental Assessment Committee (DAC) for promotion of Scientist under FCS in the Indian Plywood Industries Research and Training Institute, Bengaluru on 24 January 2017.
- External examiner to evaluate thesis and conduct viva voce of two M.Sc. (Ag.) (Agricultural Extension) students, Kerala Agricultural University.

Ms. N. Krishna Radhika

- Invited as resource person to deliver a lecture on "Transgenics" to the M.Sc. Integrated Biotechnology students at College of Agriculture, Vellayani on 14 July 2016.

Dr. V.B.S. Chauhan

- Expert for the setting up of question paper and external examiner for the conduct of the end term practical examination of B. Sc. (Horticulture), College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh.
- External examiner to evaluate the thesis and conduct the final viva voce of Ms. Ephilo Mena, M. Sc. (Horticulture), College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh.

Approved Guide, Ph. D program, University of Kerala, Kariavattom, Thiruvananthapuram

- Drs. C. A. Jayaprakas, M. N. Sheela, G. Byju, K. Susan John, G. Suja, M. L. Jeeva, T. Makeshkumar, A.N. Jyothi and C. Mohan

Linkages and Collaborations in India and Abroad

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

The Institute has established active linkages with National Institute of Agricultural Extension Management (MANAGE), Hyderabad, ICAR-National Academy of Agricultural Research Management (NAARM), Hyderabad and the Centre for Research on Innovation and Science Policy (CRISP) and conducted a national level, multi-institutional workshop on "Good practices in extension research and evaluation" at NAARM, Hyderabad. Functional collaborations were developed with College of Agriculture, Kerala Agricultural University, Vellayani to conduct two Entrepreneurship Orientation Programmes for B.Sc. (Ag.) final year students and the trainees of Agri Clinics & Agri Business Scheme (AC & ABC). State Agricultural Management and Extension Training Institute (SAMETI), Kerala has collaborated with ICAR-CTCRI for the first time to organise an entrepreneurship orientation programme on "Preparation of Bankable Projects" for the state extension officers.

Under the North-Eastern Hill Region programme, for establishing village incubation centres, linkages were developed with KVKs-DKVK, Khowai, Tripura and other centres of ICAR-NEH-Research Complex. Under Tribal Sub Plan, linkages were developed with research organizations, NGOs and Department of Agriculture in Koraput, Kandhamal and Ranchi districts for the livelihood improvement of tribal farmers. Demonstrations on tuber crops based farming systems were conducted in farmers fields.

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

The Regional Centre has established collaboration with Directorate of Horticulture and Department of Agriculture and Farmers Empowerment, Govt. of Odisha, RKVY, through external funded projects, for soil mapping, establishment of Techno-Incubation Centre at Regional Centre, Bhubaneswar and popularization of climate resilient nutrient rich varieties.

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

ICAR - All India Co-ordinated Research Project on Tuber Crops

Head Quarters, ICAR - Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala

The All India Co-ordinated 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. Presently the AICRPTC is having 22 centres, located in 14 State Agricultural Universities, 5 ICAR Institutions and one Central Agricultural University. The details of the centres and their mandate crops are mentioned below:

Sl. No.	Name of the co-ordinating 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 Peddapuram; elephant foot yam and yams at Kovvur
5	Assam Agricultural University, Jorhat, Assam	1971	Cassava, sweet potato, taro, elephant foot yam, yams and swamp taro
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, taro and bunda
8	Bidhan Chandra KrishiViswavidyalaya, Nadia, Kalyani, West Bengal	1976	Sweet potato, taro, yam bean, elephant foot yam, yams and swamp taro
9	Regional Centre of ICAR-CTCRI, Bhubaneswar, Odisha	1983	Cassava, sweet potato, aroids, yams and yam bean
10	Birsa Agricultural University, Kanke, Ranchi, Jharkand	1987	Sweet potato, taro, elephant foot yam, yams and yam bean
11	Indira Gandhi Agricultural University, Kumharwand, Jagdalpur (Baster), Chhattisgarh	1987	Cassava, sweet potato, yams, elephant foot yam, taro and bunda
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, elephant foot yam and yams
14	ICAR - Central Island Agricultural Research Institute, Port Blair, Andaman & Nicobar Islands.	2000	Cassava, sweet potato, yams, taro 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, yams 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, elephant foot yam

Achievements of ICAR-AICRP on Tuber Crops during 2016 - 2017

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

A total of 132 new collections were made by different centres during 2016-2017. Altogether 4156 different accessions of root and tuber crops were maintained as gene bank for improvement of major crops including cassava, sweet potato, aroids, yams and minor tuber crops at 22 centres. A total of 5558 accessions of different tuber crops are being maintained in the National Repository for Tuber Crops at ICAR-CTCRI, which comprises cassava (1211), sweet potato (1124), yams (1110), edible aroids (672) and minor tuber crops (200) and 1241

from Regional Centre. Augmentation of germplasm of tuber crops continued at ICAR – CTCRI with the addition of a total of 221 accessions from different parts of the country. Three exploration trips were carried out in Chhattisgarh, Assam and Karnataka in collaboration with the AICRP centres viz., IGKV, Jagdalpur, AAU, Jorhat and UHS, Dharwad. Sixty accessions were collected from the Bastar region of Chhattisgarh. Eighty nine accessions were collected from different places (Katiathuli, Diguljarani, Upper Dillaji, Rupsing Hanse, Rongpi, RophongTimung, Upper Deopani, Thakarajan, Phuloni, Gurubari, Haflong, Katlicherla) of Assam. Fifteen accessions were collected from Joida, Uttara Kannada in Karnataka. Among the centres, maximum accessions of twelve tuber crops (1329) were maintained at RAU, Dholi. IC numbers were obtained for a total of 1977 germplasm collections at different centres.

Testing of genetic resources at various agro-climatic environments

Varietal evaluation trials in cassava, sweet potato, yams, aroids and yam bean with coded entries are in progress at different centres. Pooled analysis of data of URT on K-efficient cassava lines for the last two years indicated that TCa14-6 was superior at Yethapur, Sree Athulya at Peddapuram, TCa 14-1 at Manipur and TCa 14-5 at Thiruvananthapuram. Under URT on cassava for culinary uses, TCa 13-3 produced maximum tuber yield at Thiruvananthapuram and TCa 13-7 at Jagdalpur (66.91 t ha^{-1}) based on pooled analysis. The maximum tuber yield (43.28 t ha^{-1}) and starch content (31.70 %) was recorded in TCa 12-6 at Yethapur, TCa12-9 (35.64 t ha^{-1}) at Peddapuram, and TCa12-5 at Thiruvananthapuram (41.86 tha^{-1}) under MLT on short-duration cassava entries.

Among the entries evaluated in URT on sweet potato for weevil resistance, TSp-12-3, performed well coupled with less weevil infestation at Bhubaneswar (20.97 t ha^{-1}). At Dholi, TSP 12-6 produced highest marketable tuber yield and TSp 12-4 at Rajendranagar and Kalyani based on pooled analysis. Under URT on sweet potato, maximum marketable tuber yield was recorded from TSp12-10 at Kalyani (25.87 t ha^{-1}) and TSp12-12 at Barapani.

Under URT on taro, TTr 12-5 was superior in yield at Kalyani. The entry TTr 12- 8 produced maximum yield at Ranchi, Dholi and Port Blair. The evaluation of taro entries against *Phytophthora* blight indicated that TCbl 12-4 and TCbl 12-3 showed field resistance to leaf blight and also gave better cormel yield at Kalyani, Dholi and Rajendranagar.

Pooled analysis of data of first and second years of IET on greater yam indicated that TGy 14-11 produced maximum yield at Dapoli (21.26 t ha^{-1}) and Kovvur (43.21 t ha^{-1}), TGy 14-6 at Udaipur and Imphal, TGy 14-9 at Jagdalpur (33.95 t ha^{-1}), TGy 14 - 3 at Thiruvananthapuram and TGy 14-5 at Jorhat. Under URT on greater yam, TGy12-3 produced maximum tuber yield at Bhubaneswar, Jagdalpur, Kovvur and Thiruvananthapuram. Under MLT on greater yam, maximum yield was produced by IGDA-2, both at Jagdalpur (35.88 t ha^{-1}) and Navsari (25.88 t ha^{-1}). Maximum tuber yield of 17.53 t ha^{-1} was recorded by TDb 13-6 at Jagdalpur under URT on aerial yam, TDb 13-5 at Ranchi and Dapoli based on pooled data.

Under IET on swamp taro, the highest stolon yield was produced by BCST-1 (19.98 t ha^{-1}) at Kalyani, BCST-13 at Jorhat and CAUST-1 at Imphal based on pooled analysis of two years. Under IET on tannia, among the eight entries, TTn 14-6 performed well and produced maximum tuber yield at Rajendranagar and Thiruvananthapuram, TTn 14-8 at Imphal and Jorhat, TTn 14-7 at Kalyani and TTn14-5 at Jagdalpur. In the first year of URT on yam bean, TYb14-8 was superior at Bhubaneswar, and TYb14-9 at Dholi.

Agro-techniques

The farming system studies involving tuber crops introduced in Hadibadi (village), Chakapada (Block), Kandhamal (District), Odisha, generated a gross income of Rs. 1, 88,682 ha^{-1} with B:C ratio of 2.73 and employment generation of 304 man days ha^{-1} in place of the gross income of Rs. 90,125 ha^{-1} with B:C ratio of 1.91 and employment generation of 225 man days ha^{-1}. The gross income and net income increased at four locations of Jharkhand after interventions of different components under tuber crops based farming system studies from the

year 2012-2013 to 2016-2017. Average B: C ratio of income of the famers increased from 1.28 to 2.24. The model created an additional employment of 70 man days. Tuber crops based farming system introduced at four locations of Manipur state generated a net income of Rs. 81,675 ha^{-1} and 186 days of employment generation, compared to Rs. 41,500 ha^{-1} and 105 days prior to intervention.

Cassava responded positively to micronutrients at the various centres. Tuber yield as well as B: C ratio was maximum with the application of micronutrients viz., $MgSO_4$, $ZnSO_4$, Borax and $FeSO_4$ at Yethapur, Kalyani, Dapoli and Peddapuram. In sweet potato, application of micronutrients, (Mg, B, Zn) resulted in more tuber yield at Rajendranagar, Kalyani, Ranchi and Dholi. At Dharwad, the response of B and at Udaipur, response of Zn application was more pronounced.

Greater yam + maize (1:3) additive intercropping was 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. Validation of organic farming technologies in greater yam, elephant foot yam and taro indicated positive response of organic farming over conventional practice.

Pests and disease management

Installation of sex pheromone trap @ 1 per 100 m^2 was effective in producing maximum marketable tuber yield with less incidence of sweet potato weevil at different centres. Under integrated management of sweet potato weevil, the lowest vine infestation at collar region with minimum tuber infestation and maximum marketable tuber yield and B:C ratio were obtained by dipping the planting material in 0.02% chlorpyriphos (20 EC) for 10 min followed by spraying chlorpyriphos at 30 and 60 DAP.

Planting material production

Planting materials of improved varieties of tuber crops were multiplied and distributed to farmers by all the centres. The centres produced a total of 1,75,595 stems of cassava, 10,83,675 vine cuttings of sweet potato, 33.29 tons of elephant foot yam, 21.78 tons of taro, 100 kg of tannia, 20.23 tons of yams and 393.10 kg of yam bean as part of planting material production programme.

Research-extension-farmers-linkage

The centres were regularly involved in organising training programmes, conducting demonstrations, participating in exhibitions, radio and television programmes. ICAR–CIARI, Port Blair, organized two days training programmes on "Cultivation of tuber crops livelihood options of tribal farmers" at Vikas Nagar, Kamorta during 7-8 February 2017 under AICRP on tuber crops, in which 50 tribal farmers including 15 women participants attended. CSK HPKV, Palampur, conducted three off campus vocational training programmes on tuber crops. TNAU, Coimbatore and TCRS, Yethapur, conducted eight training programmes on tropical tuber crops. BCKV, Kalyani in collaboration with CIP (International Potato Centre), conducted one training programme on sweet potato. IGKV, Jagdalpur conducted 16 training programmes for the tuber growing farmers.

Varieties recommended for release during the 16th Annual Group Meeting of the AICRP on Tuber Crops

The meeting recommended five varieties, three in cassava (TCMS-2, TCMS-7 for central release and TCMS-5 for state of Andhra Pradesh and adjoining areas) and two in Bunda (Bidhan Ghat Kachu (BCB-2) for West Bengal and Chhattisgarh Shaken Bunda-1 (IGB-5) for the state of Chhattisgarh) for release.

The cassava var. TCMS-2 is a non branching type, completely resistant to cassava mosaic disease,

Cassava var. TCMS-2

Cassava var. TCMS-5

Bunda var. BCB- 2

Field view of bunda var. BCB-2

with high yield potential (40 t ha^{-1}) and high starch content (28-32%) recommended for Kerala and Tamil Nadu. It has 25% higher yield over H-226, the popular variety in Tamil Nadu. TCMS-5 is a semi-spreading variety completely resistant to cassava mosaic disease with high yield (45 t ha^{-1}) and medium starch content (25%) recommended for Andhra Pradesh. It has 67% higher yield than Sree Padmanabha. TCMS-7 is recommended for central release and performed well in the states of Kerala, Maharashtra and Andhra Pradesh. It is a non branching variety, completely resistant to cassava mosaic disease, with high yield (40 t ha^{-1}) and high starch content (28-30%).

The bunda variety is a seedling segregate from an open population of an indigenous collection from West Bengal. It has high bulking rate and can be fitted in intensive cropping systems in irrigated and rainfed ecosystems. It is moderately resistant to taro leaf blight and the average yield is 20.80 to 22.40 t ha^{-1}. IGB-5 is recommended for the state of Chhattisgarh, with high yield potential (43.86 t ha^{-1}) and average yield of 31.66 t ha^{-1}, tolerant to taro leaf blight and resistant to dasheen mosaic virus.

Field view of bunda var. IGB-5

Farmers with bunda var. IGB- 5

Publications

Papers in Research Journals

Anju, P.S., Susan John, K., Subhendu Bhadraray, Suja, G., Jeena Mathew, Nair, K.M., Sunitha, S. and Veena, S.S. 2016. Development of protocol for custom mixed fertilizers for elephant foot yam under intercropping in coconut gardens of the two agro-ecological units of Kerala. *J. Root Crops*, **42**(1): 66-74.

Arnau, G., Bhattacharjee, R., Sheela, M.N., Chair, H., Malapa, R., Lebot, V., Abraham, K., Perrier, X., Petro, D., Penet, L. and Pavis, C. 2017. Understanding the genetic diversity and population structure of yam (*Dioscorea alata* L.) using microsatellite markers. *PLOS One*, **12**(3): 1-17.

Arun Kumar, P., Ravinder Reddy, K., Reddy, R.V.S.K., Pandravada, S.R. and Saidaiah, P. 2016. Heritability studies in dual purpose tomato genotypes for growth, yield and quality attributes. *Plant Archives*, **16**(2): 885-889.

Arun Kumar, P., Ravinder Reddy, K., Reddy, R.V.S.K., Pandravada, S.R. and Saidaiah, P. 2016. *Per se* performance of dual purpose tomato genotypes for growth, yield and quality attributes. *Plant Archives*, **16**(2): 695-699.

Arun Kumar, P., Ravinder Reddy, K., Reddy, R.V.S.K., Pandravada, S.R. and Saidaiah, P. 2016. Character association studies for yield and quality in tomato genotypes. *Adv. Life Sci.*, **5**(19): 8717-8724.

Arun Kumar, P., Ravinder Reddy, K., Reddy, R.V.S.K., Pandravada, S.R. and Saidaiah, P. 2016. Genetic divergence studies in tomato genotypes. *The Bioscan*,. (in press).

Asha, K.I., Krishna Radhika, N., Vineetha, B., Asha Devi, A., Sheela, M.N. and Sreekumar, J. 2015. Diversity analysis of arrowroot germplasm using ISSR markers. *J. Root Crops*, **41**(1): 17-24.

Asha, K.I., Sheela, M.N. and Asha Devi, A. 2016. *In vitro* propagation of endemic wild edible yams of Western Ghats – the hotspot of global biodiversity and its conservation in India. *Acta Hort.*, (ISHS) **1118**: 207-216.

Behera, S.S. and Ray, R. C. 2016. Konjacglucomannan, a promising polysaccharide of *Amorphophallus konjac* K. Koch in healthcare. *Int J. Biol. Macromol.*, **92**: 942- 956.

Behera, S.S. and Ray, R.C. 2016. Nutritional and potential health benefits of konjacglucomannan, a promising polysaccharide of elephant foot yam, *Amorphophallus konjac* K. Koch: Review. *Food Rev. Int.*, DOI: 10.1080/87559129.2015.1137310.

Buckseth, T., Sharma, K.K., Pandey, B., Singh, P. and Muthuraj, R. 2016. Methods of pre-basic seed potato production with special reference to aeroponics. *Sci. Hort.*, **204**: 79-87.

Byju, G., Nedunchezhiyan, M., George, J., Sunitha, S., Kamalkumaran, R., Singh, P.P., Mamatha, K., Mitra, S., Tarafdar, J., Desai, K., Ravi, V., Vani, M., Sabitha Soman and Remya Ramesh, K.R. 2016. Fertilizer best management practices by SSNM and customized fertilizers for elephant foot yam (*Amorphophallus paeoniifolius*) cultivation in India. *Indian J. Agric. Sci.*, **86**(4): 485-493.

Byju G., Sabitha Soman and M. Vani. Projected changes in mean temperature and total precipitation and climate suitability of elephant foot yam in major growing environments of India. *Indian J. Hort.* (Accepted).

Chaïr, H., Traore, R.E., Duval, M.F., Rivallan, R., Mukherjee, A., Aboagye, L.M., Van Rensburg, W.J., Andrianavalona, V., Pinheiro de Carvalho, M.A.A., Saborio, F., Sri Prana, M., Komolong, B., Lawac, F. and Lebot, V. 2016. Genetic diversification and dispersal of taro (*Colocasia esculenta* (L.) Schott). *PLOS One* **11**(6): e0157712. https://doi.org/10.1371/journal.pone.0157712.

Chithra, S., Susan John, K., Manikantan Nair, M. and Sreekumar, J. Management of cassava factory solid waste (Thippi) through composting to a nutrient-rich organic manure. *Commun. Soil Sci. Plant Anal.*, **48**(6): 595-607.

Chithra, S., Susan John, K. and Sreekumar, J. 2016. Low cost traditional cassava starch factory solid waste (Thippi) composting: A possible strategy for organic nutrient management and economic security for tribal farmers. *J. Root Crops*, **42**(2): 52-58.

Deepthi, D.C. and Makeshkumar, T. 2016. A simple protocol for isolating small RNA from cassava (*Manihot esculenta* Crantz). *J. Root Crops*, **42**(1): 43-56.

Deepthi, D.C. and Makeshkumar, T. 2016. Elimination of cassava mosaic disease through meristem culture and field evaluation for yield loss assessment in cassava genotypes. *J. Root Crops*, **42**(1): 45-52.

Dona. P., Sheela Immanuel, Ojha. S.N. and Ananthan, P.S. 2016. Occupational needs of shrimp farmers in Kerala. *Indian Res. J. Extn. Edu.*, **16**(3): 20-24.

Gajbhiye, N.A., Jayanti, M., Dhanani, T. and Saravanan, R. 2016. Development and validation of LC-ESI-

MS/MS method for simultaneous determination of four coumarin derivatives and an alkaloid from root and stem bark of *Aegle marmelos Correa*. *Acta Chromatogr*., DOI:10.1556/1326.2016.28.4.6.

Giri, N.A. and Mridula, D. 2016. Development of energy bar utilizing potato extrudates. *Asian J. Dairy Food Res*., **35**(3): 241-246.

Giri, N.A. and Mridula, D. 2016. Optimization of potato flour for development of biscuits by using response surface methodology. *Potato J*., **43**(2): 153-161.

Giri, N.A., Sheriff, J.T., Sajeev, M.S. and Chinta, P. 2016. Development and physico-nutritional evaluation of sweet potato flour based gluten free cookies. *J. Root Crops*, **42**(1): 74-81.

Gopala Krishna Reddy, A., Suresh Kumar, J., Maruthi, V., Venkata Subbaiah, K. and Srinivasa Rao, C.H. 2016. Fruit production under climate changing scenario in India: A review. *Environment and Ecology*, **35**(2): 1010-1017.

Govender, I.S., Ramakrishna, M., Phulukdaree, A., Veena, S.S., Gengan, R.M., Rajeshbabu D., Pandey, M., Nageswara Rao, G., Nagiah, S. and Chuturgoon, A. 2017. *In vitro* antiproliferative effect of ethanolic extracts of indigenous strains of *Ganoderma lucidum* on hepato carcinoma cells. *Intl J. Med. Mushrooms* (In Press).

Harish, E.R., Mani Chellappan., Makeshkumar, T., Ranjith, M.T. and Ambavane, A.R. 2016. Morphometric variations in cassava (*Manihot esculenta* Crantz) whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) from different agro-ecological zones of Kerala, India. *J. Root Crops*, **42**(2): 90-102.

Hegde, V., Makeshkumar, T., Sheela, M.N., Visalakshi Chandra, C., Koundinya, A.V.V., Shirly Raichal Anil., Muthuraj, R. and Darshan, S. 2016. Production of synthetic seed in cassava *(Manihot esculenta* Crantz). *J. Root Crops*, **42(**2): 5-9.

Jayanti, M., Dholakiya, B.Z., Gajbhiye, N.A. and Saravanan, R. 2016. Extractive determination of bioactive flavonoids from butterfly pea (*Clitoria ternatea* Linn.). *Res. Chem. Intermediat.,* pp. 1–17 DOI 10.1007/s11164-016-2664-y.

Jayanti, M., Dholakiya, B.Z., Gajbhiye, N.A. and Saravanan, R. 2016. Assessment of chemical diversity in *Clitoria ternatea* accessions by an improved and validated HPTLC method. *Indian J. Agric. Sci.,* **86**(9): 1133-1139.

Koundinya, A.V.V., Dhankhar, S.K., Ramesh, D. and Kumar, P.P. 2016. Genetic divergence for yield and yield components in advanced breeding lines of okra. *Bangladesh J. Bot.,* **45**(1): 47-53.

Lakshmipriya, P., Vishnu. S. Nath., Veena, S.S., Anith, K.N., Sreekumar, J. and Jeeva, M.L. 2016. *Piriformospora indica*, a cultivable endophyte for growth promotion and disease management in taro (*Colocasia esculenta (*L.). *J. Root Crops*, **42**(2): 107-114.

Laxminarayana, K. 2016. Response of mycorrhiza, organic sources, secondary and micro nutrients on soil microbial activities and yield performance of *Colocasia* (*Colocasia esculenta* L.) in Alfisols. *Commun. Soil Sci. Plant Anal.,* **47**(6): 775-786.

Laxminarayana, K. and Nayak, A. 2016. Enumeration of microbes and microbial activities in coastal saline soils of eastern India. *J. Indian Soc. Soil Sci.,* **64**(3): 276-284.

Menon, R., Padmaja, G., Jyothi, A.N., Asha, V. and Sajeev, M.S. 2016. Gluten-free starch noodles from sweet potato with reduced starch digestibility and enhanced protein content. *J. Food Sci.Technol.,* **53**(9): 3532–3542.

Mithra. M.G., Sreekumar, J. and Padmaja. G. 2017. Binary-and triple cocktails their application mode affect fermentable sugar release from pretreated lignocellulo-starch biomass. *Biomass Conv. Bioref.,* DOI 10.1007/s13399-017-0273-y.

Mukherjee, A., George, J., Pillai, R., Chakrabarti, S.K., Naskar, S.K., Patro, R., Nayak, S. and Lebot, V. 2016. Development of taro (*Colocasia esculenta* (L.) Schott) hybrids overcoming its asynchrony in flowering using cryostored pollen. *Euphytica*, **212**(1): 29-36.

Murugesan P., Aswathy, G.M., Sunil Kumar, K., Masilamani, P., Vinod Kumar and Ravi, V. 2017. Oil palm (*Elaeis guineensis*) genetic resources for abiotic stress tolerance: A review. *Indian J. Agric. Sci.,* **87**(5): 571–579.

Muthuraj, R., George, J. and Sunitha, S. 2016. Effect of growth regulator and chemical treatment on dormancy breaking in elephant foot yam. *J. Root Crops*, **42**(2): 75-80.

Muthuraj, R., Singh, B.P., Buckseth, T., Singh, R.K., Singh, S. and Sharma, A.K. 2016. Effect of micro plants hardening on aeroponic potato seed production. *Potato J.*, **43**(2): 214-219.

Muthuraj, R., George, J. and Ravi, V. 2016. Seed certification standards for quality planting material production of cassava, sweet potato, lesser yam and taro. *J. Root Crops*, **42**(1): 3-8.

Nair, S. B., Jyothi, A.N. and Sajeev, M.S. 2017. Chitosan-konjac glucomannan-cassava starch-nanosilver composite films with moisture resistant and antimicrobial properties for food-packaging applications. *Starch-Stärke*, **69,** 1600210: doi:10.1002/star.201600210.

Nath, V.S., Shyni, B., Jeeva, M.L. and Veena, S.S. 2016. Genetic and phenotypic characterization of *Phytophthora colocasiae* in taro growing areas of India. *J. Plt. Pathol. Microbiol.,* DOI: 10.4172/2157-7471.1000383.

Nedunchezhiyan, M., Mukherjee, A., Byju, G., Ravi, V. and George, J. 2016. Growth, dry matter production and nutrient uptake of elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) as influenced by drip irrigation and fertigation levels. *J. Root crops,* **42**(1): 28-38.

Nedunchezhiyan, M., Ravi, V., George, J. and Veena S.S. 2017. Effect of weed control methods on the yield and starch content of storage root of cassava (*Manihot esculenta*) and soil health. *Indian J. Agric. Sci.,* **87**(3): 342–349.

Patil, V.U., Vanishree, G., Hegde, V., Chaturvedi, K.K. and Chakrabarti, S.K. 2016. Computational analysis of Short Tandem Repeat (STR) markers from genome wide expression regions of sugar beet (*Beta vulgaris*). *J. Appl. Bioinform. Comput. Biol*., 5(2). doi:10.4172/2329-9533.1000125.

Prakash, P and Pramod Kumar. 2016. Performance of Kisan credit card scheme in Tamil Nadu. *Indian. J. Agric. Econ.,* **71**(2): 191-211.

Prince Kumar, Byju, G., Singh, B.P., Minhas, J.S. and Dua, V.K. 2016. Application of QUEFTS model for site-specific nutrient management of NPK in sweet potato (*Ipomoea batatas* L. Lam). *Commun. Soil Sci. Plant Anal.,* **47**(13-14): 1599-1611. DOI: 10.1080/00103624.2016.1194989.

Ravi, V., Chakrabarti, S.K., Saravanan, R., Makeshkumar, T. and Sreekumar, J. 2016. Differential gene expression signatures of Small Auxin Up-Regulated RNA (SAUR) and GretchenHagen 3 (GH3) genes in storage root as compared to non-tuber forming fibrous root of sweet potato (*Ipomoea batatas*). *J. Root Crops,* **42**(1): 14-21.

Ravi, V., Chakrabarti, S.K., Saravanan, R., Makeshkumar, T. and Sreekumar, J. 2017. Differential gene expression signatures of auxin response factors and auxin/indole 3-acetic acid genes in storage root as compared to non-tuber forming fibrous root of sweet potato (*Ipomoea batatas*). *Indian J. Agric. Sci.,* **87**(4): 512–520.

Remya, R., Jyothi, A.N. and Sreekumar, J. 2017. Comparative study of RS4 type resistant starches derived from cassava and potato starches via octenylsuccinylation. *Starch-Stärke*, 1600264. doi:10.1002/star.201600264.

Sabitha Soman, Byju, G. and Sreekumar, J. 2016. Projected changes in mean temperature and total precipitation and climate suitability of cassava (*Manihot esculenta*) in major growing environments of India. *Indian J. Agric. Sci.,* **86**(5): 647–653.

Sahoo, B., Nedunchezhiyan, M. and Acharya, P. 2016. Incidence of collar rot in elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) as influenced by varied nutrient regimes in East and South-eastern coastal plain zone of Odisha. *J. Crop Weed,* **12**(3): 160-162.

Samanta, J.N., Mandal, K., Saravanan, R., Gajbhiye, A.N. and Ravi, V. 2016. Influence of tapping position, intensity of tapping and season on gummosis of guggal (*Commiphora wightii*), oleo-gum-resin yield and quality. *Indian J. Agric. Sci.,* **86**: 143-146.

Samantaray, T. and Korada, R.R. 2016. Electrophysiological and behavioural responses of sweet potato weevil, *Cylas formicarius* to green leaf volatiles and terpenoids. *Curr. Sci.,* **110**(5): 902-908.

Samantaray, T. and Korada, R.R. 2016. Electrophysiological and behavioural responses of sweet potato weevil, *Cylas formicarius* Fab. to sweet potato varieties. *Curr. Sci.,* **111**(5): 895-900.

Sangeetha, B.G., Jayaprakas, C.A., Jithine, J.R. and Mohandas, C. 2016. Optimization of media for antimicrobial acitvity of *Enterobacter* sp. associated with entomopathogenic nematode *Rhabditid* sp. *J. Root Crops,* **42**(2): 121-127.

Saranya, G., Vishnu, S. Nath., Jeeva, M.L. and Makeshkumar, T. 2016. Mining of resistance genes associated with anthracnose infection in greater yam (*Dioscorea alata* L.). *J. Root Crops,* **42**(2): 115-120.

Saravanan, R., Ravi, V., Roy Stephen, Sheriff, J.T. and George, J. 2016. Post-harvest physiological deterioration of cassava (*Manihot esculenta*) – A review. *Indian J. Agric. Sci.,* **86**(11): 1383–1390.

Sarita, S. and Laxminarayana, K. 2016. Impact of heavy metals on enzymes and microbial activities in the soils adjacent to mines and industrial areas of Odisha. *Intl. J. Sci. Appl. Res.,* **3**(2): 16-21.

Shanida Beegum, S.U., Susan John, K., Sheela, M.N. and Sreekumar, J. 2015. Low cost cassava production strategy through nutrient use efficient

genotypes integrated with low input management. *J. Root Crops*, **41**(2): 42-48.

Sheela, M.N., Abhilash, P.V., Asha, K.I. and Arnau, G. 2016. Genetic diversity analysis in greater yam (*Dioscorea alata* L.) native to India using morphological and molecular markers. *Acta Hort*., (ISHS) **1118**: 51-58.

Suja, G., Byju, G., Jyothi, A.N., Veena, S.S. and Sreekumar, J. 2017. Yield, quality and soil health under organic vs conventional farming in taro. *Sci. Hort*., **218**: 334-343, http://dx.doi.org/10.1016/j.scienta.2017.02.006.

Suja, G., Jyothi, A.N. and Byju, G. 2016. Response of varieties of elephant foot yam (*Amorphophallus paeoniifolius*) to organic management. *Indian J. Agric. Sci*., **86**(10): 1343-1349.

Sunitha, S., George, J. and Sreekumar, J. 2016. Productivity of cassava as affected by precision management under humid tropical environment in India. *Acta Hort.*, **1118**(3): 17-23.

Sunitha, S., George, J., Muthuraj, R., Sheela, M.N. and Makeshkumar, T. 2016. Quality planting material production of elephant foot yam. *J. Root Crops*, **42**(2): 59-61.

Surendran, U., Ramesh, V., Jayakumar, M., Marimuthu, S. and Sridevi, G. 2016. Improved sugarcane productivity with tillage and trash management practices in semi arid tropical agro ecosystem in India. *Soil Tillage Res*., **158**: 10–21.

Suresh Kumar, J., More, S.J., Ravi, V., Byju, G. and George, J. 2016. Leaf area estimation in yam bean (*Pachyrrhizus erosus* L.) using linear measurement of leaf parameters. *J. Root Crops*, **42**(2): 86-89.

Susan John, K., George, J., Shanida Beegum, S.U. and Shivay, Y.S. 2016. Soil fertility and nutrient management of tropical tuber crops-An overview. *Indian J Agron*., **61**(3): 263-273.

Susan John, K., Shanida Beegum, S.U., Sheela, M.N. and Suja, G. 2016. Nutrient efficient genotypes in cassava: scope to substitute for chemical fertilizers and in C sequestration. *Acta Hort.*, **1118**: 193-200.

Visalakshi Chandra, C., Deo, I., Pandey, D. and Darshan, S. 2016. Molecular characterisation for blast resistant genes in rice genotypes using microsatellite markers. *The Ecoscan*., **IX**: 937-943.

Books/Book Chapters

Books

Ray, R.C. and Resell, C. M. 2016. *Microbial Enzyme Technology in Food Applications*, CRC press, Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL, 528 p.

Book Chapters

George, J. and Sajeev, M.S. 2016. Tuber crops based novel products and functional foods for improving profitability. In: *Doubling Farmers Income through Horticulture*, Chadha, K. L. et al. (Eds.). Daya Publishing House, Astral International Pvt. Ltd., New Delhi, pp. 657-664.

Koundinya, A.V.V. and Pandit, M.K. 2016. Snake gourd, taxonomy, botany, cultural practices, harvesting, major diseases and pests. In: *Hand Book of Cucurbits: Growth, Cultural Practices and Physiology*, Pessarkli, M. (Ed.), CRC Press, Taylor & Francis Group, Boca Raton, Florida, USA. ISBN: 13: 978-1-4822-3458-9.

Krishnakumar, T., Rawason, A., Sheriff, J.T., Sajeev, M.S. and Thamilselvi, C. 2016. Optimisation of ultra sound assisted extraction of starch from cassava. In: *Food and Bio Process Engineering*. Das, S.K. et al. (Eds.). Excel India Publishers, New Delhi, India, pp. 210-217.

Laxminarayana, K., Mishra, S. and Sarita, S. 2016. Good agricultural practices in tropical root and tuber crops. In: *Tropical Roots and Tubers Production, Processing and Technology.* Sharma, H.K., Njintang, N.Y., Singhal, R.S. and Kaushal, P. (Eds.), Wiley Blackwell Publishers, Singapore, pp. 183-224.

Mani, M., Kalyanasundaram, M., Jayaprakas, C.A., Harish, E.R., Sreerag, R.S. and Nedunchezhiyan, M. 2016. Tuber crops. In: *Mealybugs and their Management in Agricultural and Horticultural Crops.* Mani, M. and Shivaraju, C. (Eds.), Springer India, New Delhi, pp. 471-494.

Muthuraj, R. and Sharma, A.K. 2016. Potato seed certification. In: *Advances in Quality Potato Production and Post Harvest Management*. Pandey, N.K., Singh, D., Singh, B.P., Baswaraj, J. and Singh, B. (Eds.), pp. 284-295. ISBN:978-81-8321-425-4.

Muthuraj, R., Buckseth, T. and Pandey, K.K. 2016. Potato micropropagation through tissue culture. In: *Advances in Quality Potato Production and Post Harvest Management*. Pandey, N.K., Singh, D., Singh, B.P., Baswaraj, J. and Singh, B. (Eds.), pp. 296-304. ISBN:978-81-8321-425-4.

Panda, S.K. and Ray, R.C. 2016. Fermented foods and beverages from tropical roots and tubers. In: *Tropical Roots and Tubers: Production, Processing and Technology.* Sharma, H.K., Njintang, N.Y., Singhal,

R.S. and Kaushal, P. (Eds.). John Wiley & Sons, Ltd, Chichester, UK, pp. 225- 252.

Ray, R.C. and Behera, S.S. 2016. *Amorphophallus*: Technological Interventions, In: *Tropical Roots and Tubers: Production, Processing and Technology.* Sharma, H.K., Njintang, N.Y., Singhal, R.S. and Kaushal, P. (Eds.). John Wiley & Sons, Ltd, Chichester, UK, pp. 591- 612.

Sajeev, M.S., Edwin, K.W., Jyothi, A.N., Veena, S.S. and Sheriff, J.T. 2016. Developments of biodegradable film from enzyme modified cassava starch. In: *Food and Bio Process Engineering*, Das, S.K. et al. (Eds.). Excel India Publishers, New Delhi, India, pp. 197-209.

Sheela, M.N., George, J. and Sunitha, S. 2017. Kizhanguvilakalile Jaiva Vaividhyam. *VITHU*. Published by M.S. Swaminathan Research Foundation Community Agrobiodiversity Centre, Pothuvayal, Wayanad.

Sivakumar, P.S. 2017. Communication design for instructional media: A learner-oriented approach. In: *Emerging Trends in Communication and Essential Skill Sets of Extension Professionals for Effective Technology Transfer*, Agricultural College and Research Institute, Madurai, pp.1-9.

Suja, G. 2017. Package of Practices, Kerala. In: *Organic Farming Crop Production Guide*. Ravisankar, N., Panwar, A.S., Prasad, K., Kumar, V. and Bhaskar, S. (Eds.). Network Project on Organic Farming, ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, pp.175-184.

Course/Training Manuals

Nedunchezhiyan, M., Bansode, V.V., Chauhan, V.B.S. and Mukherjee, A. 2016. *Root and Tuber Crops Based Integrated Farming System: A Way Forward to Address Climate Change and Livelihood Improvement*. 19-26 September 2016, Regional Centre, ICAR- Central Tuber Crops Research Institute, Bhubaneswar, Odisha, India, 150 p.

Ramesh, V., Sunitha, S. and Muthuraj, R. 2016. *Orientation Training Programme on Soil Analysis*, 26-30 July 2016, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram. 126 p.

Sivakumar, P.S., Sontaki, B.S., Rasheed Sulaiman, V. and Saravanan R. 2017. *Manual on Good Practices in Extension Research and Evaluation*, Hyderabad, Agricultural Extension in South Asia. 255 p.

Popular Articles

Muthuraj, R. and George, J. 2016. Seed certification standards for production of quality planting material in lesser yam (*Dioscorea esculenta*). *ICAR-CTCRI News letter*, **33**(1): 8.

Sajeev, M.S. and Padmaja, G. 2016. Maracheeniyil Tharanira (Stardom in Tapioca). *Kerala Karshakan*, December 2016, pp.19-20.

Sajeev, M.S. and Sheriff, J.T. 2016. Cassava processing equipments. *Kalpadhenu*, April-June 2016, pp. 21-23.

Suja, G. 2017. Good companion for sustainable yield (Susthiravilavinunallakootukettu: In Malayalam). *Kerala Karshakan*, **62**(6): 52-54.

Suresh Kumar, J. 2016. Capsicum sagukasulapanta (in Telugu). *Namaste Telangana*, 11 August 2016, pp.11.

Suresh Kumar, J. 2017. Sasyarakshana chepadite uhakandani digubadi (in Telugu). *Namaste Telangana*, 9 March 2017, pp.11.

Suresh Kumar, J. 2017. Ushnatapamlonu adhika labham (in Telugu), *Namaste Telangana*, 19 January 2017, pp. 12.

Susan John, K. 2015. Soil Health Card. *ICAR-CTCRI Newsletter*, **32**(4): 10.

Susan John, K., Ravindran, C.S., George, J., Shanida Beegum, S.U. and Manikantan Nair, M. 2015. Zn Nutrition in cassava (*Manihot esculenta* Crantz). Experience from 25 years of continuous application in an Ultisol of Kerala, India. *ICAR-CTCRI Newsletter*, **32**(4): 8.

Folders/Leaflets/Pamphlets

Korada, R.R., Mukherjee, A., Pati, K., Sahoo, B.K. and Paikary, K. 2016. *Integrated Pest Management of Sweet Potato Weevil* (English). ICAR-Central Tuber Crops Research Institute, Regional Centre, Odisha, India.

Mukherjee, A., Korada, R.R., Pati, K., Sahoo, B.K. and Das, B.B. 2016. *Production Technology of Sweet Potato* (Oriya). ICAR-Central Tuber Crops Research Institute, Regional Centre, Odisha, India.

Mukherjee, A., Korada, R.R., Pati, K., Sahoo, B.K. and Das, B.B. 2016. *Production Technology of Taro* (Oriya). ICAR-Central Tuber Crops Research Institute, Regional Centre, Odisha, India.

Muthuraj, R. and Ravi, V. 2016. *Good Quality Disease Free Quality Planting Material Production of Cassava* (Tamil). ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, India. 4 p.

Suja, G., Jyothi, A.N., Seena Radhakrishnan, A.R., Lintu Maria, C. and Rakhi K. Raj. 2016. *Techniques*

for Organic Production of Tropical Tuber Crops, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India, 6 p.

Papers in Conferences/Proceedings/Symposia/ Workshop/Seminars

Abhilash, P.V., Shersha, A.S., Athulya Dev, S. and Sheela, M.N. 2016. Genetic diversity among released varieties of cassava in India. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 54.

Ambu, V., Mohan, C. and Sreekumar, J. 2016. Identification and validation of SSR and SNP markers related to mosaic disease resistance in cassava (*Manihot esculenta* Crantz). In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp.58.

Anju, P.S., Susan John, K., Bhadraray, S., Suja, G., Jeena Mathew., Nair, K. M., Sunitha, S., Veena, S.S., Renjith, B.R. and Monu, S.R. 2016. Nutrient customization for elephant foot yam intercropped in coconut gardens for the two AEU's of Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 99-100.

Aravind, M., Swetha S. Pillai., Jyothi, A. N. and Susan John, K. 2017. Grafted starch-coated urea fertilizer with sustained release properties. In: *Abstracts of Papers, 29th Kerala Science Congress*, 28-30 January 2017, Thiruvalla, Pathanamthitta, Kerala, India.

Arutselvan, R and Reddy, K. 2017. Rapid detection of tomato leaf curl Bangalore virus through loop mediated isothermal amplification assay. In: *Abstracts of Papers, International Conference, Global Perspectives in Virus Disease Management*, 7-10 December 2016, ICAR–Indian Institute of Horticultural Research, Bengaluru, Karnataka, India.

Arutselvan, R., Kamala, S. and Makeshkumar, T. 2016. Immunocapture reverse transcription loop mediated isothermal amplification for rapid detection of *Dasheen Mosaic Virus* (DsMV) without RNA extraction. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 139-140.

Asha Devi, A., Anandan, S., Khar, A., Mahajan, V. and Lawande, K.E. 2016. Application of haploidy as a technique in short day onion improvement program. In: *Souvenir and Abstract Book*, 2nd National Symposium on Edible *Alliums*: Challenges and Future Strategies for Sustainable Production, 7-9 November 2016, Jalna, Maharashtra, India.

Asha Devi, A., Ann P. George., Krishna Radhika, N. and Prakash Krishnan, B.S. 2016. Usefulness of Inter Simple Sequence Repeat (ISSR) markers in differentiating species of important aroids. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 49-50.

Asha, K.I., Sheela, M.N., Asha Devi, A., Shirly Raichal Anil, Krishna Radhika, N. and Hegde, V. 2016. Survey and collection from Joida Thaluk of Uttara Kannada - an unexplored hot spot of biodiversity of tuber crops. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 71-72.

Ashok, P., George, J. and Priyanka, A.P. 2016. Development of nutritionally rich orange-fleshed sweet potato lines - A way to increase consumer acceptance in Andhra Pradesh. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 46.

Ashok, P., George, J., Priyanka, A.P. and Rajasekhar, M. 2016. Classification and selection of edible cassava lines based on cyanide levels. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 55.

Athira Jyothy, Sheela, M.N., Irfa Anwar, Krishna Radhika, N., Prakash Krishnan, B.S. and Abhilash, P.V. 2016. Genetic diversity analysis of greater yam

(*Dioscorea alata* L.) landraces of Kerala. *Abstract Book, 1st International Agrobiodiversity Congress*, 6-9 November 2016, New Delhi, India. pp. 181.

Athira Jyothy, Sheela, M.N., Krishna Radhika, N., Irfa Anwar, Prakash Krishnan, B.S. and Abhilash, P.V. 2016. Morphological characterization of greater yam (*Dioscorea alata* L.) landraces in Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 62-63.

Bansode, V.V., Mukharjee, A., Cahuhan, V.B.S., Gowda, H. and Ray, R.C. 2016. Ensuring food security through tuber crops in tribal areas. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 24.

Benjamin, E. and Sheriff, J.T. 2016. Mechanisation in cassava cultivation in India: Present status and prospects. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 187.

Bull, S., Abraham, L., Thangaraj, M., Gruissem, W. and Vanderschuren, H. 2016. RNAi control of SLCMV in a commercially important Indian cassava cultivar. In: *Plant for Health - PSC Symposium*, 1 December 2016, Zurich, Switzerland.

Bull, S.E., Abraham, L., Abhilash, P.V., Kumar, V., Makeshkumar, T., Gruissem, W. and Vanderschuren, H.V. 2016. RNAi control of *Sri Lankan cassava mosaic virus* in a commercially important Indian cassava cultivar. In: *8th International Geminivirus Symposium and 6th International ssDNA Comparative Virology Workshop*, 7-10 November 2016, New Delhi, India.

Byju, G., Sabitha Soman, George, J. and Ravi, V. 2016. Projected changes in climate and climate suitability of elephant foot yam in major growing environments of India. In: *International Conference on Climate Change Adaptation and Biodiversity: Ecological Sustainability and Resource Management for Livelihood Security*, 8-10 December 2016, ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands, India.

Chintha, P. 2016. '*Ceropegia* species, an endemic medicinal tuberous plant: It's Ethnomedicine and Ethnopharmacology' In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 191-192.

Chithra, S., Susan John, K. and Sreekumar, J. 2016. Low cost traditional cassava starch factory solid waste (Thippi) composting: A possible strategy for organic nutrient management and economic security for tribal farmers. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp.92.

Chithra, S., Susan John, K. and Sreekumar, J. 2016. Thippi compost: A possible avenue for cassava starch factory solid waste management, crop and soil health. In: *Proceedings, Clean Up India 2016, International Conference on Contaminated Site Remediation*, Hotel Le Meridian, Coimbatore, 13-15 December 2016, pp. 335-336.

Chithra, S., Susan John, K., Sreekumar, J. 2017. Wealth from waste: Experience with cassava starch factory solid waste. In: *Extended Abstract of the 29th Kerala Science Congress*, 28-30 January 2017, Thiruvalla, Pathanamthitta, Kerala, pp. 628

Damodaran, V., Sankaran, M., Singh, L.B., Subramani, T., Jaisankar, I., George, J. and Roy, S.D. 2016. Tuber crops based farming system - a way forward for livelihood options of Nicobari Tribes in Andaman & Nicobar Islands. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 17-18.

Darshan, S., Sheela, M.N., Arya, K., Visalakshi Chandra, C., Hegde, V. and Abhilash, P.V. 2016. Genetic variability and inheritance studies in cassava F1 seedlings for cassava mosaic disease resistance. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 226.

Deepthi, D.C., Sreekumar, J., Mohan, C., Chakrabarti,

S.K and Makeshkumar, T. 2016. Field evaluation of recovery phenotypes of cassava for cassava mosaic disease based on symptom expression and virus load. In: *8th International Geminivirus Symposium and 6th International ssDNA Comparative Virology Workshop*, 7-10 November 2016, Hotel Vivanta by Taj, New Delhi, India.

Deepthy Chandran, A., Sheela, M.N., Sreekumar, J., Vidhya, P., Aswathy, G.H. Nair., Ambu, V., Keerthana, P.V. and Mohan, C. 2016. Identification of markers linked to post harvest deterioration (PPD) resistance in cassava lines. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 57.

Geethu S. Nair and Makeshkumar, T. 2016. Standardization of virus inoculation method for cassava mosaic disease. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 235.

George, J. 2016. Tribal communities - Traditional custodian of tuber crop resources in India. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 8-9.

George, J. and Sajeev, M.S. 2016. Tuber crops based novel products and functional foods for improving profitability. *7th Indian Horticulture Congress*, 15-18 November 2016, New Delhi, India.

George, J., Sunitha, S., Byju, G., Sajitha, P.K. and Sreekumar, J. 2016. Response of cassava (*Manihot esculenta*) to irrigation regimes and fertigation schedules. In: *Extended Summaries, 4th International Agronomy Congress*, 22-26 November 2016, New Delhi, India.

Giri, N.A., Anjudas., Sajeev, M.S., Sheriff, J.T. and Pradeepika, C. 2016. Production and evaluation of functional cookies using unexploited *Curcuma angustifolia* starch with millet and pulses for tribal communities. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 238-239.

Gouri Lekshmi, S.S. and Jyothi, A.N. 2016. A study on the changes in physicochemical properties of starch in cassava tubers of diverse varieties during their development. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 184.

Gouri Lekshmi, S.S. and Jyothi, A.N. 2016. Influence of tuber growth stage on the pasting and rheological properties of cassava starch. In: *Abstracts of Papers, 26th Swadeshi Science Congress*, 7-9 November 2016, ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala, India.

Haripriya, S., Sunitha, S., George, J. and Santhosh Mithra, V.S. 2016. Phenology of cassava (*Manihot esculenta* Crantz) under humid tropical conditions of Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 108.

Harish, E.R., Chellappan. M., Makeshkumar, T. and Ranjith M.T. 2016. Characterization of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) for genetic variability in cassava. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 232.

Harish, E.R., Chellappan. M., Makeshkumar, T. and Ranjith, M.T. 2016. Characterization of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) for vector-virus interactions in cassava. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp.143.

Harish, E.R., Chellappan, M., Makeshkumar, T. and Ranjith, M.T. 2016. Profiling of bacterial communities associated with cassava whitefly, *Bemisia tabaci* (Gennadius) in different agro ecological zones of Kerala, India. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal*

Communities (NCTTC-2016), 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 145.

Harish, E.R., Chellappan, M., Makeshkumar, T. and Ranjith, M.T. 2016. Differential responses of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) to virus infection in cassava. In: *International Conference of Indian Virological Society (IVS) on Global Perspectives in Virus Disease Management,* 8-10 December 2016, ICAR-*Indian Institute of Horticultural Research*, Bengaluru. pp.122-123.

Hegde, V., Makeshkumar, T., Sheela M.N., Visalakshi Chandra, C., Koundinya, A.V.V. and Darshan, S. 2016. Production of synthetic seed in cassava (*Manihot esculenta*). In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October, 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 242.

Hegde, V., Sheela, M.N., Visalakshi Chandra, C., Prakash Krishnan, B.S. and Darshan, S. 2016. Cryopreservation of cassava pollen for long-term conservation of nuclear genetic diversity. In: *Abstract Book, 1st International Agrobiodiversity Congress*, New Delhi, India. pp. 179.

Irfa Anwar, Sheela, M.N., Asha, K.I., Athira Jyothi, Prakash Krishnan, B.S. and Abhilash, P.V. 2016. Genetic diversity analysis of wild yams in India. In: *Abstract Book, 1st International Agrobiodiversity Congress*, New Delhi, India. pp. 327.

Irfa Anwar, Sheela, M.N., Asha, K.I., Athira Jyothy, Prakash Krishnan, B.S. and Abhilash, P.V. 2016. Biochemical characterisation of major wild yam species in Western Ghats. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 190-191.

Jayakrishnan, J.T. and Makeshkumar, T. 2016. Molecular phylogeography of cassava mosaic viruses in Kerala. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 234.

Jayaprakas, C.A., Abila, V.S. and Dev, N. 2016. Distribution pattern of spiralling whitefly, *Aleurodicus dispersus* (Hemiptera: Aleurodidae) in cassava (*Manihot esculenta*). In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 149.

Jayaseelan, D., Leen N. Abraham., Deepthi, D.C., Moushmi, M. and Makeshkumar, T. 2016. Friable embryogenic callus production and agrobacterium mediated transformation of farmer preferred Indian cassava cultivar, H-165. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 142.

Jeeva, M.L., Veena, S.S., Sheela, M.N., Jyothi, A.N. and Sreekumar, J. 2016. Management of anthracnose/ die-back caused by *Colletotrichum gloeosporioides* in greater yam (*Dioscorea alata* L.) In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp.138.

Jisha, S., Jayakrishnan, J.T and Makeshkumar, T. 2016. Cloning and expression of coat protein gene of *Sri Lankan cassava mosaic virus* in *Escherichia coli.* In: *International Conference on Global Perspectives in Virus Disease Management (VIROCON 2016),* 7-10 December 2016, ICAR-Indian Institute of Horticultural Research, Bengaluru.

Keerthana, P.V., Sreekumar, J., Deepthy Chandran, A., Vidya, P., Aswathy G.H. Nair. and Mohan, C. 2016. Molecular genetic diversity analysis of cassava chips line CMR-100 and its open pollinated progenies. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 56.

Korada, R.R. 2017. Management of sweet potato weevil: In: *Present Status and Future Directions in Brainstorming Session on Sweet Potato Weevil,* 4 February 2017, Regional Centre, ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha, India.

Korada, R.R. and Samantaray, T. 2016. Chemical dialogues between pests and their host plants: Special reference to their role in sweet potato pests management. In: *Souvenir, National Symposium on*

New Horizons in Pest Management for Sustainable Development Goals, 23-24 December 2016, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India. pp. 1-8.

Korada, R.R., Mukherjee, A., Srivastava, S.K. and Kistwaria, J. 2016. Tuber crops for combating malnutrition and ensuring food availability in the Zero district - Nabrangpur, Odisha. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 23.

Krishna Radhika N., Sheela M.N., Asha, K.I., Shirly Raichal Anil and Asha Devi, A. 2016. Gene prospecting in tuber crops for angiogenic effects. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 75-76.

Krishna Radhika, N., Sheela, M.N., Asha, K.I., Asha Devi, A., Shirly Raichal Anil., Jyothi, A.N. and Makeshkumar, T. 2017. Biotechnological interventions for increasing starch content in cassava. In: *Conference Document, National Conference on Frontiers in Biotechnology - Molecular, Epigenetic and Genomic Research Platforms in Healthcare and Food Security*, University of Kerala, Kerala, India.

Krishnakumar, T., Rawason, A., Sheriff, J.T., Sajeev, M.S. and Thamilselvi, C. 2016. Optimisation of ultra sound assisted extraction of starch from cassava. In: *International Conference on Emerging Trends in Agriculture and Food Engineering (ETAE 2016),* 27-30 December 2016, Indian Institute of Technology, Kharagpur, West Bengal, India.

Krishnakumar, T., Sheriff, J.T. and Sajeev, M.S. 2016. Effects of ozonation on bleaching and rheological properties of cassava starch. In*: Conference Document. National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 183.

Krishnaraj, S., Asha Devi, A. and Shirly Raichal Anil. 2016. Genetic diversity analysis in elephant foot yam accessions using morphological traits. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 66-67.

Kumar, H.K., Tadigiri, S. and Jayaprakas, C.A. 2016. Plant parasitic nematodes associated with elephant foot yam in Kerala In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp.146.

Kumar, H.K., Tadigiri, S. and Jayaprakas, C.A. 2017. Nematode problems and their management in tuber crops In: *National Symposium on Climate Smart Agriculture for Nematode Management*, 11-13 January 2017, Goa, India. pp. 79-80.

Lakshmipriya, P., Nath, V.S., Veena, S.S., Anith, K.N., Sreekumar, J. and Jeeva, M.L. 2016. *Piriformospora indica*, a cultivable endophyte for growth promotion and disease management in taro. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities,* 20-22 October 2016 *(NCTTC-2016),* ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 231.

Laxminarayana, K. 2016. Effect of inorganics and organic sources on soil quality and yield performance of elephant foot yam in Acid Alfisols. In: *National Seminar on Developments in Soil Science*, 20–23 October 2016, Gwalior, Madhya Pradesh, India.

Lintu Maria, C., Rakhi K. Raj, Surekha, R., Suja, G. and Subramanian, P. 2016. Validation of organic production technologies in cassava and yams intercropped in a coconut plantation. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 115.

Makeshkumar, T. 2016. Geminivirus problems in tropical tuber crops-Diagnosis and management strategies. In: *8th International Geminivirus Symposium and 6th International ssDNA Comparative Virology Workshop*, 7-10 November 2016, New Delhi, India.

Makeshkumar, T. and Jeeva, M.L. 2016. An insight into virus problems of tropical tuber crops. In: *Abstracts of Papers, International Conference on Global Perspectives in Virus Disease Management,* 7-10 December 2016, ICAR–Indian Institute of Horticultural Research, Bengaluru, Karnataka, India.

Mandal, R., Tarafdar, J., Mitra, S., Mukherjee, A., Mandal, N. and Mazumder, A. 2016. Morpho-genetic diversity in taro (*Colocasia esculenta* var *antiquorum* L. Schott.) and development of blight resistant markers. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 64.

Mhaskar, N.V., George, J. and Sheela, M.N. 2016. Conservation of genetic resources of tuber crops for prosperity. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 73.

Mithra, M.G. and Padmaja, G. 2016. Pre-treatment effect on the composition and ultrastructure of root crop processing residues for enhancing saccharification and fermentation. In*: NCTTC-2016 Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities,* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 177.

Mubashir, K.V., Sajeev, M.S. and Jyothi, A.N. 2016. 'Green' particle board from cassava stem using starch as bio adhesive. In*: Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 178-179.

Muthuraj, R. 2016. Techniques for quality planting material production of cassava. In: *Oral Presentation in the National Seminar for Tapioca Cultivation Technology for Growers, Extension Functionaries and Stakeholders*, 21 July 2016, Krishi Vigyan Kendra, Sandhiyur, Salem, Tamil Nadu, India.

Muthuraj, R., George, J., Sunitha, S. and Ravi, V. 2016. Effect of growth regulators and chemical treatments on dormancy breaking in elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 98-99.

Muthuraj, R., George, J., Sunitha, S., Sheela, M.N. and Makeshkumar, T. 2016. Impact of improved varieties of cassava on the socio-economic status of tribal farmers of Attappady and Wyanad of Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 27-28.

Muthuraj, R., George, J., Sunitha, S., Sheela, M.N. and Makeshkumar, T. 2016. Quality planting material production of cassava through farmers participatory approach in the Attappady and Wyanad tribal area of Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 109-110.

Muthuraj, R., George, J., Sunitha, S., Sheela, M.N. and Makeshkumar, T. 2016. Seed village programme in quality planting material production of greater yam for sustenance of tribal communities in Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 125-126.

Muthuraj, R., George, J., Sunitha, S., Sheela, M.N. and Makeshkumar, T. 2016. Seed village concept for quality planting material production of tuber crops through farmer participatory approach in Kerala. In: *Abstracts of Papers, 7th Indian Horticulture Congress 2016, Doubling Farmers Income through Horticulture*, 15-18 November 2016, ICAR-Indian Agricultural Research Institute, New Delhi. pp. 251.

Nedunchezhiyan, M., George, J., Mukherjee, A., Ray, R.C., Laxminarayana, K., Rao, K.R., Pati, K., Gowda, K.H., Chauhan, V.B.S., Bansode, V.V., Pandey, B. and Singh, A.K. 2016. Farming system models involving tuber crops for livelihood improvement of tribal farmers. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 16-17.

Neeraja, C.R., Suja, G. and Anjana Babu, R.S. 2016. Geo-referenced characterization of organic farmers

in Thiruvananthapuram, Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 116-117.

Padmaja, G. 2016. Functional foods from tuber crops. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 154-159.

Pandey, D., Visalakshi Chandra, C. and Sing, S. 2016. Evaluation and selection of rice (*Oryza sativa* L.) genotypes for yield and yield contributing characters under aerobic condition. In: *Abstract Book, 1st International Agrobiodiversity Congress*, New Delhi, India. pp. 131.

Pervez, R., Jayaprakas, C.A. and Eapen, S.J. 2016. Evaluation of bioactive principles isolated from cassava (*Manihot esculenta* Crantz) against burrowing nematode *Radopholus similis.* In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 147.

Pooja, N.S. and Padmaja, G. 2016. Alkali pretreatment coupled with non-ionic surfactant effect on the fermentable sugar yield from agricultural residues of cassava. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 181.

Pradnya, S., Gudadhe, R.P., Goriwale, Mhaskar, N.V., Khandekar, R.G., Salvi, B.R., Mahale, D.M., Mahadkar, U.V. and George, J. 2016. Varietal improvement in tropical tuber crops at Dapoli, Maharashtra. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 74.

Prakash, P., Kishore. A., Roy, D. and Behura, D. 2016. Analysis of sweet potato value chain and determinates of market options choice in selected district of Odisha. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 216.

Prakash, P., Kishore. A., Roy, D. and Behura, D. 2017. Analysis of sweet potato value chain in India: An assessment and policy implications. In: *9th Asian Society of Agricultural Economists International Conference*, 11-13 January 2017, Bangkok, Thailand.

Rakhi K. Raj, Lintu Maria, C. and Suja, G. 2016. Organic management of Chinese potato (*Plectranthus rotundifolius*): Safe and sustainable alternative. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 102-103.

Ramesh, V., Ravindran, C.S., Byju, G. and Sreekumar, J. 2016. Response of cassava under integrated soil and nutrient conservation measures in hill soils. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 107.

Renjith, R.S., Vishnu, V.R., Sheela, M.N., Shirly Raichal Anil., Sreekumar, J. and Jyothi, A.N. 2016. Anthocyanin rich greater yam and sweet potato: Nature's promising nutraceuticals. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 239-240.

Rathore, R.S., Pareek, S., Ameta, G.S. and George, J. 2016. Tuber crop cultivation in Mewar region of Rajasthan: Opportunities and challenges. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 129.

Rathore, R.S., Pareek, S., Sharma, S.K. and George, J. 2016. Performance of sweet potato entries under MLT in Mewar region of Rajasthan. In: *Conference Document, National Conference on Tropical Tuber*

Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016), 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 60-61.

Ravi, V., Saravanan, R., Byju, G. and George, J. 2016. Photosynthetic response of sweet potato [*Ipomoea batatas* (L.) Lam.] to photon flux density and elevated CO_2. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 94.

Ray, R.C. and M. Nedunchezhiyan. 2016. Biocontrol and IAA production efficacy of *Bacillus subtilis* strains isolated from cow dung in controlling post-harvest rotting and growth stimulation of yam (*Dioscorea rotundata* L.) minisetts. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 138-139.

Rekha, G.J., Makeshkumar, T. and Sreekumar, J. 2016. Computational prediction of novel microRNAs in *Amorphophallus paeoniifolius* using RNA sequence data. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 67-68.

Remya, K. and Suja, G. 2016. Conservation agriculture in banana + elephant foot yam system. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 122-123.

Remya, R. and Jyothi, A.N. 2016. Octenylsuccinylation as a method for developing slowly digestible starch and resistant starch in stem and root tuber starches. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 180.

Remya, R. and Jyothi, A.N. 2016. RS4 type resistant starch of cassava: Synthesis by chemical modification with citric acid and its characterization. In: *Abstracts of Papers, 26th Swadeshi Science Congress*, 7-9 November 2016, ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala, India.

Remya, R. and Jyothi, A.N. 2017. Effect of octenylsuccinylation and citric acid modification on resistant starch content and functional properties of sweet potato starch. In: *Abstracts of Papers, 29th Kerala Science Congress*, 28-30 January 2017, Thiruvalla, Pathanamthitta, Kerala, India.

Renjith, R.S., Vishnu, V.R., Jyothi, A.N. and Nisha, P. 2016. Effect of encapsulation on antioxidant and colorant properties of anthocyanins isolated from purple sweet potato and greater yam. In: *Abstracts of Papers, 26th Swadeshi Science Congress*, 7-9 November 2016, ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala, India.

Renjith, R.S., Vishnu, V.R., Sheela, M.N., Shirly Raichal Anil., Sreekumar, J. and Jyothi, A.N. 2016. Anthocyanin rich greater yam and sweet potato: Nature's promising nutraceuticals. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 239-240.

Reshmi, B.S., Mohan, C. and Sreekumar, J. 2016. Computational prediction of novel microRNA in cassava (*Manihot esculenta* Crantz). In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 59.

Sabarinath, V., Jibinraj, R.J., Kuriakose, M., Sujatha Kumari, N. and Sheriff, J.T. 2016. Dielectric properties of cassava (*Manihot esculenta* Crantz) tubers and their importance in the biochemical analysis. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 185.

Sajeev, M.S., Edwin, K.W., Jyothi, A.N., Veena, S.S. and Sheriff, J.T. 2016. Development of biodegradable film from enzyme modified cassava starch. In: *International Conference on Emerging Trends in Agriculture and Food Engineering (ETAE 2016)*, 27-30 December 2016, Indian Institute of Technology, Kharagpur, West Bengal, India.

Sajeev, M.S., Padmaja, G., Shanavas, S. and Sheriff, J.T.

2016. Techno-incubation centre: The way forward for entrepreneurship development in tuber crops. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 194.

Sangeetha. B.G., Jayaprakas, C.A., Jithine, J.R. and Mohandas, C. 2016. Optimization of media for antimicrobial activity of *Enterobacter* sp. associated with entomopathogenic nematode *Rhabditid* sp. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 141.

Santhosh Mithra, V.S., Abhinand, C.S., Riji Raj and Vandana, G. 2016. TOMS: SMS based online marketing system for tuber crops**.** In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 220.

Saranya, G., Vishnu S. Nath., Jeeva, M.L. and Makeshkumar, T. 2016. Mining of resistance genes associated with anthracnose infection in greater yam (*Dioscorea alata* L.). In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 227.

Saravanan, R., Roy Stephen. and Ravi, V. 2016. Modified storage methods of cassava (*Manihot esculenta* Crantz) roots on post-harvest physiological deterioration and root quality. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 196.

Saud, B.K., Alam, S., George, J., Hajarika, G.N., Talukdar, M.C., Kotoky, U. and Gogoi, B. 2016. Tuber crop based farming system: An approach to boost up livelihood of marginal farmers. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 91.

Senthil@Sankar, M., Sangeetha, B.G., Moushmi, R., Leen N. Abraham., Abilash, P.V., Sheela M.N., Vanderschuren, H. and Makeshkumar, T. 2016. Evaluation of African cassava mosaic virus resistant transgenic cassava against *Sri Lankan cassava mosaic virus*. In: *International Conference on Global Perspectives in Virus Disease Management (VIROCON 2016)*, 7-10 December 2016, ICAR-Indian Institute of Horticulture Research, Bengaluru, Karnataka, India.

Shalu, E., Sajeev, M.S., Jyothi, A.N. and Harikrishnan, R. 2016. Development of thermoplastic sheet from cassava starch. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 186.

Sheela Immanuel and Sivakumar, P.S. 2016. Livelihood analysis of tuber crops farmers. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 219.

Sheela, M.N., Abhilash, P.V., Darshan, S., Prakash Krishnan, B.S., Arun Kumar, P., Makeshkumar, T., Asha, K.I., Mohan, C., Sunitha, S., Krishna Radhika, N., Asha Devi, A. and George, J. 2016 Breeding for varieties resistant to cassava mosaic disease using different sources of resistance. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 42-43.

Sheela, M.N., Jyothy, A., Irfa, A., Krishna Radhika, N., Asha, K.I., Visalakshi Chandra**,** C**.,** Natarajan, S., Prakash Krishnan, B.S. and Abhilash, P.V. Diversity, distribution and management of yam landraces (*Dioscorea* spp.) in India. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 61-62.

Sheriff, J.T. and Sajeev, M.S. 2016. An overview of cassava processing industries in India. In: *Conference Document, National Conference on Tropical Tuber*

Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016), 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 175-176.

Shiny, R. and Byju, G. 2016. Current and future climate suitability of cassava in major growing environments of India. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 106.

Shirly Raichal Anil, Krishna Radhika, N., Vinaya, C., Lija, V. and Prakash Krishnan, B.S. 2016. Genetic diversity analysis in *Ipomoea* using morphological and ISSR markers. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 45.

Sivakumar, P.S. 2017. Supply chain management in fruits and vegetables. In: *Supply Chain Management in Agriculture and Allied Sectors*, 15 March 2017, Chadayamangalam, Kerala, India.

Sivakumar, P.S. and Sheela Immanuel. 2016. Development of a sensory lexicon for functional sweet potato pasta. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 214.

Sreekumar, J. 2016. Mapping of quantitative trait loci in cassava using Markov chain Monte Carlo (MCMC) method. In: *International Conference on Statistics & Big Data Bioinformatics*, 21-23 November 2016, International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, Andhra Pradesh, India.

Suja, G., Jyothi, A.N., Santhosh Mithra, V.S. and Sreekumar, J. 2016. Is organic production sustainable? Insights from tuber crops. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 89.

Suja, G., Jyothi, A.N., Seena Radhakrishnan A.R., Lintu Maria, C. and Rakhi, K. Raj. 2016. Organic tuber production is safe and sustainable: Overview of a decade research. In: *Abstracts of Papers, 4th International Agronomy Congress*, 22-26 November 2016, New Delhi, India. pp. 118-119.

Suja, G., Susan John, K., Anju, P.S., Jeena Mathew., Nair, K.M., Sunitha, S., Veena, S.S., Renjith, B.R. and Monu, S.R. 2016. Tribal ecosystem conservation through nutrient best management practices: Experience in tuber crops under coconut intercropping. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 117-118.

Sunitha, S. and George, J. 2017. Effect of micro irrigation on tuber yield and water productivity of cassava ((*Manihot esculenta* Crantz) under humid tropics. In: *National Conference on Micro Irrigation*, 1-3 March 2016, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Sunitha, S., George, J., Muthuraj, R., Sheela, M.N. and Makeshkumar, T. 2016. Quality planting material production of elephant foot yam through farmers participatory approach in the tribal belts of Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 97-98

Sunitha, S., George, J., Muthuraj, R., Sheela, M.N. and Makeshkumar, T. 2016. Impact of improved varieties of greater yam on the socio-economic upliftment of tribal farmers of Attappady region and Wyanad districts of Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 126-127

Sunitha, S., George, J., Muthuraj, R., Sheela, M.N. and Makeshkumar, T. 2016. Impact of elephant foot yam variety, Gajendra, on the socio–economic upliftment of tribal farmers of Kerala. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016),* ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 28-29.

Sunitha, S., George, J., Suja, G., Haripriya, S. and Sreekumar, J. 2016. Impact of irrigation schedules on corm yield and water productivity of elephant

foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). In: *Abstracts of Papers, Fourth International Agronomy Congress*, 22-26 November 2016, ICAR-Indian Agricultural Research Institute, New Delhi, India.

Suresh Kumar, J., More, S.J., Ravi, V., Byju, G. and James George. 2016. Method for leaf area estimation in yam bean (*Pachyrrhizus erosus* L.). In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 128.

Susan John K., Sheela, M.N., Shanida Beegum, S.U., Suja, G. and Ravi, V. 2016. Nutrient use efficient genotypes of cassava: A good alternative for tribal livelihood for healthy sustenance. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 90.

Tadigiri, S., Kumar, H.K. and Jayaprakas, C.A. 2016. Bioefficacy of cassava based biopesticide against *Meloidogyne incognita* under *in vitro* conditions. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 148.

Veena, S.S., Misra, R.S. and Jeeva, M.L. 2016. Progress and prospects of collar rot management in elephant foot yam. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 137.

Vikas, V.K., Jayaprakas, C.A., Sivasamy, M., Ajesh, G., Kumar, P.S. and Rajeswari, L.S. 2016. *Manihot esculenta* Crantz: A potential source for mining insecticidal molecules for the management of *Sitophilus oryzae* L. in stored wheat grain (*Triticum aestivum* L.). In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 236.

Visalakshi Chandra, C., Sheela, M.N., Raju, S., Mohan, C., Hegde, V., Darshan, S. and Vijayan, A. 2016. Characterization and identification of genotypes for tolerance to post-harvest physiological deterioration in cassava. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 233.

Vishnu S. Nath., Shyni, B., Jeeva, M.L. and Veena, S.S. 2016. Novel technologies for mining resistance in tropical tuber crops. In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 75.

Vishnu, V.R., Renjith, R.S., Jyothi, A.N. and Sheela, M.N. 2016. Anthocyanins from purple-fleshed greater yam (*Dioscorea alata*): Structure and *in vitro* anticancer studies. In: *Abstracts of Papers, 26th Swadeshi Science Congress*, 7-9 November 2016, ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala, India.

Vishnu, V.R., Renjith, R.S., Suja, G. and Jyothi, A.N. 2016. Phytochemical analysis of phenolics and terpenoids in Chinese potato (*Plectranthus rotundifolius*). In: *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 240-241.

Conference Document

Sheela Immanuel, Suja, G., Krishna Radhika, N., Jeeva, M.L., Namrata Ankush Giri, Prakash, P. Pradeepika Chintha, Koundinya, A.V.V., Saravanan R., Sreekumar, J. and Muthuraj, R. 2017. *Conference Document, National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)*, 20-22 October 2016, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, 242 p.

Lecture Notes in Short Courses

Chauhan, V.B.S., Mukherjee, A., Pati, K., Gowda, H. and Bansode, V.V. 2016. Low cost protected cultivation of vegetable crops for sustainable farm income. In: *Root and Tuber Crops Based Integrated Farming System: A Way Forward to Address Climate Change and Livelihood Improvement*. 19-26 September

2016, Regional Centre, ICAR-Central Tuber Crops Research Institute, Bhubaneswar. pp. 41-46.

Jyothi, A. N. 2016. Industrial products from tuber crops. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops,* , Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August – 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Muthuraj, R. 2016. Quality planting material production in tuber crops. In*: Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August – 9 September 2016, ICAR–Central Tuber Crop Research Institute, Kerala, India. pp. 288-300.

Muthuraj, R. 2016. Role of soil quality for quality planting material production of tuber crops. In: *Training Manual, Orientation Training Programme on Soil Analysis*, 12-16 June 2016, ICAR–Central Tuber Crop Research Institute, Thiruvananthapuram, Kerala, India. pp. 122-126.

Muthuraj, R. 2016. Role of soil quality for quality planting material production of tuber crops. In: *Training Manual, Orientation Training Programme on Soil Analysis*, 26-30 June 2016, ICAR–Central Tuber Crop Research Institute, Thiruvananthapuram, Kerala, India. pp. 122-126.

Muthuraj, R. 2016. Role of soil quality for quality planting material production of tuber crops. In: *Training Manual, Orientation Training Programme on Soil Analysis*, 27 September – 1 October 2016, ICAR–Central Tuber Crop Research Institute, Thiruvananthapuram, Kerala, India. pp. 122-126.

Muthuraj, R. 2016. Role of soil quality for quality planting material production of tuber crops. In: *Training Manual, Orientation Training Programme on Soil Analysis*, 1-5 November 2016, ICAR–Central Tuber Crop Research Institute, Thiruvananthapuram, Kerala, India. pp. 122-126.

Nedunchezhiyan, M., Jata, S.K., Gowda, K.H., Chauhan, V.B.S., Bansode, V.V. and Mukherjee, A. 2016. Livelihood improvement through tuber crops based integrated farming system. In: *Root and Tuber Crops Based Integrated Farming System: A Way Forward to Address Climate Change and Livelihood Improvement*. ICAR-CTCRI, Regional Centre, Bhubaneswar, pp. 22-34.

Pati, K., Mukherjee, A. and Chauhan, V.B.S**.** 2016. Tuber crop varieties for integrated farming system. In: *Root and Tuber Crops Based Integrated Farming System: A Way Forward to Address Climate Change and Livelihood Improvement*. ICAR-Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar. pp. 47-50.

Pradeepika, C. 2016. Emerging technologies in tuber crops processing: Vacuum frying and near infrared spectroscopy. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August – 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. pp. 258-264.

Sajeev, M.S. and Padmaja, G. 2016. Entrepreneurship development in tuber crops. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August - 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Sajeev, M.S. 2016. Textural qualities of food products-concepts and measurements. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August - 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Sajeev, M.S. and Jyothi, A.N. 2016. Starch: a potential raw material for biodegradable packaging films. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August - 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Sajeev, M.S. and Sheriff, J.T. 2016. Technology for the production of cassava starch, sago and wafers. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August - 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Sajeev, M.S., Padmaja, G. and Sheriff, J.T. 2016. Techno-Incubation Centre (CTCRI-SFAC Venture): Creating entrepreneurship in tuber crops. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August - 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Sajeev, M.S., Sheriff, J.T. and Nanda, S.K. 2016. Secondary processing equipments in tuber crops. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August - 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Sheriff, J.T. 2016. Quality and standardisation of cassava products. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August - 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Sheriff, J.T., Sajeev, M.S. and Nanda, S.K. 2016. Primary processing equipment for cassava. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August-9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Sheriff, J.T. and Sajeev, M.S. 2016. Extruded snacks from tropical tuber crops. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August - 9 September 2016, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Suja, G. 2016. Best agronomic practices for quality tuber crop production. In: *Training Manual, ICAR Sponsored Short Course on Processing Machineries, Product Diversification and Entrepreneurship Development in Tuber Crops*, Sajeev, M.S. Sheriff, J.T. and Jyothi, A. N. (Eds.), 31 August-9 September 2016, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala.

Institute Publications

Annual Report of ICAR – CTCRI, 2015-16 (Bilingual).

Annual report of AICRP on Tuber Crops, 2015 – 2016.

Research Highlights of ICAR – CTCRI, 2015-2016.

ICAR-CTCRI News Letter – December 2015; March, June 2016 (Bilingual).

42nd Annual Institute Research Council Meeting: Proceedings and Activity milestones, ICAR-CTCRI, 2016-2017.

43rd Annual Institute Research Council Meeting, Salient Achievements, ICAR-CTCRI, 2016- 2017.

Technical Report of the 16th Annual Group Meeting of AICRP on Tuber Crops held at Bidhan Chandra Krishi Viswavidyalaya, Kalyani.

Proceedings of the Midterm Review Meeting of AICRP on Tuber Crops, 2016, held at ICAR-CTCRI, Thiruvananthapuram.

Radio Talks

Sheela Immanuel. 2016. A talk on 'Outreach activities of ICAR-CTCRI' at AIR, Thiruvananthapuram on 31 May 2016.

Sheela Immanuel. 2016. A talk on 'Food security through tuber crops' at AIR, Thiruvananthapuram on 17 March 2017.

Suja, G. 2016. A talk on 'Cassava and pulses (Maricheeniyumpayarvargangalum)', at AIR, Thiruvananthapuram on 22 September 2016.

Suja, G. 2017. Interview on 'Elephant foot yam: Improved varieties and scientific practices for better yield (Chena : Ulpathanakshamathayarnnainangalum, sastheeriyaparicharanavum)', at AIR, Thiruvanantha-puram on 10 March 2017.

Susan John, K. 2016. A talk on 'Significance of leguminous crops in relation to soil health' at AIR, Thiruvananthapuram on 9 May 2016.

Susan John, K. 2016. Interview on 'Intercropping of pulses in cassava' at AIR, Thiruvananthapuram on 28 August 2016.

Susan John, K. 2017. Interview on 'Nutrient management of crops: New approaches', at AIR, Thiruvananthapuram on 14 February 2017.

Ongoing Projects

Institute projects

Sl. No.	Project code	Project title	PI	C0-PIs
1	HORTICARCTCRI SIL2015 001 01457	Conservation and utilization of germplasm of tuber crops for sustaining production	M.N. Sheela	Archana Mukherjee, K.I. Asha, C. Mohan, A. Asha Devi, Shirly Raichal Anil, N. Krishna Radhika, Kalidas Pati, T. Makeshkumar, M.L. Jeeva, S.S. Veena, H. Kesava Kumar, V.B.S. Chauhan, K. Hanume Gowda, Vivek Hegde, C. Visalakshi Chandra, J. Sreekumar, A.N. Jyothi
2	HORTICARCTCRI SIL2015 001 01458	Genetic improvement of tuber crops through conventional breeding and molecular approaches	Archana Mukherjee	M.N. Sheela, K.I. Asha, C. Mohan, A. Asha Devi, Shirly Raichal Anil, N. Krishna Radhika, Kalidas Pati, T. Makeshkumar, M.L. Jeeva, S.S. Veena, R.C. Ray, M. Nedunchezhiyan, K. Laxminarayana, Rajasekhar Rao Korada, V.B.S. Chauhan, K. Hanume Gowda, Vivek Hegde, C. Visalakshi Chandra, J. Sreekumar, A.N. Jyothi, S. Sunitha, G. Suja, V. Ravi, Saravanan Raju
3	HORTICARCTCRISIL 2015 003 01459	Integrated crop, water and nutrient management for improving productivity of tropical tuber crops	G. Byju	James George, R. Muthuraj, G. Suja, M. Nedunchezhiyan, S. Sunitha, K. Laxminarayana, V. Ramesh, T. Makeshkumar, M.N. Sheela, Archana Mukherjee, A. Asha Devi, Saravanan Raju, S.S. Veena, J. Sreekumar, V. Ravi, A.N. Jyothi, V.S. Santhosh Mithra, V.K. Dua (ICAR-CPRI, Shimla), Madhumita Das (ICAR-IIWM, Bhubaneswar)
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	James George, G. Byju, Saravanan Raju, N. Krishna Radhika, R. Muthuraj, Prince Kumar, (ICAR-CPRI, Regional Station), V.S. Santhosh Mithra, G. Suja, V. Ramesh, M.N. Sheela, V.K. Dua, (ICAR-CPRI, Shimla), K. Laxminarayana

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, H. Kesava Kumar, Sirisha Tadigiri, B.G. Sangeetha, E.R. Harish, S.S. Veena, J. Sreekumar
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	S.S. Veena, M. Nedunchezhiyan, G. Byju, A.N. Jyothi, K.I. Asha, V.S. Santhosh Mithra, T. Makeshkumar, R. Arutselvan, Sirisha Tadigiri
7	HORTICARCTCRISIL 2015 007 01463	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, Pradeepika Chintha, P.S. Sivakumar, P. Prakash
8	HORTICARCTCRI CIL 2015 008 01464	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, V.S. Santhosh Mithra, P. Sethuraman Sivakumar, M.N. Sheela, P. Shinoj J. Sreekumar, G. Suja, Vivek Hegde
9	HORTICARCTCRI SIL2015 009 01465	Cassava mosaic disease-variability, diagnostics, vector relation and management	T. Makeshkumar	M.L. Jeeva, B.G. Sangeetha, E.R. Harish, C. Mohan, J. Sreekumar, C.A. Jayaprakas, K. Susan John, S. Sunitha, R. Muthuraj, Vivek Hegde, Saravanan Raju, James George, R. Arutselvan
10	HORTICARCTCRI SIL2015 010 01466	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, J.T. Sheriff , P.S. Sivakumar, K. Susan John, P. Prakash

Externally aided projects

Sl. No	Title	PI	Co-PIs	Funding agency
1	Adapting clonally propagated crops to climatic and commercial changes	Archana Mukherjee	J. Sreekumar	European Union
2	Development of standards of DUS testing and establishment of 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	Consortium research project (CRP) on agro-biodiversity	M.N. Sheela	K.I. Asha, A. Asha Devi, Shirly Raichal Anil, N. Krishna Radhika, Vivek Hegde	ICAR
5	Tuber crops development project, Kerala: Area expansion of tuber crops using quality planting materials	James George	S. Sunitha, R. Muthuraj, M.N. Sheela, T. Makeshkumar, M.S. Sajeev, Sheela Immanuel	Department of Agriculture, Govt. of Kerala
6	Climate smart natural resource management of cassava (*Manihot esculenta* Crantz) using geoinformatics tools	G. Byju	-	Kerala State Council for Science, Technology and Environment, Govt. of Kerala
7	Network Project on Organic Horticulture (NPOH)	G. Suja	S. Sunitha, V. Ramesh, A.N. Jyothi, P. Subramanian	ICAR- Indian Institute of Spices Research, Kozhikode
8	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
9	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
10	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

11	Establishment of Techno-Incubation Centre at the ICAR-Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar for the commercialization of value added products from sweet potato and other tuber crops	M. Nedunchezhiyan	R.C. Ray, M.S. Sajeev, V. Bansode	Rashtriya Krishi Vikas Yojana
12	Outreach programme on the management of sucking pests in horticultural crops	C.A. Jayaprakas	-	ICAR
13	Participatory technology transfer of cassava based biopesticides for the management of vegetable pests	C.A. Jayaprakas	-	Department of Agriculture, Govt. of Kerala
14	PhytoFuRa: Leaf blight of taro	M. L. Jeeva	S. S. Veena	ICAR network (IISR outreach project)
15	Indo – Swiss cassava network	T. Makeshkumar M.N. Sheela	E.R. Harish, B.G. Sangeetha, C. Visalakshi Chandra	Indo-Swiss Collaboration in Biotechnology, (ISCB), Swiss Agency for Development & Co-operation, Bern and New Delhi and Department of Biotechnology, Govt. of India, New Delhi
16	CRP on vaccines and diagnostics	T. Makeshkumar	M.L.Jeeva, R. Muthuraj, K.I. Asha, R. Arutselvan	ICAR
17	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, New Delhi
18	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
19	Consultancy project on integration of sweet potato production and processing in Belgaum	J.T. Sheriff	M.S. Sajeev, A.N. Jyothi, P. Sethuraman Sivakumar, Namrata Ankush Giri	M/S Belgaum Minerals, Belgaum
20	ICAR-EMR project on establishment of mechanized cassava and sweet potato model farms	J.T. Sheriff	M.S. Sajeev, G. Suja	ICAR

21	High value compounds/ Phytochemicals	A.N. Jyothi	J. Sreekumar, Shirly Raichal Anil	ICAR
22	Development and evaluation of starch based functional polymers for controlled plant nutrient delivery	A.N. Jyothi	M.S. Sajeev, K. Susan John	Kerala State Council for Science, Technology and Environment, Govt. of Kerala
23	Techno-Incubation centre	M.S. Sajeev	J.T. Sheriff A.N. Jyothi Namrata Ankush Giri	SFAC, Govt. of Kerala
24	Rural entrepreneurship development though training cum demonstration of value added products in tuber crops	M.S. Sajeev	G. Padmaja	KSCSTE-BIRD Project, Govt. of Kerala
25	Developing models for predicting commercialisation potential of functional foods from starchy staples	P. Sethuraman Sivakumar	Sheela Immanuel	ICAR Extramural Research Project - Extension
26	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
27	Tribal Sub Plan 'Livelihood improvement of tribal farmers through tuber crops technologies'	M. Nedunchezhiyan	Archana Mukherjee, R.C. Ray, K. Laxminarayana, K. Rajasekhara Rao, Kalidas Pati, J.T. Sheriff, M.S.Sajeev, ORRISSA (NGO), Kandhamal, PRAGATI (NGO), Koraput, SOVA (NGO) Ramakrishna Mission, Ranchi, Jharkhand, Dr. Brijesh Pandey Dr. Ajeet Kumar Singh Ramakrishna Mission, Naranyanpur, Chhattisgarh	ICAR

Institute Research Council, Research Advisory Committee, Institute Management Committee

Institute Research Council

The 43rd Annual Institute Research Council

The 43rd meeting of the Annual Institute Research Council of ICAR-CTCRI was held during 23-25 March, 2017 at the Millennium Hall of ICAR-CTCRI. The meeting was chaired by Dr. James George, Director (Acting) on 23 March 2017 and Dr. Archana Mukherjee, Director during 24-25 March 2017. All the scientists from head quarters and Regional Centre attended the meeting. Dr. Saravanan Raju, Member Secretary, IRC welcomed the chairman and all the scientists especially the newly joined scientists. He gratefully acknowledged the efforts of Dr. James George, Director (Acting) for chairing the pre-IRC meetings conducted during 16 to 18 March 2017 and actively discussed the research activities in various projects with ICAR-CTCRI scientists as well as with the scientists of RC through video conferencing. He congratulated the ICAR-CTCRI scientists, who bagged awards and recognitions during 2016-2017.

Dr. James George, Director (Acting), in his opening remarks appreciated all the scientists for contributing towards tuber crops research. He referred to the achievements of the Division of Crop Improvement for releasing more than 53 different varieties of tuber crops since the inception of the institute. He also proposed to form a Biotech core group to take up challenging research in the area of biotechnology. The contribution of Division of Crop Production in generating various package of practices especially on organic farming and INM and other production technologies for improving the productivity of tuber crops was specially mentioned. The bio-pesticides and other technological interventions of Crop Protection Division were also highlighted. He also stressed that the problem of CMD was a serious threat and suitable protection technologies were to be developed for the management of CMD and its vector. The various value addition technologies and products developed by Crop Utilization Division enhanced the visibility of ICAR-CTCRI. He wished the Division to take up bio-ethanol production to pilot-scale considering its importance. He stressed the need for strengthening the extension activities for transferring tuber crop technologies to farmers and creation of model farms in MGMG villages. He wished that the 43rd IRC meeting would actively discuss the research issues and come out with valid recommendations to improve the R & D activities of the institute.

Dr. G. Suja, Member Secretary, RAC, made a presentation of RAC recommendations on 23 March 2017. There were totally 10 ongoing institute projects, which were presented by the PIs, which covered 56 activities under four Divisions and one section viz., Crop Improvement, Crop Production,

43rd Annual Institute Research Council Meeting

Crop Protection, Crop Utilisation and Extension and Social Sciences. Heads of Divisions presented the overall achievements of their Division. Twelve new and one collaborative activity were presented by the respective activity leaders. All the projects were thoroughly discussed and the suggestions were recorded and documented in the proceedings. Dr. Archana Mukherjee in her concluding remarks expressed happiness about the successful conduct of the 43rd IRC and appreciated the young scientists, who have presented the new activities. She also appreciated the work of Dr. R.C. Ray, Principal Scientist (Microbiology), Regional Centre, ICAR-CTCRI who will be superannuating in September 2017, for his commendable work and contributions made in various value added products and pickles from tropical tubers.

Research Advisory Committee

The third meeting of RAC VII was held during 22-23 February 2017 in the Millennium Hall, ICAR-CTCRI. Dr. P. Rethinam, Former ADG, ICAR, chaired the meeting. The following members were present:

1. Dr. Umesh Srivastava, Former ADG, Hort. Sci., ICAR
2. Dr. P.S. Naik, Former Director, ICAR-IIVR
3. Dr. V.G. Malathi, Adjunct Faculty & Emeritus Scientist, TNAU
4. Dr. D. Sreenivasa Murthy, Principal Scientist, ICAR-IIHR
5. Dr. James George, Director (Acting), ICAR-CTCRI
6. Dr. Suja G., Principal Scientist, ICAR-CTCRI (Member Secretary)

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

Dr. Suja, G., 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, technologies commercialized, publications, infrastructure developed, equipment procured, planting material production, field level demonstrations/OFTs conducted and other general activities like MGMG and Swachh Bharath. Dr. James George, Project Co-ordinator, AICRP on Tuber Crops also briefed about the activities and achievements of AICRP on tuber crops. The Techno-Incubation Centre of ICAR-CTCRI was well appreciated by the chairman and members.

The Chairman and members of RAC gave their preliminary observations. The highlights of the suggestions in the opening remarks are:

- The importance of reducing the germplasm by removing the duplicates was highlighted. Characterization of germplasm should be completed in a time frame. More exploration trips need to be undertaken to Bastar to collect maximum germplasm.
- A Technical Bulletin on Tuber crops based cropping system/farming system should be brought out by AICRP.
- At least 50-60% of time needs to be devoted for proper planning of research programmes.
- Studies on impact of climate change on tuber crops to be strengthened.
- Top priority to be given for production of virus free planting material of cassava and development of diagnostic kits.
- Greater focus should be given on the science part of CMD resistance.
- The RAC appreciated the efforts of scientists in the development of value added products from tuber crops. Product display along with TEFR is needed for further promotion.
- A retrospective of basic research undertaken so far and the gaps in basic research to be identified. Basic research also needs to be strengthened.
- Greater emphasis for conservation and efficient use of water and nutrient resources, viz., more crop per drop, drip irrigation with mulching, water harvesting techniques, use of SAP for water conservation, use of low cost inputs, reducing the use of inorganic fertilizers, converting naturally available biomass (Glyricidia, cowpea, sunhemp) into organic fertilizer, organic residue recycling.

- Water harvesting possibilities of Andaman model may be looked into and replicated at CTCRI to solve the water shortage especially during summer months. Deepening of wells to be done on a priority basis for this.
- Efforts for doubling the income of farmers by 2021, by way of technologies for higher productivity and higher price as well as reducing production costs, is required. Minimum processing with more value addition will also help a great deal in this regard.

The action taken report of the second 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 26 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:

In situ vermi composting

More crop per drop: Drip irrigation in taro

Field visit of RAC chairman and members

Recommendations

Crop Improvement

- There is a need to explore Odisha (Kalahandi, Dhenkanal, Kandhamal, Rayagoda, Jagatsinghpur and Kendrapara areas), Central, South Central and Western parts of Bastar (Antagarh, Abujhmarh, Dhaudai, Narayanpur, Bijapur, Bhopalpatnam, Jagargunda, Sukma, Bailadila, Dentewada and Tirthgarh area) and parts of NEH for collection of different striking germplasm of tuber crops.
- Digitization of old catalogues to be done on a priority basis. IC numbers should be obtained for very old collections also, which are used as breeding lines. EC numbers of the lost ones to be obtained from NBPGR. The entire germplasm should be characterized at the headquarters and Regional Centre/AICRP centres, core set may be developed and detailed evaluation of crop wise core collections (each lot for at least for 2 years) based on acceptable traits may be completed in a phased manner by 2020. Crop wise evaluation schedule may be prepared in consultation with AICRP Centres. Molecular characterization may be taken on core set germplasm only.
- The CMD resistant lines identified may be used for raising mapping population. Markers may be identified using genome information and

RAC meeting in progress (top) and Dr. P. Rethinam, RAC chairman being honoured (bottom)

validated. Markers for low cyanide varieties are to be developed.

Crop Production

- Since heavy metal analyses of soil and tubers under the activity "Assessment of micronutrients and heavy metal contaminants in tuber crops based cropping systems adjacent to mines and industrial areas of Odisha'' has not yet been done, the objectives and technical programme of the activity may be redefined in the forthcoming IRC. Since infrastructure is not available in our institute, the heavy metal analysis may be got done, where facilities are available.
- The data generated from remote sensing should be checked with the ground data. Efforts may be made to strengthen research on soil nutrient and water management for mitigation/adaptation to climate change.

Crop Protection

- Studies on epidemiology and ecological factors contributing to disease development may be systematically done for leaf blight in taro and repeated for mosaic in cassava. Full genome sequencing of at least 2 or 3 isolates of *Phytophthora colocasiae* may be done. The data on actual field spread of CMD after distribution of disease free material in Kerala and in AICRP Centres may be generated. During survey, information on other surrounding crops may also be collected. Data on whitefly and disease incidence may be obtained from AICRP Centres.
- Collaboration with other ICAR institutes to establish the efficacy of cassava based biopesticides against the major pests of national importance is needed. Studies on compatibility of cassava based biopesticides with other pesticides/fungicides may be undertaken. The nematicidal activity of *Trichoderma* spp and PGPRs may be explored in the field and work in this direction may be intensified.

Crop Utilization

- The possibilities of using coir fibre in making cassava starch based particle boards/mulch may be explored. Technology for using cassava starch for encapsulation of pharmaceutical tablets may be intensified. Cost-benefit ratio may be worked out while developing value added products. Efforts should be intensified for developing high value products.

Visit of RAC chairman and members to techno-incubation centre

Extension and Social Sciences

- The title of the institute project no. 8, "Improving knowledge and skill of stakeholders for sustainable production of tuber crops" may be modified considering the nature of research activities, in the forthcoming IRC. Cost:benefit analysis of FLD/demonstrations needs to be worked out. Impact studies on livelihood improvement of farming system models involving tuber crops for tribal farmers may be taken up after 3-5 years as a follow up study.
- At least 50 tuber crop based model farms is to be laid out in collaboration with AICRP for doubling the income.
- Socio-economic impact analysis of released varieties and technologies needs to be further strengthened by estimating overall benefit as well as returns to research investment in tuber crops.

Advisory Note

- A quarantine facility with equipment and manpower need to be established so that biosafety is ensured.
- There is a need to take up basic studies on (a) White fly genotypes specific to cassava, their transmission and characteristics in comparison

to others (b) Genetics of CMD resistance, looking for different resistance genes and explore markers for it.

- Capacity building and training may be arranged in the areas of genomics, genome editing and development of markers for specific traits.
- Possibilities of displaying ethnic products from tuber crops in the various national airports of our country may be explored in consultation with the concerned airport authorities.
- Possibilities of exploiting the biofuel potential and medicinal value of tuber crops may be explored.

The RAC finally appreciated the commendable work done by Dr. James George, Director and Dr. G. Suja, Member Secretary.

Institute Management Committee

- The XIV Institute Management Committee Meeting of ICAR-Central Tuber Crops Research Institute was held on 29th November 2016 under the Chairmanship of Dr. James George, Director (Acting), ICAR-CTCRI, Thiruvananthapuram, in the conference hall and the following Members/Dignitaries/Officers attended the meeting.

Dr. James George Director, ICAR-CTCRI, Thiruvananthapuram	Chairman
Dr. V. Krishnakumar, Head, RC of ICAR-CPCRI, Kayamkulam, Kerala	Member
Dr. P. Sivarama Bhat, Principal Scientist, ICAR-IIHR, Bangalore	Member
Dr. P. Murugesan, Principal Scientist & SIC, IIOPR Regional Station, Palode	Member
Dr. M. Nedunchezhiyan, Principal Scientist, ICAR-CTCRI Regional Centre, Bhubaneswar	Member
Dr. (Mrs.) M.N. Sheela, Head, Division of Crop Improvement, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
Dr. C.A. Jayaprakas, Head, Division of Crop Protection, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
Dr. V. Ravi, Head, Division of Crop Production, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
Dr. (Mrs.) Sheela Immanuel, Head, Section of Extension & Social Sciences, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
Dr. G. Byju, Principal Scientist & SIC (PME), ICAR-CTCRI, Thiruvananthapuram	Special Invitee
Dr. M.S. Sajeev, Principal Scientist & SIC (E&M), ICAR-CTCRI, Thiruvananthapuram	Special Invitee
Dr. J. Sreekumar, Principal Scientist & SIC (Farm), ICAR-CTCRI, Thiruvananthapuram	Special Invitee
Smt. R. Sari Bai, FAO, ICAR-CTCRI, Thiruvananthapuram	Special Invitee
Shri. Davis Joseph, Senior Administrative Officer, ICAR-CTCRI, Thiruvananthapuram	Member Secretary

At the outset, Chairman of the IMC & Director, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, welcomed all the members present in the XIV Institute Management Committee Meeting of the Institute. 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 research achievements, since the last IMC meeting. This was followed by a brief presentation of the minutes of the previous meeting held on 31.10.2015 by the Member Secretary. The action taken on each item during the previous meeting was read out by the Member Secretary, which was approved by the House. The Finance & Accounts Officer presented the Plan BE/RE of 2016-2017, the Non-Plan RE 2016-2017 and Progressive Expenditure during the financial year 2016-2017.

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

Programme	Particulars of the Programme	Name of the participants
International Conference on Recent Advances in Food Processing & Biotechnology	Banaras Hindu University, Varanasi, 5-6 April 2016	Mrs. Namrata Ankush Giri
State Level Executive Committee Meeting for Soil Health	Rajiv Bhawan, Dept. of Agriculture & Farmers' Empowerment, Govt. of Odisha, 8 April 2016	Dr. K. Laxminarayana
Meeting for the revision of IPM package of practices of cassava for the Ministry of Agriculture and Farmers' Welfare	National Institute of Plant Health Management, Hyderabad, 13 April 2016	Dr. C.A. Jayaprakas Dr. K. Susan John
Review Meeting of Indian Council of Agricultural Research	Munnar, Kerala, 16 April 2016	Dr. James George Dr. G. Byju
Annual Review Workshop of KVK Zone VIII	Krishi Vigyan Kendra, Ambalavayal, Wayanad, Kerala, 21 April 2016	Dr. G. Suja
Workshop on Enhancing the Economic Viability of Coconut Based Cropping Systems for Land Use Planning in Kerala State	National Bureau of Soil Survey and Land Use Planning, Bengaluru, 21-22 April 2016	Dr. K. Susan John Dr. S. Sunitha
16th Annual Group Meeting of All India Coordinated Research Project on Tuber Crops	Bidhan Chandra Krishi Viswavidyalaya, Kalyani, 24 – 26 May 2016	Dr. James George Dr. S. Sunitha Dr. T. Makeshkumar Dr. M.N. Sheela Dr. V. Ravi Dr. G. Byju Dr. Sheela Immanuel Dr. C.A. Jayaprakas Dr. R. Muthuraj Dr. M.S. Sajeev Dr. Asha Devi Dr. J. Sreekumar Dr. V.S. Santhosh Mithra Dr. Shirly Raichal Anil
Workshop on Pulses for Sustainable Agriculture and Human Health	International Food Policy Research Institute, South Asia Office, New Delhi, 31 May-1 June 2016	Mr. P. Prakash
Review Meeting of CRP on Vaccines and Diagnostic	Indian Veterinary Research Institute, Bengaluru, 16 – 17 June 2016	Dr. T. Makeshkumar
H.H. Sree Visakham Thirunal Endowment Lecture	ICAR- Central Tuber Crops Research Institute, Thiruvananthapuram, 17 June 2016	All scientists
Hindi Workshop	ICAR- Central Tuber Crops Research Institute, Thiruvananthapuram, 20 June 2016	All scientists
Yoga Day	ICAR- Central Tuber Crops Research Institute, Thiruvananthapuram, 21 June 2016	All scientists

Workshop on Tuber Crops Technology Transfer and Commercialization	ICAR- Central Tuber Crops Research Institute, Thiruvananthapuram, 25 June 2016	Dr. M.L. Jeeva Mr. E.R. Harish Dr. H.Kesava Kumar Ms. Sirisha Tadigiri
Pradhan Manthri Fasal Bima Yojana Technology Week Celebrations	KVK, Kumarakom, Kottayam, Kerala, 29 June 2016	Dr. G. Suja
Performance Review Meeting of ICAR-CTCRI by Parliamentary Committee	Indian Council of Agricultural Research, New Delhi, 30 June 2016	Dr. James George
Workshop on Horticulture for East Coast	Regional Centre, ICAR – Central Tuber Crops Research Institute, Bhubaneswar, 1 July 2016	Dr. James George
Discussion Meet on IPR Policy and National Workshop on IPR and its Enforcement organized by Kerala State Council for Science, Technology and Environment (KSCSTE) and Technology Information, Forecasting and Assessment Council (TIFAC)	Thiruvananthapuram, 14-15 July 2016	Dr. Saravanan Raju
RAC Meeting of All India Radio	Thiruvananthapuram, 19 July 2016	Dr. Sheela Immanuel
Sensitizing Seminar on Production Technologies for Cassava to 100 Farmers of Salem District	Krishi Vigyan Kendra, Santhiyur, Salem, Tamil Nadu, 21 July 2016	Dr. M.N. Sheela, Dr. G. Byju, Dr. S. Sunitha, Dr. R. Muthuraj
4th Lecture Programme in the Biotechnology Lecture Series on *In Vitro* Biology: Strategies of Kew 2015-2020	Kerala Biotechnology Commission and Kerala State Council for Science, Technology and Environment, Thiruvananthapuram, 5 August 2016	Dr. A. Asha Devi
State Farmers Day Celebrations	Andoorkonam Krishi Bhavan, 17 August 2016	Dr. Sheela Immanuel
XI Annual Group Meeting of the Network Project on Organic Farming (NPOF)	ICAR-Indian Institute of Soil Science, Bhopal, 17-19 August 2016	Dr. G. Suja
Tribal Farmers Seminar	River Research Centre, Vazhachal, Thrissur, 20 August 2016	Dr. S. Sunitha
Group Meeting of All India Coordinated Research Project on Potato	ICAR – Central Potato Research Institute, Shimla, 21 August 2016	Dr. James George
SAC Meetings	Krishi Vigyan Kendra, Mitraniketan, 26 August 2016	Dr. Sheela Immanuel
Review Meeting of Indo-Swiss Cassava Network Project	Tamil Nadu Agricultural University, Coimbatore, 29-31 August 2016	Dr. T. Makeshkumar
Biopreneurs Meet on Growing Beyond the Future Through Life Science Innovations	Kerala State Industrial Development Corporation, Hotel Mascot, Thiruvananthapuram, 6 September 2016	Dr. Sheela Immanuel Mr. P. Prakash
Special Meeting with the High Level Technical Delegation from Thailand	Department of Agriculture and Cooperation, Ministry of Agriculture, Indian Council of Agricultural Research, Krishi Bhavan, New Delhi, 6 September 2016	Dr. James George
3rd Asian Food Safety and Security Association Conference	Kalinga Institute of Industrial Technology, Bhubaneswar, 15-17 September 2016	Dr. R. C. Ray Mr. Venkatraman Bansode

SAC Meeting	Krishi Vigyan Kendra, Tirupathisarem, 17 September 2016	Dr. Sheela Immnauel
Zonal Workshop on Food & Agriculture	Bhubaneswar, 19 September 2016	Dr. Archana Mukherjee
Farmers Program on Tropical Tuber Crops Development	Department of Agriculture Development and Farmers' Welfare, West Elari, Nileswar, 22 September 2016	Dr. T. Makeshkumar
Meeting of Central Variety Sub-Committee for Horticulture Crops	Indian Council of Agricultural Research, Pusa, New Delhi, 22 September 2016	Dr. James George
Pre-Rabi Discussion on the Scientist-Extension Interface at Communication Centre	Mannuthy, Thrissur, Kerala, 23 September 2016	Dr. K. Susan John
Review Meeting of Indian Council of Agricultural Research	ICAR – Indian Institute of Spices Research, Khozikode, 23-24 September 2016	Dr. James George
59th Meeting of Town Official Language Implementation Committee	Indian Institute of Technology, Bhubaneswar, 24 September 2016	Dr. V.B.S. Chauhan
Pre-Rabi Scientist - Extension-Farmer Interface	Kerala Agricultural University, Thrissur, Kerala, 7 October 2016	Dr. K. Susan John Dr. Sheela Immanuel
One Day Conference on Global Agri Connect-2016	Hotel Hyatt Regency, New Delhi, 14 October 2016	Mr. Venkatraman Bansode
Annual Project Review Meeting of 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, Kayamkulam, 14 October 2016	Dr. K. Susan John
Midterm Review Meeting of All India Coordinated Research Project on Tuber Crops	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 19 October 2016	Dr. James George Dr. S. Sunitha Dr. M.N. Sheela Dr. G. Byju Dr. R. Muthuraj Dr. Sheela Immanuel Dr. T. Makeshkumar
National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 20-22 October 2016	All scientists
National Seminar on Development in Soil Science- 2016	Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya, Gwalior, 20-23 October 2016	Dr. K. Laxminarayana
Brain Storming Session-cum-Interaction Meet on Engineering Interventions for Production & Processing of Horticultural Crops	ICAR – Central Institute of Agricultural Engineering, Bhopal, 24-25 October 2016	Dr. James George
Meeting for Agricultural Departments Staffs jointly organized by State Agricultural Management and Extension Training Institute and ICAR- Central Tuber Crops Research Institute	State Agricultural Management and Extension Training Institute, Thiruvananthapuram, 3 November 2016	Dr. M.L. Jeeva Mr. E.R. Harish
National Seminar on Soil Health Assessment with Mrida Parikshak	ICAR – Indian Institute of Soil Science, Bhopal, 4-5 November 2016	Dr. K. Susan John Dr. K. Laxminarayana

10th International Conference on Controlled Atmosphere and Fumigation	Hotel Asoka, Chanakyapuri, New Delhi, 6–11 November 2016	Dr. Saravanan Raju
8th International Geminivirus Symposium	Hotel Vivanta by Taj, New Delhi, 7-10 November 2016	Dr. T. Makeshkumar
6th International Ss-dna Comparative Virology Workshop	Hotel Vivanta by Taj, New Delhi, 7-10 November 2016	Dr. T. Makeshkumar
25th Meeting of ICAR Regional Committee No. VIII	Tamil Nadu Agricultural University, Coimbatore, 11-12 November 2016	Dr. James George
7th Indian Horticultural Congress: International Meet Doubling Farmers Income through Horticulture	Indian Agricultural Research Institute, Pusa campus, New Delhi, 15-18 November 2016	Dr. James George Dr. R. Muthuraj
Statistics & Big Data Bioinformatics in Agricultural Research	International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, 21-23 November 2016	Dr. J. Sreekumar
4th International Agronomy Congress	ICAR-Indian Agricultural Research Institute, New Delhi, 22-26 November 2016	Dr. James George Dr. M. Nedunchezhiyan Dr. G. Suja Dr. K. Susan John Dr. S. Sunitha
National Conference on Trends in Nanobiotech	Chaudhary Charan Singh Haryana Agricultural University, Hisar, 29 – 30 November 2016	Dr. Rajshekar Rao Korada
Workshop on Grafting in Solanaceous and Cucurbitaceous Vegetable Crops for Mitigation of Edaphic Constraints	ICAR-Indian Institute of Horticultural Research, Central Horticultural Experimental Station, Bhubaneswar, 30 November 2016	Dr. Kalidas Pati Dr. V.B.S. Chauhan
Training on Institutional Innovations in Extension	National Institute of Agricultural Extension Management, Hyderabad, 2 December 2016	Dr. P.S. Sivakumar
Triennial Conference on Indian Women Scientists' Association	Mumbai, 2 December 2016	Dr. Archana Mukherjee
International Conference on Global Perspectives in Virus Disease Management (VIROCON-2016)	ICAR-Indian Institute of Horticultural Research, Bengaluru, 7-10 December 2016	Dr. T. Makeshkumar, Mr. R. Arutselvan
International Conference on Climate Change Adaptation and Biodiversity : Ecological Sustainability and Resource Management for Livelihood Security	ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman & Nicobar Islands, 8-10 December 2016	Dr. G. Byju
Tuber Crops Day	ICAR-Central Tuber Crops Research Institute, 9 December 2016	All scientists
Farmers Day at TSP-Tuber adopted Village - Mohlai	Mohlai, Bakawand, 15 December 2016	Dr. S. Sunitha
One Day Workshop on Production Technology of Summer *Colocasia* (Arvi & Bunda) in River Banks of Bastar	S.G. College of Agriculture and Rsearch, Kumhrawand, Jagdalpur, 16 December 2016	Dr. S. Sunitha

Technology Week Celebrations of Agricultural Technology Management Agency	ICAR- Central Tuber Crops Research Institute, Thiruvananthapuram, 19-21 December 2016	All scientists
4th National Symposium on New Horizons in Pest Management for Sustainable Development Goals	Orissa University of Agriculture and Technology, Bhubaneswar, 23-24 December 2016	Dr. Rajshekar Rao Korada
Krishi Darshan Advisory Committee Meeting	Doordarshan Kendra, Kudapannakunnu Thiruvananthapuram, 6 January 2017	Dr. Sheela Immanuel
National Symposium on Climate Smart Agriculture for Nematode Management	ICAR-Central Coastal Agricultural Research Institute, Goa, 11-13 January 2017	Dr. H. Kesava Kumar
5th Lecture Programme in the Biotechnology Lecture Series	Kerala Biotechnology Commission and Kerala State Council for Science, Technology and Environment, Thiruvananthapuram, 21 January 2017	Dr. A. Asha Devi
Indian Population, History, Genetic Diversity and Public Health - Padmasri. Lalji Singh	Rajiv Gandhi Centre for Biotechnology and Kerala State Council for Science, Technology and Environment, 21 January 2017	Dr. S.S. Veena
Meeting of Farmer First Programme	ICAR-Central Plantation Crops Research Institute, Regional Station, Kayamkulam, Kerala, 27 January 2017	Dr. G. Suja
Brainstorming Session on Management of Sweet Potato Weevil: Present Status and Future Directions	ICAR-Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar, 4 February 2017	Dr. James George Dr. K. Rajasekhar Rao Dr. C.A. Jayaprakas Mr. E.R. Harish
J-Gate – Multiple Platforms	I CAR- Central Tuber Crops Research Institute, 9 February 2017	All scientists
Pre Action Plan Meeting	Krishi Vigyan Kendra, Mitraniketan Thiruvananthapuram, 9 February 2017	Dr. Sheela Immanuel
Emerging Trends in Communication and Essential Skill Sets of Extension Professionals for Effective Technology Transfer	Agricultural College and Research Institute, Tamil Nadu Agricultural University Madurai, 9 February 2017	Dr. P.S. Sivakumar
National Workshop on Recent Trends in Agriculture	Hoogly, West Bengal, 9 February 2017	Dr. Archana Mukherjee
Karshika Engineering Mela- 2017 organized by Kerala Agricultural University, Tavanur and ICAR–Central Plantation Crops Research Institute, Kasaragod	Selvam Auditorium, Vadakkanjeri, Thrissur, Kerala, 10 February 2017	Dr. M.S. Sajeev
Celebration of National Productivity Week	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, 12-18 February 2017	All scientists
District Level Interface of Kottayam District	Kizhthadiyoor Service Cooperative Bank, Palai, 13 February 2017	Dr. K. Susan John
ICAR – All India Coordinated Research Project Review Meeting	National Academy of Agricultural Sciences, Indian Council of Agricultural Research, Pusa, New Delhi, 13 February 2017	Dr. James George

ICAR Directors' Conference	National Academy of Agricultural Sciences, Indian Council of Agricultural Research, Pusa, New Delhi, 14-15 February 2017	Dr. James George
RAC Meeting of All India Radio	Changanassery Social Service Society, Changanaserry, 15 February 2017	Dr. Sheela Immanuel
National Science Day Celebrations	ICAR- Central Tuber Crops Research Institute, 16-17 February 2017	All scientists
Group Monitoring Workshop of the Science Research Schemes	Kerala State Council for Science, Technology and Environment, Thiruvananthapuram, 1 March 2017	Dr. A.N. Jyothi
National Conference on Frontiers in Biotechnology-Molecular, Epigenetic and Genomic Research Platforms in Healthcare and Food Security	Inter-University Centre for Genomics and Gene Technology, Department of Biotechnology, University of Kerala, 1-3 March 2017	Ms. N. Krishna Radhika
National Workshop on Statistics in Agriculture	Kolkata, West Bengal, 2 March 2017	Dr. Archana Mukherjee
Supply Chain Management in Agriculture and Allied Sectors	Chadayamangam, Kerala, 15 March 2017	Dr. P. S. Sivakumar
State Level Seminar on Plant Architecture and Flower Regulation In Mango	ICAR-Indian Institute of Horticultural Research, Central Horticultural Experimental Station, Bhubaneswar, 18 March 2017	Dr. Kalidas Pati Dr. V.B.S. Chauhan
Meeting on Image Processing and Machine Vision	Department of Computer Science, University of Kerala, Kariyavattom, 22-24 March 2017	Dr. Santhosh Mithra
Meeting on Agricultural Extension and Nutrition Linkages: Towards Nutrition Security and Better Health	Home Science College, Tamil Nadu Agricultural University, Madurai, 28 March 2017	Dr. P. S. Sivakumar

Visits Abroad

Name of the scientists	Period	Place of visit	Purpose
Dr. C.A. Jayaprakas	6-9 October 2016	Bosnia and Herzegovina	Attended VII International Scientific Agriculture Symposium Agrosym 2016
Mr. P. Prakash	11-13 January 2017	Bangkok, Thailand	Participated and presented an oral research paper in the 9th Asian Society of Agricultural Economists International Conference on Transformation in Agricultural and Food Economy in Asia

Mr. P. Prakash at Bangkok, Thailand

Distinguished Visitors

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

- Shri. Radha Mohan Singh, Union Minister of Agriculture & Farmers Welfare, Government of India, New Delhi.
- Shri.Sudarshan Bhagat, Union Minister of State for Agriculture & Farmers Welfare, Government of India, New Delhi.
- Dr. Trilochan Mohapatra, Secretary (DARE) & Director General (ICAR), New Delhi.
- Dr. Shashi Tharoor, Members of Parliament (Lok Sabha), Thiruvanathapuram, Kerala.
- Shri.V.S. Sunilkumar, Minister for Agriculture, Kerala.
- Shri. Kadakampally Surendran, Minister for Electricity & Devaswom, Kerala.
- Shri. K. Jayakumar, Vice-chancellor, Thunchathezhuthachan Malayalam University, Tirur, Malappuram, Kerala.
- Dr. G. Gopa kumar, Vice Chancellor, Central University of Kerala.
- Dr. N.K. Krishna Kumar, Deputy Director General (Horticulture Science), ICAR, New Delhi.
- Dr. Janakiram, Assistant Director General (Horticulture Science), ICAR, New Delhi.
- Dr. S. Dam Roy, Director, ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands.
- Shri. Biju Prabhakar, IAS, Directorate of Agriculture, Vikas Bhavan, Thiruvanathapuram, Kerala.
- Smt. D. Sreedevi, Chairperson of Kerala Women's Commission, Pattom, Thiruvanathapuram, Kerala.
- Dr. Samuel N. Mathew, Executive Director, National Institute for Speech and Hearing, Thiruvananthapuram, Kerala.
- Shri.Muraleedharan Thazhakara, Programme Executive, All India Radio, Thiruvananthapuram, Kerala.
- Shri. L.P. Chither, Director, Suchitwa Mission, Government of Kerala
- Dr. R.P. Raja, Member of Travancore of the Royal Families, Thiruvanathapuram, Kerala.
- Shri. Sam Raj, Southern Railway Hindi Officers (Retd), Chennai, India.
- Dr. P. Rethinam, Former Assistant Director General, ICAR & Chairman, RAC VII.
- Dr. Umesh Srivastava, Former Assistant Director General (Horticulture Science), 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.
- Ms. Tiffany Brar, Founder, "Jyothirgamaya", A Mobile Blind School, Ambalamukku, Thiruvananthapuram.
- Shri. Alathara Anilkumar, Councillor, Cheruvaikal, Thiruvananthapuram, Kerala.

Shri. Radha Mohan Singh, Union Minister of Agriculture and Farmers Welfare, Government of India, New Delhi unveiling the plaque after laying foundation stone of the Farmers Facilitation Centre at ICAR-CTCRI, Thiruvananthapuram

Shri. Sudarshan Bhagat, Union Minister of State for Agriculture & Farmers Welfare, Government of India, New Delhi, releasing the publications at ICAR-CTCRI, Thiruvananthapuram

Dr. Trilochan Mohapatra, Secretary (DARE) & Director General (ICAR), visiting the experimental fields at ICAR-CTCRI, Thiruvananthapuram, on the occasion of NCTTC-2016

Managerial Personnel

Director	:	Dr. Archana Mukherjee (w.e.f. 24.3.2017)
Director (Acting)	:	Dr. James George (up to 23.3.2017)
Project Coordinator	:	Dr. James George
Head, Regional Centre, Bhubaneswar (i/c)	:	Dr. M. Nedunchezhiyan
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. Sheela Immanuel

Personnel

Director	Dr. Archana Mukherjee (w.e.f. 24.3.17)
Director (Acting)	Dr. Jame George (up to 23.3.17)
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
Social Sciences	Dr. Sheela Immanuel
Division of Crop mprovement	
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
Dr. P. Arunkumar	Scientist
Dr. A.V.V. Koundinya	Scientist
Dr. Senthilkumar K.M.	Scientist
Division of Crop Production	
Dr. G. Byju	Principal Scientist
Dr. G. Suja	Principal Scientist
Dr. K. Susan John	Principal Scientist
Dr. V. Ramesh	Principal Scientist
Dr. R. Muthuraj	Senior Scientist
Shri. Sanket J. More	Scientist
Shri. J. Sureshkumar	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. Kesavakumar	Scientist
Ms. Sangeetha B.G.	Scientist
Ms. Sirisha Tadigiri	Scientist
Shri. Arutselven R.	Scientist
Division of Crop Utilization	
Dr. M.S. Sajeev	Principal Scientist
Dr. A.N. Jyothi	Principal Scientist
Dr. Saravanan Raju	Senior Scientist
Ms. Namrata Ankush Giri	Scientist
Ms. Pradeepika Chintha	Scientist
Dr. Krishnakumar T.	Scientist
Section of Social Sciences	
Dr. S. Ramanathan (Rtd. on 30.6.16)	Principal Scientist & Head
Dr. T. Srinivas	Principal Scientist
Dr. V. S. Santhosh Mithra	Principal Scientist
Dr. J. Sreekumar	Principal Scientist
Dr. P. Sethuraman Sivakumar	Senior Scientist
Shri. Prakash P.	Scientst
Library/PME Unit/ Photography	
Shri. R. Bharathan	Chief Technical Officer
Smt. T. K. Sudhalatha	Assistant Chief Technical Officer
Shri. V. S. Sreekumar	Technical Officer
Ms. B. S. Deepa	Technical Assistant
Field/Farm/Lab.Technicians	
Ms. Sujatha Kumari N.	Chief Technical Officer
Dr. L.S. Rajeswari	Assistant Chief Technical Officer
Shri. A. Madhu	Assistant Chief Technical Officer
Shri. I. Puviyarasan	Assistant Chief Technical Officer
Shri. M. Kuriakose	Assistant Chief Technical Officer
Shri. G. Venukumaran (Rtd. on 30.11.16)	Senior Technical Officer
Shri. C.S. Salimon	Senior Technical Officer

Shri. L.V. Ajithkumar	Senior Technical Officer
Shri. V. R. Sasankan	Senior Technical Officer
Shri. B. Renjith Kishor	Senior Technical Officer
Shri. V. Ganesh	Technical Officer
Shri. Patric M. Mascrene	Technical Officer
Shri. S. Natarajan	Technical Officer
Shri. A. S. Manikuttan Nair	Technical Officer
Shri. G. Suresh	Senior Technical Assistant
Shri. N.P. Ramadasan (Expired on 16.9.16)	Senior Technical Assistant
Dr. S. Shanavas	Senior Technical Assistant
Shri. B.S. Prakash Krishnan	Senior Technical Assistant
Dr. S. Karthikeyan	Senior Technical Assistant
Shri. Luke Armstrong	Technical Assistant
Shri. G. Shajikumar	Technical Assistant
Ms. Pallavi Nair K.	Technical Assistant
Shri. K. Sunil	Technical Assistant
Shri. T. Raghavan	Senior Technician
Shri. B. Satheesan	Senior Technician
Shri. D.T. Rejin	Senior Technician
Shri. T.M. Shinil	Senior Technician
Shri. C. Krishnamoorthy	Technician
Shri. K. Velayudan	Technician
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 (Retd on 31.3.2017)	Assistant
Shri. Hareendrakumar	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
Skilled Support Staff	
Smt. S. Ushakumari	Skilled Support Staff
Shri. P. Udayakumar	Skilled Support Staff
Shri. K. Saratchandra Kumar	Skilled Support Staff
Shri. G. Madhu	Skilled Support Staff
Shri. A. Chandran	Skilled Support Staff
Smt. C.T. Chellamma	Skilled Support Staff
Smt. M. Syamala	Skilled Support Staff
Shri. T. Lawrence	Skilled Support Staff
Shri. K. Sivadas	Skilled Support Staff
Smt. J. Thenmozhi	Skilled Support Staff
Shri. L. Samynathan	Skilled Support Staff

Shri. S. Sreekumaran	Skilled Support Staff
Shri. T. Manikantan Nair	Skilled Support Staff
Shri. K. Chandran	Skilled Support Staff
Shri. N. Appu (Expired on 28.11.16)	Skilled Support Staff
Shri. P. Ramankutty (VRS on 1.9.16)	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. Vidya P.	Skilled Support Staff
Mr. Arunraj D.	Skilled Support Staff
Mr. Sreenath Vijay	Skilled Support Staff
Ms. Anjitha S.	Skilled Support Staff
Shri. Sudhish S.	Skilled Support Staff
Shri. Aswin Raj P.	Skilled Support Staff
Ms. Saritha S.D.	Skilled Support Staff
Ms. Remya V.S.	Skilled Support Staff
Ms. Lekshmi S. Nair	Skilled Support Staff
Regional Centre, Bhubaneswar	
Dr. Archana Mukherjee (up to 23.3.2017)	Head, Regional Station
Dr. M. Nedunchezhiyan (w.e.f. 24.3.2017)	Principal Scientist & Head i/c
Dr. R. C. Ray	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. N. C. Jena	Technical Officer
Shri. Niranjan Pattnaik	Technical Officer
Shri. Pramod Kumar Mati	Technical Officer
Shri. Bibhudi Bhusan Das	Technical Officer
Shri. Bharat Kumar Sahoo	Senior Technical Assistant
Shri. Sushanta Kumar Jata	Senior Technical Assistant
Shri. Keshab Paikaray	Technician
Administrative and Accounts	
Shri. P.C. Noble	Assistant Administrative Officer
Shri. P. K. Acharya	Private Secretary
Shri. K. Lakshamana Rao	Assistant
Skilled Support Staff	
Shri. Ramachandra Das	Skilled Support Staff
Shri. Bijoykumar Nayak	Skilled Support Staff
Shri. Akshayakumar Nayak	Skilled Support Staff
Shri. Purna Samal	Skilled Support Staff
Shri. Bhajaman Malik	Skilled Support Staff
Shri. Sauri Pradhan	Skilled Support Staff
Shri. 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

National Technology Day Celebrated

Workshop on "Creative Strategies for Generating Innovative Agricultural Technologies", sponsored by the Kerala State Council for Science, Technology and Environment (KSCSTE) was organised at ICAR-CTCRI, Thiruvananthapuram on 11 May 2016 as a part of National Technology Day. The workshop was organised to sensitize the research students from agriculture and related disciplines on the importance and utility of creative approaches in developing innovative agriculture technologies. Shri. Ashok Kumar Thekkan, Director, Department of Agriculture, Govt. of Kerala, in his inaugural address added that Kerala state is producing several high value crops such as pineapple, pepper, jack fruit, banana, but there is a dearth of viable agro-industries to process them into value added products. He stressed that agricultural students and rural youth should come forward to create new start-ups on novel agricultural products to meet emerging consumer needs. Dr James George, Director, ICAR – CTCRI presided the function. Dr. P. Sethuraman Sivakumar, Senior Scientist co-ordinated the workshop. Various creative approaches like brain storming, SCAMPER, attribute listing were demonstrated and students had opportunity to personally interact with eminent scientists from ICAR-CTCRI and Indian Institute of Space Science and Technology, Valiamala. About 40 students from various colleges in Thiruvananthapuram participated in the programme.

National Technology Day celebrations-2016

Annual Group Meeting of the AICRP on Tuber Crops

The 16th Annual Group Meeting of the AICRP on Tuber Crops for the year 2015-2016 was held at Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani during 24 – 26 May 2016. Dr. N. K. Krishna Kumar, Hon'ble DDG (Hort.), ICAR, formally inaugurated the event, which was presided over by Prof. Dr. Manas Mohan Adhikary, Hon'ble Vice Chancellor, BCKV, Kalyani. The Best Centre Award during 2015-2016 was presented to Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra by Dr. N. K. Krishna Kumar, Hon'ble DDG (Hort.), ICAR, during the inaugural session. The meeting recommended five varieties, three in cassava (TCMS-2, TCMS-7 for central release and TCMS-5 for the state of Andhra Pradesh and adjoining areas) and two in Bunda (Bidhan Ghat Kachu (BCB-2) for West Bengal and Chhattisgarh Shaken Bunda-1 (IGB-5) for the state of Chhattisgarh for release.

Release of technical bulletins in the16th Annual Group Meeting of the AICRP on Tuber Crops held at BCKV, Kalyani

H.H. Sree Visakham Thirunal Endowment Lecture - 2016

The Sixth H.H. Sree Visakham Thirunal Endowment lecture was held at ICAR-CTCRI on 17 June 2016. The function was organized by Indian Society for Root Crops (ISRC) in collaboration with ICAR-CTCRI. This year's lecture was delivered by Shri. K. Jayakumar, IAS, Vice Chancellor, Thunchathezhuthachan Malayalam University, Tirur, Kerala. In his lecture he commented that "Tuber crops had played a major role to tide over different challenges in health and nutritional

scenarios". He also stressed that traditional wisdom available with us provide solutions to the problems faced in the modern era. The meeting was presided over by Dr. James George, Director, ICAR-CTCRI. Dr. C.A.Jayaprakas, President, ISRC welcomed the gathering. Dr. R.P. Raja, representative from Royal family of Travancore and Dr. B.R. Reghunath, Dean, College of Agriculture, Vellayani, Thiruvananthapuram offered felicitations. Dr.V.S. Santhosh Mithra, Secretary, ISRC proposed the vote of thanks. First circular on National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016) was released during the function. About 200 participants attended the function.

Shri. K. Jayakumar, IAS, Vice Chancellor, Thunchathezhuthachan Malayalam University, inaugurating the H.H. Sree Visakham Thirunal Endowment lecture - 2016

Visit of Shri. Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare

Shri. Radha Mohan Singh, Hon'ble Minister of Agriculture and Farmers Welfare, Government of India, visited ICAR-CTCRI, Thiruvananthapuram, on 29 September 2016. The Hon'ble minister laid the foundation stone of the newly proposed Farmers Facilitation Centre, which is intended to be a single window, where all the needs of the farmers, will be met. Later, Shri. Radha Mohan Singh addressed farmers, scientists and staff of the institute, wherein he stressed that the Union Government has increased the allocation for frontline demonstration and other agricultural extension activities and education in Kerala in order to spread the technologies developed at research stations to farmers. The Hon'ble minister also underscored the importance of developing and spreading water saving technologies such as micro irrigation and drip irrigation, production of quality planting materials and value addition of agricultural produce, which will ultimately fetch more income to the farmers. The minister also mentioned the importance of mobile based advisories to farmers and the need for disseminating the newly developed technologies through such ICT based tools. He was apprehensive of the repercussions of climate change and suggested that research programme must be aimed at thwarting climate change related catastrophes. The minister also released Annual Report 2015-2016 (Hindi) and a Technical Folder on Techniques for Organic Production of Tropical Tuber Crops during the occasion.

Release of ICAR-CTCRI publications by Shri. Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare. Dr. James George, Director (Acting) and Sri. P.R. Muraleedharan, Member, Coconut Development Board are also seen

National Conference on the Role of Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities (NCTTC-2016)

The NCTTC-2016 was organized jointly by the ISRC and ICAR-CTCRI during 20-22 October 2016 at ICAR-CTCRI, Thiruvananthapuram. The inaugural function was held on 20 October 2016 at 3.30 pm in the millennium hall of ICAR-CTCRI. The conference was inaugurated by Dr. Shashi Tharoor, Hon'ble Member of Parliament, Thiruvananthapuram. The function was presided

over by Dr. James George, Director, ICAR-CTCRI. Dr. T. Mohapatra, Hon'ble Director General, Indian Council of Agricultural Research, delivered the keynote address. Shri. V.S. Sunil Kumar, Hon'ble Minister for Agriculture and Family Welfare, Government of Kerala gave special address during the occasion. Dr. C.A. Jayaprakas, President, ISRC, welcomed the gathering and Dr.V.S. Santhosh Mithra, Secretary, ISRC proposed the vote of thanks.

About 400 delegates from different universities, ICAR institutes, NGO's, Tribal organizations, Tribal Welfare Department of Government of Kerala, Sponsoring agencies like NABARD, NHB, KSCSTE, State Bank of Travancore, CIP (International Potato Centre, New Delhi), SPAC and SAGOSERVE etc. participated in the conference. Tribal farmers as well as those farmers cultivating tuber crops also attended. Many other agro-processing industries also were represented. Number of invited guests like Directors of sister ICAR institutes of Kerala, dignitaries from Kerala Agricultural University etc. were also present in the conference. A galaxy of eminent experts in various fields of tuber crops and tribal development were invited as chairman/co-chairman of different sessions or as invited speakers.

The plenary session of the conference was chaired by Dr. James George, Director, ICAR-CTCRI. Dr. C.A. Jayaprakas, President, ISRC welcomed the gathering. Prizes were presented to various award winners. Dr.V.S.Santhosh Mithra presented the recommendations of the conference and proposed the vote of thanks.

Agriculture Education Day

The Agriculture Education Day was celebrated for the first time at ICAR-CTCRI in the Millennium Hall of the institute on 3 December 2016. The program was inaugurated by Dr. James George, Director, ICAR-CTCRI at 10.30 am. The inauguration was followed by a variety of competitions. Four competitions were conducted like debate competition on "Demonitization", essay writing competition on "Potential of secondary agriculture in India", drawing competition on "Village watershed

Dr.Shashi Tharoor, Hon'ble MP inaugurating NCTTC-2016 by lighting the ceremonial lamp in the presence of Dr. T. Mohapatra, Hon'ble DG (top) Shri.V.S. Sunil Kumar, Hon'ble Minister for Agriculture and Family Welfare, Government of Kerala delivering special address (bottom)

scenario" and crop identification competition. All the scientists, technical, administrative and supporting staff, research scholars, M. Sc. students, apprentice trainees and college and school students actively participated in the meeting.

World Soil Day

The 'World Soil day' programme was celebrated on 5 December 2016 at ICAR-CTCRI. Dr. James

Celebration of World Soil Day - 2016 at ICAR-CTCRI

George, Director, ICAR-CTCRI, presided. Dr. K. Ushakumari, Professor, Kerala Agricultural University was the chief guest. Shri. Alathara Anilkumar, Councillor, Sreekariyam Panchayat offered felicitations. Dr. K. Susan John, Principal Scientist, Division of Crop Production proposed the vote of thanks.

Tuber Crops Day-2016

Tuber Crops Day was celebrated on 9 December 2016 in the Millennium Hall of ICAR-CTCRI. The function was organized by ISRC in association with ICAR-CTCRI. The celebration was inaugurated by Dr. G. Gopa kumar, Vice Chancellor, Central University of Kerala. In his inaugural speech, he pointed out the importance of tuber crops as food-cum-livelihood security crop, especially to the poor tribal communities. The meeting was presided over by Dr. James George, Director, ICAR-CTCRI. Dr. C.A. Jayaprakas, President, ISRC welcomed the gathering. Shri. Alathara Anilkumar, Councillor, Thiruvananthapuram Corporation offered felicitations. Two progressive tuber crops farmers, Shri. K.P. Khalid, Mankada, Malappuram and K.K. Subramannian, Punnayam were felicitated during the function. Awards for the Best Employees of the institute in various categories were also presented during the function. Dr.V.S. Santhosh Mithra, Secretary, ISRC proposed the vote of thanks. The inaugural function was followed by Scientist-Farmer interface. About 200 farmers attended the function.

Technology Week Celebrations

The technology week celebrations was organised at ICAR-CTCRI in collaboration with the ATMA, Thiruvananthapuram during 19-21 December 2016. Three hundred farmers and officials from 11 blocks of Thiruvananthapuram participated in the training. Classes were held in tuber crops production and value addition and also in agriculture, animal husbandry and dairy. An exhibition was also organized in the venue and 13 stalls were arranged.

National Productivity Week Celebrations

The National Productivity Week was celebrated at both headquarters and regional centre of ICAR-CTCRI, during 12-18 February 2017. The inaugural ceremony was flagged off by Dr. Janakiram, ADG (Hort.) on 13 February 2017 at the headquarters. A series of competitions were held for the staff and students of the institute on the theme “From waste to profits through reduce, recycle and reuse”. On 18 February, the valedictory function was conducted at the institute. Shri. L.P. Chither, Director, Suchitwa Mission, Government of Kerala was the chief guest. He elaborated on the waste management measures taken by the Kerala State government to reduce, recycle and reuse waste in Kerala. Dr. James George, Director, ICAR-CTCRI, in his welcome address explained about the activities taken by the organisation to reduce waste. Prizes were also distributed to the winners of the competition in this occasion. Dr. Sheela Immanuel, Principal Scientist and Head, Section of Social Sciences delivered the vote of thanks. The programme was attended by the scientists, students and other staff members of the Institute. At Regional Centre, Bhubaneswar, debate, essay competition and awareness programme was conducted for all the staff members. Live TV talks

Tuber Crops Day-2016

National Productivity Week Celebrations-2017

in DD Odia on recycling and reuses of tropical tuber crop waste was held on 17 February 2017 between 6-6.30 pm, which was re-telecast at 6.00 am on 20 February 2017.

Visit of Shri. Sudarshan Bhagat, Hon'ble Union Minister of State for Agriculture and Farmers Welfare

Shri. Sudarshan Bhagat, Hon'ble Union Minister of State for Agriculture and Farmers Welfare, Government of India visited ICAR-CTCRI, Thiruvananthapuram on 28 January 2017. The minister inaugurated the precision water and nutrient management facility as a part of *'More crop per drop'* research programme of the Institute to fulfill the objective of the Hon'ble Prime Minister's dream programme of Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) with the vision of extending the coverage of irrigation 'Har Khet ko pani' and improving water use efficiency. The minister also visited the crop museum and farm of the institute and made a review of the work done and facilities available at the institute such as germplasm conservation, Techno-Incubation Centre, E-crop, biopesticides laboratory and transgenics laboratory. The minister also inaugurated the cashless transaction facility at the Institute as well as distributed planting materials of tropical tuber crops to the selected model farmers for on-farm demonstration of ICAR-CTCRI technologies under the *'Mera Gaon Mera Gaurav'* programme of the Government. The minister visited one of the model IFS organic farms of Mr. Robinson, Chandavila, Kattayikonam, 10 kms away from the institute, under *'Mera Gaon Mera Gaurav'*, and inaugurated the introduction of released varieties of tuber crops to the model farm by planting three high yielding varieties of elephant foot yam released by ICAR-CTCRI.

Shri. Sudarshan Bhagat, Hon'ble Union Minister of State for Agriculture and Farmers Welfare inaugurating the drip fertigation facility established at the institute as a part of 'More crop per drop' programme

National Science Day Celebrations-2017

The National Science Day for the year 2017 was celebrated by ICAR-CTCRI during 16-17 February 2017. The programme was sponsored by the Kerala State Council for Science, Technology and Environment (KSCSTE) and supported by the Department of Science & Technology, Govt. of India. The theme of this year's Science Day was "Science and technology for specially abled persons". Dr. James George, Director, ICAR-CTCRI presided over the inaugural function held on 16 February 2017. Dr. Shirly Raichal Anil was the Co-ordinator of the celebrations and Dr. V. Ramesh was the Convenor. Ms.Tiffany Brar,"Jyothirgamaya" was the chief guest of the inaugural function. Drawing competition was conducted for the students of National Institute for Speech and Hearing (NISH), Aakulam on the theme "Home stead farm in a village". Elocution and quiz competitions for the staff and students of ICAR-CTCRI were also held. The topic for elocution competition was **"**Role of modern technology in assisting specially abled children". The students were also taken to the different laboratories, especially Techno-Incubation Centre and experimental fields of ICAR-CTCRI. Dr. Samuel N. Mathew, Executive Director, NISH, Thiruvananthapuram, was the chief guest in the

Ms.Tiffany Brar addressing the inaugural session of the National Science Day Celebrations-2017

valedictory function and delivered the National Science Day lecture. The valedictory function was presided over by Dr. James George, Director, ICAR-CTCRI.

Library Corner

Library continued the information support services to the research and training activities of the Institute. In addition to the routine services, the major activities undertaken were:

Purchase of publications for research purpose

The total budget of Rs. 1.7388 lakhs allotted to the library was utilized for the purchase of following publications:

- A total of six Indian Journals worth Rs. 10, 019
- Books (seven numbers) worth Rs. 36, 993
- Online Database (indiastat.com) worth Rs. 60, 376

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

1. **Circulation of books**: A total of 338 books were issued to the users on loan and it was recorded properly in the books issue register.
2. **CeRA:** About 75 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 1050 users availed the facility of reference services from the library.
4. **Reading and reference facilities to the research students within and outside the institute**: Services were extended to the students from Colleges and University Departments, who undertook their B.Sc., M.Sc. project works, Ph. D. and PDF works under the guidance of the scientists of the institute during 15 days, 1-3 months and 3-5 years respectively. They were given necessary guidance in the use of reference resources and also photocopying facility.
5. **Photocopying:** Library continued to provide photocopying service to the institute staff and other library users on official/payment basis. During this period, 68,920 copies were provided against their work indents, which included 63,566 official copies and 5354 private copies.
6. **Services to the Regional Centre:** 30 ICAR publications (Books) were sent to the Regional Centre, ICAR-CTCRI, Bhubaneswar.
7. **Training-cum-awareness programme:** A training-cum-awareness programme on J-Gate @ CeRA was arranged to the various catagories of users of the institute about the usage of jgateplus.com

Hindi Corner

A one day Hindi workshop was organized at ICAR-CTCRI on 14 June 2016 for the officers/ officials of this institute on the topic, "Official Language Policy, Implementation and Incentives" by Shri. A. Somadethan, Retd. Assistant Director (OL). Thirty four participants availed the benefit of the workshop. The Hindi Fortnight 2016 was celebrated in the institute during 14-28 September 2016. The fortnight celebration was inaugurated by Dr. James George, Director, ICAR-CTCRI. Various competitions like recitation, translation, essay writing, calligraphy, elocution, just a minute, story writing, poem writing, memory test 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 2016 was conducted on 5 November 2016. The workshop was on the topic, "'Official Language Implementation" and classes were taken by Mr. Samraj, Assistant Director (OL) (Retd.), Indian Railway and Official Language Consultant (cDAC), 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.

State of art of MGMG

MGMG at Headquarters, ICAR-CTCRI

The scientists made 42 visits to the MGMG villages and met 1625 farmers. Twenty nine meetings were conducted, which were attended by 1509. Mobile based advisories numbering 3392 were given on improved varieties, tuber crop production and value addition, nutrient management, decision support tool for cassava nutrient management, pests and disease control in various crops, application of bio-pesticides for management of different pests and diseases, cassava marketing, vegetable cultivation and manuring in coconut. Tuber crop leaflets (1237) were also supplied to farmers. Bio-pesticides were distributed to 95 farmers. Planting materials of cassava, greater yam and elephant foot yam were given to 26 farmers.

The major problems identified in the MGMG villages were: climate change, labour shortage and high wage rate, unseasonal rainfall and water logging, banana pseudostem weevil, water scarcity, soil fertility related soil acidity and nutritional disorders, cassava mosaic disease, coconut fruit drop, sucking pests in tuber crops, tuber rotting in elephant foot yam, lack of tuberization in sweet potato and tannia, price fluctuation of agricultural produce, non-availability of healthy planting material in tuber crops and vegetables, pests and diseases of ornamental crops, instability of cassava market price and cassava mosaic disease. Soil samples were collected from fields of 100 farmers for issuing soil health cards to the MGMG farmers.

Distribution of planting material under MGMG (top) and planting of elephant foot yam by Hon'ble Union Minister of State, Shri. Sudarshan Bhagat (bottom), while inaugurating the model farm under MGMG at Thiruvananthapuram

Linkages were created with ATMA, Thiruvananthapuram, Krishi Bhavan, Pothencode, Krishi Bhavan, Kazhakootam, VFPCK, KAU, Veterinary hospital, State horticulture department, KVK, Mitraniketan, Department of Veterinary and Animal Sciences, MATSYAFED, Thiruvananthapuram, Department of Fisheries, Panchayat Vikasana Samithi.

The Model Farm under MGMG was inaugurated by the Hon'ble Union Minister for State, Department of Agriculture and Farmers Welfare, Shri. Sudarshan Bhagat on 28 January 2017 at ICAR-CTCRI. Planting of elephant foot yam var. Gajendra was done by the Hon'ble Minister in one of the MGMG farmers' field.

MGMG at Regional Centre, ICAR-CTCRI

Altogether 35 visits, 80 interface meetings, 10 trainings, 35 demonstrations, 50 mobile based advisories, 35 awareness programmes were made during the period. In addition, 10 folders were distributed to each farmer. Demonstrations on tuber crops technology were conducted and 50 kg of elephant foot yam, 50 kg of greater yam, 50

Distribution of planting materials of tuber crops in Kaluniari and Bhagavatipur, Odisha

Greater yam demonstration field in Ramabali, Odisha

kg of taro and 1000 cuttings of sweet potato were distributed. About 961 farmers were benefited. Linkages were created with block officials of Tangi, Banpur and Ranpur.

Swaccha Bharat Abhiyan

ICAR-CTCRI is dedicatedly involved in various activities related to "Swachha Bharat Mission", the nation-wide cleanliness programme conceptualised by the Hon'ble Prime Minister of India. Since its inception in 2014 at ICAR-CTCRI, various cleanliness initiatives has been implemented such as:

- Swaccha Bharat Abhiyan was conducted weekly on every Saturday for half an hour and all the staff members were instructed to clean their respective laboratories and sitting areas.
- On the last working day of the month, Swaccha Bharat Abhiyan was conducted for one hour, during which all the staff members were involved in cleaning the campus as a whole.
- Attendance register was maintained to keep record of presence of members.
- Dust bins, hand gloves and brooms for cleaning were purchased and Swaccha Bharat Abhiyan logo and tag line were used in the institute.
- All members participated to clean offices, cabins, laboratories, garden area, main road area, processing complex, canteen and field area.
- Plastics, bottles, papers etc. were collected and destroyed completely by using incinerator.
- Old and broken items, furniture, glassware and plastic were replaced.

Swacchta Pakhwada

ICAR-CTCRI organised the Swacchta Pakhwada from 16-31 October 2016 to spread the message of cleanliness to the public. 'Swachhata Shapath' was administered by Dr. James George, Director with all the members of institute. Dr. Trilochan Mohapatra, Secretary (DARE) & Director General (ICAR), who was invited to ICAR-CTCRI, Thiruvananthapuram, to inaugurate the National Conference on Tropical Tuber Crops for the Sustenance and Welfare of Tribal Communities, participated in cleaning activities along with Director and staff of ICAR-CTCRI**.** The scientists and the other staff of ICAR- CTCRI were involved

Participation of Dr. Trilochan Mohapatra, Secretary (DARE) & Director General (ICAR) in the cleaning drive at ICAR-CTCRI during Swacchhta Pakhwada

Swacchta Pakhwada

in the cleaning of the campus. Plastic, weeds and waste materials were removed from the field and other places.

A Swachhata rally was also conducted from ICAR-CTCRI to Govt. High school Chavadimukku, Sreekariyam. The rally was flagged off by the Hon'ble Justice D. Sreedevi, Retd. High Court Judge & Chairperson of Kerala State Women's Commission. Dr. James George, Director, along with all the scientific, technical and supporting staff of the institute actively participated in the Swachhata rally .The Director explained the concept and need of the cleanliness campaign to create awareness among the students and people at large. One field in the school premises was prepared and planted with selected tuber crops by the Director of ICAR-CTCRI, Principal of the School, staff of ICAR-CTCRI and staff and students of the school. The backside area of the school was cleaned and was planted with cassava stems and banana. More than 100 school students participated in the programme.

Recreation Club Corner

The Independence Day function was organized on 15 August 2016 by the recreation club of ICAR-CTCRI. The club felicitated the ICAR south zone sports winners on 7 September 2016. Two day celebrations in connection with Onam 2016 were organized on 7 September 2016 and 9 September 2016. 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 staff members. A folk music and dance troupe entertained the house thereafter. Also, the staff members were gifted with 'Onakkodi'. The New Year was welcomed with a get together of all club members. 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 activities 2016-17

Field Level Demonstrations/OFTs conducted

- Field Level demonstrations were conducted at Belagavi under commercial sweet potato systems.
- OFTs on customized fertilizers conducted in 42 locations in Kerala and Odisha: *Validation of customised fertilizers for cassava in 35 farmers' fields in 5 districts of Kerala. Validation of customised fertilizers for sweet potato in 7 farmers' fields in Denkanal district of Odisha.*
- A total of 14 field trials were conducted with cassava and elephant foot yam as intercrops under coconut to evolve best management practices (BMP) for cassava and elephant foot yam and for developing customized fertilizer formulations for elephant foot yam in two agro-ecological units of Kerala.
- Two validation trials on organic farming of yams and cassava in coconut garden at ICAR-Central Plantation Crops Research Institute, Kasaragod.

Participations in Exhibitions

ICAR-CTCRI participated in the following exhibitions:

1. CTCRI Foundation Day Exhibition, organized by ICAR-CTCRI at Sreekariyam, Thiruvananthapuram, 27 July 2016
2. National Meet on Prospects of Coconut Sector in India, organized by ICAR-Central

Plantation Crops Research Institute (CPCRI), Regional Station, Kayamkulam, Alapuzha, 29-30 September 2016.

3. National Conference Exhibition, organized by ICAR-CTCRI at Sreekariyam, Thiruvananthapuram, 20-22 October 2016.
4. MANAVEEYAM 2016, organized by Government High School at Veiloor, Thiruvananthapuram, 24-26 October 2016.
5. AGRI TECH IDUKKI 2016, organized by Department of Agricultural Development and Farmers Welfare at Vengalloor, Thodupuzha, 04-05 November 2016.
6. Eureka 2016, organized by Sarvodaya Central Vidyalaya at Nalanchira, Thiruvananthapuram, 09 November 2016.
7. Vaiga 2016, organized by Government of Kerala at Kanakakunnu palace, Thiruvananthapuram, 01-05 December 2016 **(Bagged SECOND PRIZE).**
8. Krishi Mela Centenary Expo 2016, organized by ICAR-CPCRI at Kasaragod, 09-13 December 2016 (**Bagged FIRST PRIZE**).
9. Technology Meet 2016, organized by Agricultural Technology Management Agency (ATMA) at ICAR-CTCRI, Thiruvananthapuram, 19-21 December 2016.
10. Regional Horticulture Fair 2017, organized by ICAR-Indian Institute of Horticultural Research at Bengaluru, 15-17 January 2017 **(Bagged SECOND PRIZE)**.
11. National Exhibition of 29th Kerala Science Congress, organized by Kerala State Council for Science Technology and Environment at Marthoma College, Thiruvalla, 26-30 January 2017.
12. Exhibition in connection with Minister's visit organized by ICAR-CTCRI at Sreekariyam, Thiruvananthapuram, 28 January 2017.
13. VIVIDHA 2017, organized by Kerala State Bio-diversity Board at Tagore Theatre, Vazhuthukadu, 22-26 February 2017.

Vaiga 2016 exhibition at Kanakakunnu palace, Thiruvananthapuram

वर्ष 2016 -17 के दौरान इस संस्थान में की गयी राजभाषा कार्यान्वयन से सम्बन्धित कार्यक्रम

राजभाषा कार्यान्वयन समिति की बैठक का आयोजन

इस संसथान की निदेशक की अध्यक्षता में, ता. 28.06.2016, 26.09.2016, 23.12.2016 और 27.03.2017 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 २०१६/०६/२० को «राजभाषा नीति, कार्यान्वयन एवं प्रोत्साहन" पर एक दिन की हिन्दी कार्यशाला आयोजित किया गया। डॉ. वी. रवि,प्रधान, फसल उत्पादन (प्रभारी- निदेशक) ने अध्यक्षीय भाषण दिया । उन्होंने हिन्दी के महत्व पर प्रकाश डालते हुए समारोह का उद्घाटन किया । डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभा का स्वागत किया, विशेष रूप से श्री. ए. सोमदत्तन, सेवानिवृत सहायक निदेशक(राजभाषा), तिरुवनंतपुरम का स्वागत किया और कार्यशाला में अच्छी उपस्थिति पर संतोष प्रकट किया। श्री. ए. सोमदत्तन ने «राजभाषा नीति, कार्यान्वयन एवं प्रोत्साहन" पर क्लास लिया । कुल ३६ प्रतिभागियों ने कार्यशाला में उत्साहपूर्व भाग लिया । प्रतिभागियों की राय थे 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. ए. सोमदत्तन की क्लास की सराहना की।

b) ता. 05.11.2016 को "राजभाषा कार्यान्वय" पर एक दिन की हिन्दी कार्यशाला आयोजित किया गया । डॉ. जेम्स जोर्जे, निदेशक(प्रभारी) और अध्यक्ष(राजभाषा) ,कार्यशाला का उद्घाटन किया । डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभा का स्वागत किया , विशेष रूप से श्री. सामराज , सेवानिवृत सहायक निदेशक (राजभाषा), भारतीय रेल एवं राजभाषा सलाहकार ,सीडैक तिरुवनंतपुरम का स्वागत किया और कार्यशाला में अच्छी उपस्थिति पर संतोष प्रकट किया। श्री. सामराज ने "राजभाषा कार्यान्वय" पर क्लास लिया। कुल ३० प्रतिभागियों ने कार्यशाला में उत्साहपूर्व भाग लिया । श्रीमती. टी. के सुधालता, तकनीकी अधिकारी (हिंदी) ने धन्यवाद प्रस्ताव पेश किया और श्री. सामराज की क्लास की सराहना की और सभी प्रतिभागियों को, कार्यशाला से प्राप्त ज्ञान उपयोग करने के लिए अनुरोध किया।

हिन्दी पखवाड़ा समारोह का आयोजन

ता. 14-28 सितम्बर 2016 को हिन्दी पखवाड़ा मनाया गया । इस संस्थान की स्टाफ और बच्चों के लिए विविध हिंदी प्रतियोगिताएं आयोजित की गई. । (1. निबंध लेखन 2. अनुवाद 3. भाषण 4. कविता पाठ 5. सुलेख 6. खुला मंच 7. अन्ताक्षरी 8. सिर्फ एक मिनट आदि प्रतियोगिताएं आयोजित की गई.)। सितंबर 2016 में हिंदी पखवाड़ा समारोह के संचालन के संबंध में, निम्नलिखित 5 श्रेणियों के लिए 8 हिंदी प्रतियोगिताओं का आयोजन किया गया।

1. वैज्ञानिक
2. तकनीकी / प्रशासन
3. कुशल सहायक कर्मचारी
4. अस्थायी कर्मचारी
5. बच्चों

प्रतियोगिताओं में कुल 70 प्रतिभागियों ने भाग ले करके विविध पुरस्कार प्राप्त हुए ।

हिंदी पखवाड़ा समारोह का समापन समारोह 5 नवंबर 2016 को आयोजित किया गया । डॉ. जेम्स जोर्जे, इस संस्थान की निदेशक (प्रभारी) और अध्यक्ष (राज भाषा) समारोह की अध्यक्षता की । समापन समारोह की अवसर पर आमंत्रित विशेष अतिथि श्री. सामराज, सेवा निवृत्त सहायक निदेशक (रा भा), भारतीय रेल एवं सी डैक, तिरुवनंतपुरम की राजभाषा सलाहकार द्वारा सभी विजेताओं को पुरस्कार वितरण किया गया ।

इसके अलावा तिरुवनंतपुरम नगर राज भाषा कार्यान्वयन समिति के तत्वावधान में आयोजित हिंदी प्रतियोगिताओं में इस संस्थान के प्रतिभागियों ने भाग ले करके पुरस्कार प्राप्त हुए ।

तिरुवनंतपुरम नगर राज भाषा कार्यान्वयन समिति के बैठकों में , इस संस्थान के निदेशक (प्रभारी) और अध्यक्ष(राजभाषा), डॉ. जेम्स जोर्जे, डॉ. आशा देवी, प्रधान वैज्ञानिक और संपर्क अधिकारी (राजभाषा) और श्रीमती. टी. के सुधालता, सहायक मुख्य तकनीकी अधिकारी (हिंदी) ने भाग लिया।

* <u>प्रोत्साहन योजना</u>

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 ।

* 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 काग जा त याद्विभाषी रूप में कि था।
* हिंदी में प्राप्त पत्रों के उत्तर हिंदी में दिए गए।
* वार्षिक कार्यक्रम के निर्धारित लक्ष्यानुसार अधिक से अधिक पत्राचार हिंदी में किया था।

हिंदी पखवाड़ा क्षेत्रीय केंद्र में

हिंदी पखवाड़ा तारीख 14 से 28 सितंबर 2016 तक मनाया गया।

• सभी प्रतियोगिताओं में सभी वैज्ञानिक / तकनीकी / प्रशासनिक कर्मचारी / कुशलसहायक स्टाफ / एसआरएफ / अपरेंटिस / प्रशिक्षुओं ने भाग लिया।

• क्विज प्रतियोगिता, वाद- विवाद , निबंध लेखन आदि विभिन्न गतिविधियों कोआयोजित किया गया और विजेताओं को पुरस्कार वितरित किया गया।

• डॉ मनीष गायकवाड़, प्रमुख (शरीर -रचना विज्ञान प्रभाग), एआई आई एम् एस, बीबीएसआर, समापन समारोह के मुख्य अतिथि थे।

Appendix 1
List of varieties of ICAR-CTCRI registerd with ICAR-NBPGR

Sl. No.	Crop name	Botanical name	National identity	Donor identity	Variety name	Ingr. No.	Year	Pedigree	Developer	Developing institute	Novel unique features
1	Cassava	*Manihot esculenta*	IC0586850	Triploid Cassava: 4-2	Sree Athulya	10144	2010	OP-4 (2x) X Sree Visakham (4x)	M.T. Sreekumari, K. Abraham, M. Unnikrishan and S. Ramanathan	ICAR-CTCRI Thiruvananthapuram, Kerala	Higher yield and high extractable starch
2	Cassava	*Manihot esculenta*	IC0586851	Triploid Cassava: 5-3	Sree Apoorva	10145	2010	Ambakkadan (2x) X Sree Sahya (4x)	M.T. Sreekumari, K. Abraham, M. Unnikrishan and S. Ramanathan.	ICAR-CTCRI Thiruvananthapuram, Kerala	Higher yield and high extractable starch
3	Sweet potato	*Ipomoea batatas*	IC0593650	ST-14	Bhu Sona	13020	2013	JP-14	S.K. Naskar and Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar, Odisha	High β carotene (13-14.5 mg $100g^{-1}$) and salinity tolerance
4	Sweet potato	*Ipomoea batatas*	IC0593651	ST-13	Bhu Krishna	13021	2013	JP-13	S.K. Naskar and Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar, Odisha	High anthocyanin (85-90 mg $100g^{-1}$) and salinity tolerance
5	Sweet potato	*Ipomoea batatas*	IC0593652	ST-10	Bhu Swami	13022	2013	JP-10	S.K. Naskar and Archana Mukherjee	RC, ICAR-CTCRI Bhubaneswar, Odisha	High extractable starch (20-21%)

भाकृअनुप
ICAR

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किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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