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अनुसंधान की मुख्य विशेषताएँ
Research Highlights
2015 - 2016

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

ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
An ISO 9001-2008 Certified Institute
Sreekariyam Thiruvananthapuram 695 017 Kerala India

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18 July 2016

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Preface

Ever since its establishment in the year 1963, the ICAR-Central Tuber Crops Research Institute with its headquarters at Thiruvananthapuram and Regional Centre at Bhubaneswar has been facilitating scientific production and utilization of tropical tuber crops for food, nutrition and livelihood security. In order to keep informed our clientele farmers, entrepreneurs, industrialists, extension personnel and policy makers about our latest achievements, we proudly present a concise document on highlights of research during 2015-2016.

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

Strategies for management of sweet potato weevil using sex pheromones, repellents and EPNs, bio-intensive management of taro leaf blight, collar rot of elephant foot yam and yam anthracnose, exploitation of cassava based bio-formulations for pest management in vegetables were some of the major achievements from crop protection side. Technologies for the production of taro flour based gluten free cookies and bread, sweet potato nutribar, protein rich sweet potato muffins, sweet potato gluten free cookies, curcuma starch based extrudates, lacto-pickle from yam bean, particle boards from cassava stems, solid adhesive from oxidized cassava starch, water soluble curcumin loaded on a modified nano cassava starch for pharmaceutical application were the major research highlights in the utilization front. Real-time agro-advisories as SMS to farmers through the electronic device (E-Crop) and a nutrient decision support system in CD, CASSNUM version 1.1, for site specific nutrient management of cassava, deserves special mention. Hosting of the Tuber Food Fest-2016 was yet another feather in the cap of achievements in which various tuber food preparations and value added products from 20 states were exhibited, attracting a huge crowd. For detailed description of all the technologies, readers may go through the Annual Report 2015-2016 available in our website (http://www.ctcri.org).

I am extremely grateful to Dr. S. Ayyappan and Dr. Trilochan Mohapatra the former and the present Secretary, DARE and Director General, ICAR respectively for their wise counsel and advises. I also place on record my deepest sense of appreciation and gratefulness to Dr. N. K. Krishna Kumar, DDG (Horticultural Science) for his constant support and guidance. I am thankful to Dr. T. Janakiram, ADG (HS I), and other officers and Staff of the SMD for their timely help and interventions. I also record on my personal behalf and on behalf of the Institute, our sincere gratitude to Dr. S. K. Chakrabarti, the former Director, ICAR-CTCRI, for his capable guidance and valuable contributions in enabling the institute to gain international repute and fame. I appreciate the sincere efforts made by Dr. G. Suja and her team in publishing this document on time.

18 July 2016

James George
Director (Acting)

About ICAR-Central Tuber Crops Research Institute

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. The Head quarters completed its golden jubilee during 2012-2013 and became an ISO (ISO 9001:2008) certified Institute since 31 March 2014. ICAR-CTCRI has one Regional Centre (RC) at Bhubaneswar with a farm area of 20 ha. The All India Coordinated Research Project on Tuber Crops (AICRPTC) was started at ICAR-CTCRI in 1968 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 All India Coordinated Research Project on Harvest and Post-Harvest Technology. The ICAR-CTCRI is conducting basic and applied research on various edible tropical tuber crops ever since its establishement.

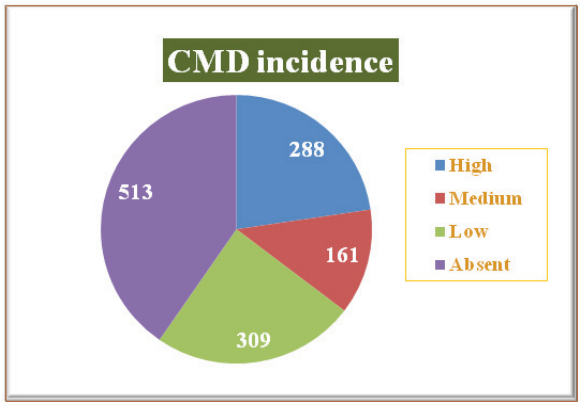
Research Achievements

There were 10 ongoing projects, including two flagship projects and 25 externally aided projects during 2015-2016. The salient achievements of the projects are highlighted here. The scientific staff strength was 46 including Director during the reporting period.

CROP IMPROVEMENT

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

with 20 cassava, 130 yam, 30 taro, 42 elephant foot yam and seven arrowroot accessions.



Cassava germplasm screened for cassava mosaic disease incidence under field epiphytotic conditions

- A total of 1271 accessions of cassava comprising of the indigenous, exotic, landraces and breeding lines were characterized for five qualitative above ground vegetative plant traits viz., early stem, leaf, petiole and lamina-petiole joint colour as well as cassava mosaic disease (CMD) incidence under field epiphytotic conditions. The analyzed data indicated that 288 accessions showed high incidence of CMD, while 513 accessions were found to be free of any symptoms in the early stages of plant growth. The stem colour showed a wide range of variation from brownish, greyish, orange to violet. The leaf colour also showed much variation from green in 56 accessions to brownish green in 1045 accessions, while lamina-petiole joint colour varied from green in 457 accessions to purple in 714 accessions.
- Eighty exotic accessions of cassava were screened both in the field as well as through PCR technique for cassava mosaic virus and 15 were found free from symptoms.
- Consistency of cooked tubers, texture and sweetness were assessed as per IPGRI descriptors. Among the orange-fleshed accessions, SD-11, SD-24, SP-10 and 148/12 were having very high starch and taste, but sweetness was high for SD-

Sweet potato germplasm maintained at ICAR-CTCRI, Thiruvananthapuram

526/7

SD-24

SD-55

SD-11

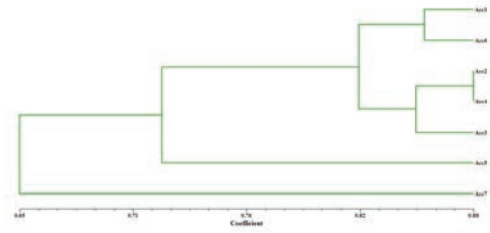
Promising high yielders of sweet potato

24. Among the white/yellow-fleshed, JASM5C, 526/12 and OP-S1 were tasty with medium to high starch and very high sweetness. Accessions 112/11 and AF3 have high starch and low sweetness.

- Molecular characterization of greater yam accessions (73), white yam (30), lesser yam (10) and wild yams were undertaken using 10 polymorphic SSR and 15 ISSR primers. The study identified a high yielding, highly divergent white yam genotype, DR-17 that could be used for the genetic improvement program in future. Seven sets of duplicates could be identified in greater yam.

- Among 64 accessions of greater yam screened for *in vitro* detached leaf assay for anthracnose resistance, 14 accessions showed high resistance to *Colletotrichum gloeosporioides* with no lesions. Screening for lesser yam accessions (50 acc.) for yam mild mosaic virus using DAS ELISA showed the presence of virus in 60% of the samples.
- Molecular characterization using 10 polymorphic SSR markers were done for 30 taro accessions from Kerala. All the primers gave polymorphic bands. The PIC value ranged from 0.639 to 0.857. The highest heterozygosity was obtained for the primer uq 97-256 with a value of 0.871 and the lowest was obtained for the primer uq 84-207 with a value of 0.694. Number of alleles per locus ranged from 1.90-4.56 with the maximum alleles shown by uq 97-256 and the minimum by uq 84-207 and uq 201-302. No duplicates could be identified.
- Two hundred and twelve taro accessions were subjected to field screening for taro leaf blight, of which, 56 were highly susceptible, 18 susceptible and 138 showed tolerance.
- Molecular characterization using nine ISSR markers were done for 12 elephant foot yam accessions including cultivars and wild ones. The similarity coefficient ranged from 0.62 - 0.93. No duplicates could be identified.
- Seven arrowroot germplasm collections from different states were characterized for 20 (5 quantitative and 15 qualitative) above ground vegetative plant traits. The plant height ranged from 101.60 cm (Assam) to 112.40 cm (Bihar) while, stem diameter ranged from 9.00 cm (Assam) to 16.60 cm (Kerala). The leaf lamina length and width were highest for Assam (31.50 cm) and Orissa (11.98 cm) collections, respectively. The highest petiole length of 37.00 cm was recorded in the Bihar collection. However, the stem colour, stem sheath colour, sheath margin and tip colour, stem hairiness, leaf lamina, margin, tip and vein colour, leaf hairiness, petiole colour and flower colour did not show any variation.
- These seven arrowroot accessions were screened using 12 ISSR markers, which produced 124 bands, of which 66 were polymorphic. The accessions formed two major clusters with two outliers in the grouping. Cluster 1 and II consisted of two and three accessions respectively having 72% similarity. The similarity coefficient based on ISSR markers ranged from 0.61 to 0.88. The accessions from Kerala and Maharashtra remained as outliers with only 65% similarity.

Field genebank of arrowroot at ICAR-CTCRI



Dendrogram showing the clustering pattern in 7 arrowroot accessions using 12 ISSR markers

- Under *in vitro* conservation of germplasm, 211 accessions of sweet potato including 65 accessions from NBPGR and accessions from pre-identified core collections, released varieties of tuber crops; cassava (2 breeding lines, 13 varieties, 3 landraces and 18 accessions); sweet potato (9 varieties); yams (7 accessions and 10 breeding lines) are also being maintained *in vitro*. At the Regional Center, 38 sweet potato, 21 taro, 12 cassava, 5 yam, 5 Chinese potato, 2 elephant foot yam and 5 yam bean varieties and pre-release varieties as well as elite lines are being maintained *in vitro* at Regional Centre. Eight hundred and seventy five cultures of released and exotic lines are maintained under *in vitro* conditions at Regional Centre.
- In cassava, 572 hybrid seedlings were produced by crossing early bulking clones. Out of these, 10 hybrids were observed with starch >30%. Six new hybrid seedlings had dark yellow flesh colour.
- In the experiment for improving the starch quality of CMD resistant cassava, friable embryogenic callus (FEC) was initiated in CMD resistant cassava 9S-127.
- For increasing the starch content in CMD resistant cassava lines, the *Agrobacterium* EHA105 having *glgC* gene was confirmed for the presence of *glgC* gene and also positively confirmed the revived colony as *Agrobacterium* through molecular and biochemical methods; i.e. PCR with *Agrobacterium* specific primers and 3-ketolactose test. This culture was used for transforming TMS60444 cassava FEC.
- For pyramiding of cassava mosaic resistant genes, *cmd1* and *cmd2*, a total of 325 seedlings of cassava were raised from crosses between TMS 30572 x CR43/11, TMS 96/1089A x CR43/11 and its reciprocal crosses. 150 hybrids were identified with both *cmd1* and *cmd2* gene.

- Using bioinformatics tools, 56 SNPs were identified in cassava, of which 30 SNPs were non-synonymous and 26 were synonymous SNPs. Out of the five SNPs validated in the wet lab, one SNP (SNP896) was able to clearly differentiate between the resistant and susceptible varieties.
- Of the 357 SSR's identified in cassava using MISA, 217 were mono, 132 were di, 139 were tri, 3 were tetra, 1 was penta, 3 was hexa and 42 were complex SSRs. Five sequences which had high hit percentage were validated and the SSR (SSR2063) was able to clearly differentiate between the resistant and susceptible varieties.
- Of the 619 genotypes of sweet potato (265 germplasm + 29 OP lines + 325 diallele bred hybrids) evaluated for early maturity with other valued traits, 26 were observed to be of early maturing types, 19 with 75 days including C_1 of F_1 and 7 with 90 days maturity.
- Out of a stock of 265 genotypes of sweet potato evaluated, 22 were observed to be promising (orange-3, rest white). Those on evaluation in the succeeding year, 75 days maturity was observed only in 7 lines (1-orange and 6–white fleshed lines).
- In sweet potato, open pollination generated 29 breeding lines, of which 9-purple, 9-white and 11–orange-fleshed were evaluated consecutively for the 4^{th} clonal generation, 90 days maturity was observed in 5-purple and 2-white fleshed lines.
- Of the 500 seedlings of sweet potato, clonal generation was raised from 325 seedlings. Progressive evaluation of clonal generations of F1 hybrids of those revealed 75 days maturity in 12 lines with yield of 20.40 to 25.60 t ha^{-1}. Of which flesh colour was observed to be orange-4, light purple-1, light orange-1 and white-6.
- Of the 12 lines, 4 lines (orange-2, white-1, light purple-1) had no weevil attack even at dry spell. All these when harvested after 110 days of planting showed less than 10% infestation.
- All the improved lines of sweet potato evaluated from germplasm collections, OP or diallel bred gave yield more than 17 t ha^{-1}, starch (>16%), β-carotene (>10 mg $100g^{-1}$) and anthocyanin contents (>75 mg $100g^{-1}$). Few such lines had high starch >18%, β-carotene (>14 mg $100g^{-1}$) and anthocyanin (>1g $100mg^{-1}$). All these lines were also observed with less (<8%) weevil infestation.

- In the advanced yield trial of greater yam clones, Dah-9/196 produced the highest yield (30.20 t ha^{-1}) followed by Da-293 under non-trailing conditions. Seven hybrids of greater yam showed high resistance to anthracnose. Among white yam hybrids evaluated, Drh-1150 produced the highest tuber yield (61.70 t ha^{-1}) followed by Drh-1125 (59.70 t ha^{-1}). The dwarf white yam hybrids viz., Drd-1038, Drd-1110, Drd-1835, Drd-920, Drd-1089 and Drd-1078 had excellent cooking quality. The semi dwarf SD-15 also was a high yielder.

Da-293, a promising pre-release greater yam clone suited to non-trailing condition

Pre-release white yam hybrid, Drh-1047

- Of the 19 taro accessions screened artificially, six (IC087153, IC012601, IC012294, IC310104, TCR 267 and TCR 326) showed moderate resistance to taro leaf blight. Preliminary work on identification of molecular markers linked to TLB showed that ISSR primer UBC 825 and $(AG)_9AC$ gave an extra band in all the six resistant accessions selected in the 685 bp and 808 bp regions, respectively. Taro evaluation trials showed that IC211587 outperformed Sree Rashmi (Check) having an average cormel yield of 11.62 t ha^{-1}. The percentage oxalate content ranged between 0.19 to 0.31% on dry wt. basis and all had good cooking quality

- Biochemical analysis of seven arrowroot accessions showed that the total starch content ranged from 15.61% (M5) to 20.21% (M1), while the total sugars ranged from 0.11% (M5 and M7) to 0.12% (others). In yam bean, five best F1 hybrids were identified and selected based on yield evaluation (3 x 10, 9 x 10, 3 x 5, 3 x 8 and 3 x 9). Tuber yield in yam bean ranged from 43.33 t ha^{-1} (3 x 9) to 46.66 t ha^{-1} (3 x 10) as compared to 27.77 t ha^{-1} in RM-1 as a check variety. Starch content in yam bean ranged from 11.12-17.33% and sugar content ranged from 5.88- 8.06%.

CROP PRODUCTION

- Rice (var. Kanchana)-short-duration cassava (var. Sree Vijaya) + black gram (Co-7) resulted in higher energy equivalent, tuber equivalent yield (38.86 t ha^{-1}), production efficiency (107.94 kg ha^{-1} day^{-1}) and profitability (added profit of Rs. 52,107 ha^{-1} over sole cassava) besides saving nutrients, half FYM and N and full P to short-duration cassava in this system.
- Sustainability of cassava for continuous cultivation was confirmed even after the 11th season crop with a tuber yield of 15.17 t ha^{-1}, without any manures or fertilizers. Application of NPK @ 125:50:125 kg ha^{-1} produced significantly the highest tuber yield of 32.85 t ha^{-1}. Soil test based application of NPK @ 78:0:94 kg ha^{-1} along with FYM @ 5 t ha^{-1} (22.27 t ha^{-1}), recommended POP (FYM @ 12.5 t ha^{-1} + NPK @ 100:50:100 kg ha^{-1}) (27.62 t ha^{-1}) and NPK @ 50:25:100 (25.18 t ha^{-1}) were on par with respect to tuber yield.
- Different organic manures sources viz., green manuring *in situ* with cowpea (@ 4.868 t ha^{-1} on DW basis) (26.89 t ha^{-1}), vermicompost @ 3.91 t ha^{-1}

N efficient genotype, W-19

CR 43-8, a promising N efficient genotype

(27.27 t ha^{-1}) and coir pith compost @ 4.6 t ha^{-1} (25.78 t ha^{-1}) were found as substitutes to FYM @ 12.5 t ha^{-1} (27.62 t ha^{-1}) in cassava production. Organic manures alone (crop residue as cassava leaf residue @ 3.75 t ha^{-1} (DW basis) and stem residue @ 10.43 t ha^{-1} (DW basis) + coir pith compost @ 4.6 t ha^{-1} + vermicompost @ 3.91 t ha^{-1} and ash @ 2.7 t ha^{-1}) also resulted in an yield (23.06 t ha^{-1}) on par with the recommended POP (27.63 t ha^{-1}). Evaluation of the N efficiency potential of the K efficient genotypes indicated that W-19 (30.23 t ha^{-1}) and CR 43-8 (31.69 t ha^{-1}) were good performers.

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

Thippi

Thippi compost

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

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

A nutrient decision support system in CD, CASSNUM

Estimation of soil hydraulic properties under different tillage and mulching treatments

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

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

- Studies to develop integrated soil and water conservation strategies for rainfed hill cassava production systems indicated that soil moisture content under ground cover sheets was 30.60% higher and soil temperature lower by 9.50% as compared to control. The cassava tuber yield in farmer's vs scientific practice

were 24.40 and 28.90 t ha^{-1}; sheet vs no sheet (control) treatment were 32.60 and 21.60 t ha^{-1} respectively. Ground cover sheets along with scientific nutrient management practices at Pachamalai hills proved to be an ideal technology for rainfed hill cassava cultivation, especially in mild to moderate sloping lands in Eastern Ghats of Tamil Nadu.

- Application of N, P_2O_5 and K_2O @ 50: 40: 75 kg ha^{-1}, respectively was optimum to realize higher yields of good quality sweet potato tubers in the natural saline soils under island ecosystem of Andaman.

Prospects of use of ground cover sheets in rainfed hill cassava production systems

- The first year study for evolving best management practice for cassava and elephant foot yam involving soil test based application of NPK, lime @ 1 t ha^{-1} for correcting surface acidity, gypsum @ 2 t ha^{-1} for correcting subsoil acidity, $MgSO_4$ @ 80 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1} and borax @ 10 kg ha^{-1} gave significantly higher yield for elephant foot yam in two agro-ecological units (AEU) of Kerala.

- In the process of developing customized fertilizers for elephant foot yam, the rates of NPK was standardised as NPK @ 142:12.5:160 kg ha^{-1} for AEU3 and 156:12.5:180 kg ha^{-1} for AEU9 (based on the rate trials conducted) and the rate of secondary nutrients viz., Ca, Mg and micronutrients viz., Zn and B was standardized as dolomite as 1.5 t ha^{-1}, $MgSO_4$ @ 120 kg ha^{-1}, $ZnSO_4$ @ 30 kg ha^{-1} and borax @ 18.75 kg ha^{-1} for the two AEUs' of Kerala.

- A field experiment was conducted for inducing early and uniform sprouting in elephant foot yam. Corm treatment with GA_3 @ 200 ppm produced significantly higher corm yield (10.21 t ha^{-1}) followed by IAA @ 100 ppm (7.31 t ha^{-1}). Corms

treated with thiourea at 0.5% produced significantly higher number of corms (10059 per ha).

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

Studies on root distribution pattern in elephant foot yam

- The use of weed control ground cover resulted in higher weed control efficiency (96.90%) and higher corm yield (37.40 t ha^{-1}) in elephant foot yam. Though maximum gross return (Rs 5,60,600 ha^{-1}) was obtained under weed control ground cover treatment, higher benefit:cost ratio (2.31) was obtained under two rounds of manual weeding (30 and 60 days after planting (DAP)) + glyphosate (90 DAP) treatment due to low cost of cultivation.
- Organic production technologies developed for yams and cassava were validated in organically raised 48 year old coconut plantation at ICAR-CPCRI, Kasaragod. Yield under organic mode (0.97 and 0.75 respectively of conventional) was on a par with chemical system in both yams (7.18 and 7.44 t ha^{-1}) and cassava (8.06 and 10.86 t ha^{-1}) intercropped in coconut. Based on two years' experimentation

at ICAR-CTCRI in Chinese potato, organic production technologies involving FYM @ 10 t ha^{-1}, green manure, neem cake @ 1 t ha^{-1} and ash @ 2 t ha^{-1} or biofertilizers (*Azospirillum*, P solubilizer and K solubilizer @ 3 kg ha^{-1} each) were developed; yield under organic management (13.94 t ha^{-1}) was 10.50% higher over conventional system (12.61 t ha^{-1}).

Organic production of Chinese potato

Validation trial on organic farming of yams at ICAR-CPCRI, Kasaragod

- Under field conditions, foliar spraying of $CaCl_2$ (0.20%), Salicylic acid (0.20%) and BA (1000 ppm) during 4^{th} to 8^{th} month increased corm yield in elephant foot yam by 14.35%, 21.82% and 7.90% respectively as compared to control under ~32°C day temperature.
- Under polychamber conditions, foliar spraying of $CaCl_2$ (0.20%), Salicylic acid (0.20%) and BA (1000 ppm) during 4^{th} to 8^{th} month increased corm yield in elephant foot yam by 17.26%, 29.13% and 3.92% respectively as compared to control under ~32-38°C day temperature (10 am – 4 pm).

- In greater yam + maize intercropping system, drip irrigation at 100% CPE resulted in higher maize yield. However, greater yam yield (34.90 t ha^{-1}) and tuber equivalent yield (37.80 t ha^{-1}) were higher at 100% CPE during 1-90 DAP + 80% CPE during 91-270 DAP. Drip fertigation of N-P_2O_5-K_2O 160-90-160 kg ha^{-1} resulted in higher maize, greater yam and tuber equivalent yield, which was on par with N-P_2O_5-K_2O 140-90-140 kg ha^{-1}. Drip irrigation at 100% CPE during 1-90 DAP + 80% CPE during 91-270 DAP along with fertigation of N-P_2O_5-K_2O 140-90-140 kg ha^{-1} resulted in higher water and nutrient use efficiency as well as B:C ratio (2.82).
- Sixteen soil samples (0-30 cm depth) from areas adjacent to mines and industrial areas of Koraput district, Rayagada district and Jagatsinghpur districts of Odisha including one soil sample representing arable land were collected and characterized for physico-chemical properties, enzyme activities and the pattern of accumulation of heavy metals due to pollutants.
- A total number of 145 micro plants of different cassava varieties were indexed against cassava mosaic virus through micropropagation technique in the tissue culture laboratory. A total of 50 numbers of elephant foot yam (var. Gajendra) were also indexed. Cassava varieties, Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Swarna were planted in 2.70 acres. A total of 50,000 cassava stems of good quality were produced. Quality planting material of elephant foot yam var. Gajendra were multiplied in 3.60 acres. A total of 13 tons of elephant foot yam was produced. Greater yam multiplication was taken up in a total area of 2.05 acres with Sree Keerthi, Sree Roopa and Sree Shilpa varieties and the production was 7 tons. Taro var. Muktakesi was planted in an area 0.20 acre and the production was 300 kg.

Quality planting material production of cassava varieties, vars. Sree Jaya (left) and Sree Vijaya (right)

CROP PROTECTION

- Survey of sweet potato weevil in Dhenkanal, Boudh, Angul, Kalahandi, Koraput, Navranpur, Bargarh districts of Odisha showed yield loss ranging from 15 to 75%. Sex pheromone technology demonstrations for sweet potato weevil were conducted in sweet potato fields in Dhenkanal, Bargarh, Navranpur and Koraput districts of Odisha. In Dhenkanal, the weevil population and tuber damage (86%) were reduced significantly, when sex pheromone was used in 500 ha @ 10 per ha. The cost of pheromone traps including lures, plastic boxes etc. was only Rs. 400 per ha. Pheromone technology used plots in farmers' fields in Dhenkanal resulted in 18 tonnes of healthy tubers per ha; whereas, in control plots it was only 2 tonnes. These results made hundreds of farmers to adopt the technology, as it was easy to use, erect and operate and safe to environment.

Pheromone trap

Farmers with pheromone trap

- With the collaboration of ICAR-IARI Regional Station, Wellington, Nilgiris, the dose of *Menma* was standardised for the management of aphids in mustard and *Shreya* for mealy bugs in okra, brinjal and tomato.
- Profenophos 40 EC + Cypermethrin 4 EC (combination product) @ 400 g ai ha^{-1}, Emamectin benzoate 5SG @ 11 g ai ha^{-1}, Spinosad 45 SC @ 50 g ai ha^{-1} and Cartap hydrochloride 50 SP @ 500 g ai ha^{-1}resulted in very less infestation of sweet potato weevil, 0.20%, 0.33%, 0.87%, respectively, against control (42.93%).
- Powder formulations of weevil repellents, humulene and gurjunene, were prepared in β-cyclodextrin complexes. The formulation was evaluated in field conditions on sweet potato. Efficacy of α-humulene in powder formulation was

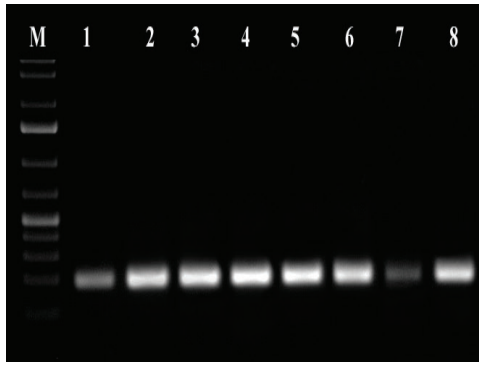
greater than α-gurjunene. Both the compounds resulted in 14 to 20% weevil infestation. Sweet potato weevil samples were collected from different states of India through AICRP centres. The genomic DNA was isolated and the mitochondrial cytochrome oxidase (MtCOX1) gene was amplified by PCR using universal primers to study the variability, if any. 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.

- Fifteen soil samples were collected from elephant foot yam fields of Block I of ICAR-CTCRI and analysed for plant parasitic nematodes. Lesion nematode, *Pratylenchus* sp. was the most predominant with a density of 0.9 nematodes per gram of soil.
- Entomopathogenic nematodes (EPNs) brought from ICAR-NBAIR, Bangalore reduced sweet potato weevil during kharif season. EPNs @ 20 kg ha^{-1} resulted in 10.67% weevil damage, whereas, the highest was recorded in control plot with 52.67% weevil damage.
- In a field experiment with susceptible, recovery and resistant lines of cassava, the disease incidence remained the same in susceptible cultivar for the entire crop growth period, whereas the recovery lines showed remission of symptoms from 5-6th month after planting and resistant lines remained symptom free. The qPCR studies showed drastic reduction in virus load during the remission of symptom and at the end of crop cycle, virus load started rebuilding in the recovery cultivars. The siRNA were isolated from these samples to understand the molecular mechanism.
- Two thousand and five hundred cassava hybrid seedlings were developed through crossing of genotypes with resistance from different sources. Seedlings free of CMD symptoms with good plant type and tuber characters were selected (404 number) for first clonal evaluation and CMD screening. Thirty promising seedlings were subjected to multiplex PCR and grafting and were free from CMV.
- Whiteflies were collected from different parts of Kerala in cassava growing regions and the morphological variability among the whitefly population was studied (body size, number of antennal segments, size of hind tarsus and genitalia)

and there was no significant variation among the collections. Molecular studies of whiteflies collected from CTCRI campus using SSR markers and mtCOI gene sequencing showed that they belonged to *Bemisia tabaci* with minor variations among them and were Aisatic biotype

- Soil and foliar application of the nutrients (N, P, K, Ca, Si, Zn, Mn, Cu, B) in alternate weeks under controlled condition (in lysimeter) indicated that the nutrients viz., Zn, Si, B, P, Ca induced tolerance to CMD in the most susceptible variety Sree Visakham. The same trend was observed in the qPCR analysis of virus load in the treated plants at different duration. There was a significant reduction in virus load in Zn, Si and Ca treatments.
- Disease free cassava plants vars. Sree Vijaya and Sree Jaya obtained from Bhubaneswar were planted in field and monitored periodically. The rate of reinfection was nil up to three months and it was 16 and 18% at 4th month and 38 and 41% at 8th month of planting, respectively. Planting of infected material showed symptoms in the first month itself and the incidence was 65 and 73% respectively in both the varieties at 8th month.
- Detected a new virus, sweet potato virus G from sweet potato. The diagnosis of sweet potato feathery mottle virus and sweet potato leaf curl virus using designed primers was validated.
- Three viruses from lesser yam, viz., *Yam mild mosaic virus* (YMMV), *Yam macluravirus* and *Yam badnavirus* were identified. The specific primers were

Lesser yam plant showing viral symptoms



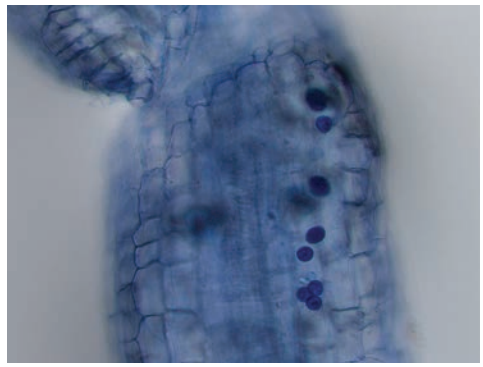
Detection of YMMV using designed YMMV F1 and YMMV R1 primers in lesser yam samples

designed for YMMV and *Yam macluravirus* and tested in lesser yam samples. YMMV was diagnosed from lesser yam tubers and validated with more samples.

- Developed the ELISA and PCR based techniques for diagnosing Dasheen mosaic virus in elephant foot yam. Multiplied the tubers from tissue cultured virus free elephant foot yam plants under field condition.
- Application of B and Si reduced taro leaf blight (TLB) incidence in taro and per cent disease incidence (PDI) was significantly less in all B and Si applied plants (3.13 to 16.20) compared to NPK alone applied plants (24.62).
- Three isolates of *Bacillus amyloliquefaciens* and vermicompost were evaluated with mefenoxam to manage TLB incidence. Even though, there was no significant difference in PDI among the treatments, least PDI (13-14) and highest yield was noticed in plants treated with *B. liquefaciens.*
- *B. amyloliquefaciens, T.asperellum*, dolomite and vermicompost were evaluated with mancozeb + carbendazim to manage collar rot incidence in elephant foot yam. Even though, there was no significant difference in disease incidence among the treatments, least incidence and highest yield was noticed in plants treated with *B. liquefaciens.*
- Root colonization ability of *Piriformospora indica* (an endophyte with properties of AMF) in taro varieties, Muktakeshi and Sree Kiran was studied by trypan blue staining. The presence was confirmed by Pitef1amplification and Confocal imaging.
- Malt extract agar (MEA) and Jaggery agar medium produced maximum mycelial aggregation at 28°C. Soil inoculation procedure was standardized and *P. indica* was found to be efficient in promoting growth in the taro varieties tested.
- Sixty three microbial isolates were obtained from different parts of the country during the period. Thirteen bacterial isolates and two *Trichoderma* isolates were short listed based on suppression of *Sclerotium rolfsii* and *Phytophthora colocasiae*.
- Seventy one bacterial isolates, which suppressed mycelial growth of *Sclerotium rolfsii* and *Phytophthora colocasiae* were screened for N fixation, P and K

solubilisation on selective media and 17 isolates that showed desired characters were selected for further study.

Isolate with P solubilisation



Piriformospora indica

- Six *Trichoderma* isolates, which showed antagonistic ability to targeted pathogens under *in vitro* condition were characterized using ITS sequencing. The isolates were identified as *Trichoderma harzianum (3), T. erinaceum, T. virens* and *T. viride*. These isolates were evaluated for their efficiency to suppress TLB incidence and based on suppression as well as growth promotion, *T. virens* was selected for further study.
- The soil application (one litre of 0.50% per plant) and tuber treatment with *Nanma* (0.50% for 10 min.) along with spraying of carbendazim @ 0.05%, seven times showed the maximum reduction in disease intensity and increase in yield compared to control, which was on par with soil and tuber treatment with *Nanma*,

Greater yam anthracnose management trial

Pathogenecity of
Colletotrichum gloeosporioides
in greater yam tissue cultured plant

soil and tuber treatment with *Trichoderma asperellum* @ 50 g of 10^7 cfu g^{-1} and tuber treatment @ 5 g in fresh cowdung slurry per kg of tuber along with spraying of carbendazim seven times.

- Standardized the pathogenecity test of *Colletotrichum gloeosporioides* causing greater yam anthracnose using whole plant assay and detached leaf method.
- Purified the inorganic phase of toxic metabolite of *Colletotrichum gloeosporioides* using silica gel column and confirmed the bio-efficacy in detached greater yam leaves. LC-MS and HPLC of the fraction has been done.
- Putative Resistant Gene Analogue (RGA) sequences of greater yam vars. Orissa Elite and Sree Keerthi were amplified using degenerate primers, cloned, sequenced and analysed.

CROP UTILIZATION

- Developed tuber crop products such as taro flour based gluten-free cookies, taro flour bread, gluten-free taro flour bread, sweet potato flour based Indian flat bread (*Chappati*), protein rich sweet potato muffins, sweet potato nutribar and sweet potato gluten free cookies and curcuma starch based extrudates.
- Taro flour based gluten-free cookies suitable for celiac patient, containing 50% taro flour along with rice flour, sorghum flour and cassava flour was developed. It provides 3.76% protein, 3.52% crude fiber and 479.62 kcal energy. The low calorie density in the cookies coupled with the high content of minerals such as phosphorus (167 mg $100g^{-1}$), potassium (723 mg $100g^{-1}$) and magnesium (1.59 mg $100g^{-1}$) could be added advantage for taro flour based gluten-free cookies.
- Sweet potato based nutribar were developed using RSM. A central composite design was prepared and the levels of sweet potato flour and sweeteners were considered as 20–30% and 40–50% respectively. The sweet potato based nutribar containing 20% sweet potato, 40% sweeteners (honey & jaggery), along with oats, puffed rice, bengal gram dhal and nuts was the best combination for development of nutribar. It contained 6.40% protein, 51.80% carbohydrates, 494.78 kcal, 4.52 mg $100g^{-1}$iron, 30 mg $100g^{-1}$ calcium and 6.06 mg $100g^{-1}$ magnesium.
- The sweet potato based functional bars enriched with resistant starch were developed by incorporating enzymatically modified cassava resistant starch.

The level of resistant starch was 5-15%. It contained moisture 5.48-6.52%, ash 2.17-2.35%, crude protein 5.37-6.80%, crude fat 21.68-28.75%, crude fiber 1.29-2.45%, carbohydrates 54.80-62.84% and energy 467.56-505.15 kcal $100g^{-1}$.

- Sweet potato flour based gluten free cookies for celiac patient could be prepared using flour blend containing 60% sweet potato flour along with other ingredients like rice flour, sorghum flour and cassava flour. High content of minerals such as phosphorus (88 mg $100g^{-1}$), potassium (270.33 mg $100g^{-1}$) and iron (24.60 mg $100g^{-1}$) could be added advantage for sweet potato flour based gluten-free cookies. It provides 2.53% protein, 7.44% crude fiber and 480.43 kcal.
- Yam beans (*Pachyrrhizus erosus*) were pickled by lactic fermentation by brining the cut and blanched tubers and inoculating with a consortium of lactic acid bacteria. Treatment with 8–10% brine was found to be organoleptically most acceptable. The antioxidant protecting properties of fermented product confirmed health benefits and could be a valuable source of antioxidant rich nutraceuticals.

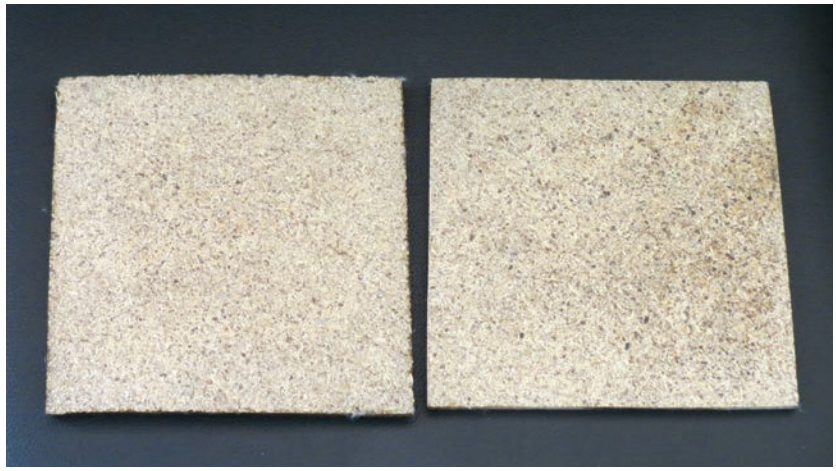
Yam bean lacto-pickle

- A power weeder developed by Industrial Extension Centre of CIAE, Coimbatore, was evaluated at ICAR-CTCRI farm and found that the weeder was suitable to address the weeding requirement of cassava planted on mounds in hilly terrains with mean weeding index of 91.90%. Cost of weeding by machine was worked out to be Rs. 6123 ha^{-1}, while that of manual method was Rs. 25,000 ha^{-1}, which denoted 75.50% of cost-saving, 90.90% of time-saving and 95.50% of energy-saving.
- Process variations in the production of high quality cassava flour were studied. It was found that drying of chips under poly-carbonated solar yard saved about 1-2

h than drying under open sun. The drying time required to dry 3 kg m^{-2} pressed gratings in the direct sun was 6 h, whereas the 5 kg m^{-2} and 7 kg m^{-2} pressed gratings took 7 and 10 h, respectively.

- Electrical properties of cassava tubers were studied for the development of cassava starch indicator. Correlation coefficient between electrical and biochemical properties (starch and moisture) of cassava tubers were worked out. Hardness of the peeled and unpeeled cassava tubers were measured and correlated with electrical and biochemical properties of tuber.
- In Belgaum district, five varieties of sweet potato viz., local, Kanaka, Sree Arun, ST-13 and ST-14 were planted and found that Sree Arun produced the highest yield of 20 t ha^{-1}.
- Moisture resistant corrugating adhesive has been successfully formulated using native cassava starch and they exhibited very good tack and fast drying properties. The solid content was 28.60% and 29.20% and gel point was 64°C and 65°C for the two successful formulations.
- An alkali free dry corrugating adhesive mix was formulated based on cassava starch.
- Cassava stem based particle boards were developed using different types of binding materials viz., urea formaldehyde, phenol formaldehyde, melamine urea formaldehyde and gelanitised starch. Boards with maximum density (1167 kg m^{-3}) and rupture force (27.58 MPa) was obtained with urea formaldehyde, whereas minimum water absorption was 0.59% and 4.70% after 2 h and 24 h soaking, respectively for the boards with melamine urea formaldehyde.
- By adding starch with urea formaldehyde, maximum density 1097 kg m^{-3}, modulus of rupture 16.56 MPa and water absorption after 2 h and 24 soaking as 33.28 and 42.90% , respectively was obtained.
- The optimum level of ingredients for the development of protein enriched pasta from sweet potato-legumes based composite flour were found to be 40% sweet potato flour, 30% lentil, 25% refined wheat flour (maida) and 5% gelatinised starch based on the physico-chemical, nutritional properties, cooking and sensory qualities.

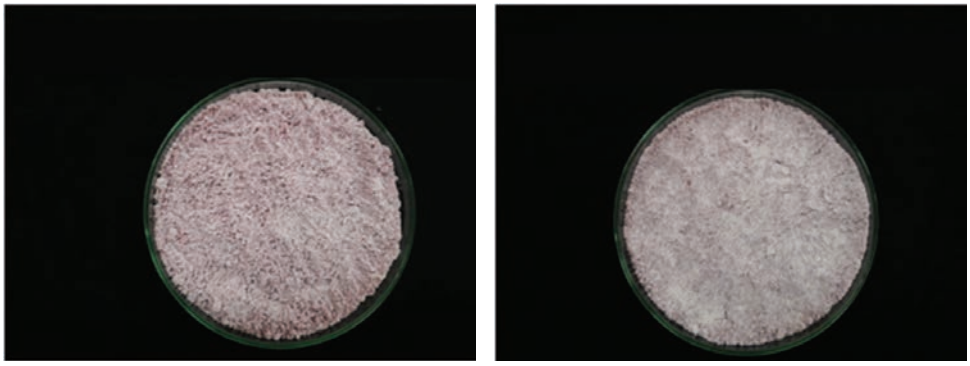
- Studies on the film forming properties of enzymatically modified cassava starch viz., liquefying (α-amylase) and debranching enzymes (pullulanase) showed that thickness, moisture content, tensile force, elongation at break and swelling capacity of the films containing pullulanase treated starch was higher and their packing ability was better owing to low permeability and solubility.



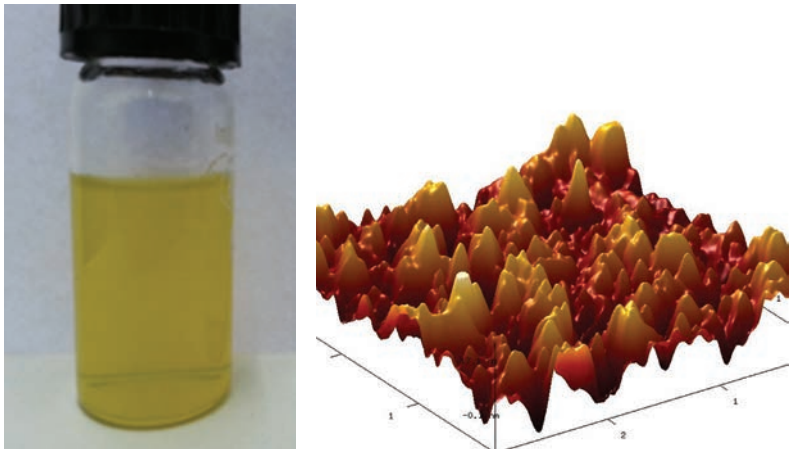
Particle boards from cassava stems

- Field experiment to evaluate the performance of superabsorbent polymer (SAP) in sweet potato showed that treatments with SAP could save 25-50% irrigation with a significant increase in total plant biomass. The water holding capacity also increased significantly (15-30%) for the polymer treated soils.
- Slow release urea and NPK fertilizers with a range of release kinetics (5 to 40% release after 25 days in aqueous medium) were synthesized by coating with grafted cassava starch. The coated fertilizers showed significantly higher water absorption capacity also. Soil incubation study is in progress.
- RS4 type and RS3 type resistant starches were made from cassava as well as sweet potato starches. The modified starches showed significantly lower glycaemic index than that of corresponding native starches.
- Slow release curcumin, incorporated in cassava starch-poly vinyl alcohol nanocomposite matrix was synthesized and characterized. The incorporated curcumin was found to be nontoxic to normal cells, whereas exhibited anticancer potential, which was significantly higher than that of pure curcumin.

- A water soluble curcumin, loaded on a modified nano cassava starch, and with significantly higher bioavailability, anticancer properties and nontoxicity has been synthesised and characterized. Pharmacokinetic study of pure curcumin and nano curcumin was carried out in Wistar Albino rats and the study showed that compared to pure curcumin, nano curcumin increased the curcumin bioavailability by 71.27%.
- Anthocyanins present in the purple-fleshed tubers of greater yam accession Da-340, in the leaves of sweet potato accession S-1467 and tubers of sweet potato variety ST-13 were isolated, purified and structurally identified.
- Encapsulated anthocyanins with extended storage stability were prepared by spray drying technology.

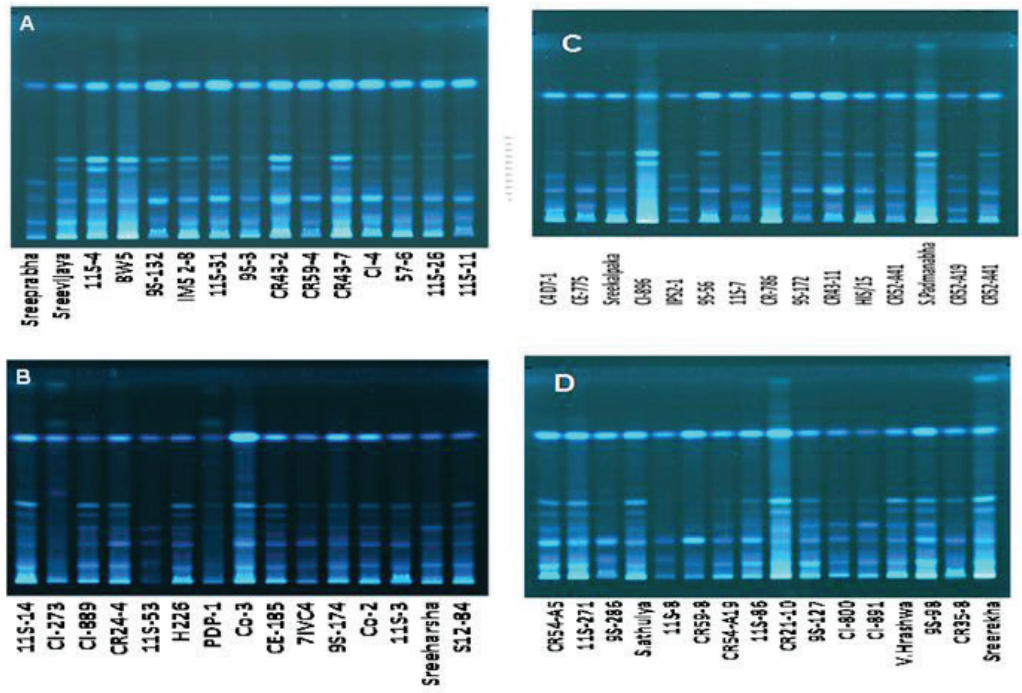


Encapsulated sweet potato anthocyanin pigment (left) and greater yam tuber anthocyanin (right)



Soluble curcumin loaded on a modified nano cassava starch (left) and its atomic force microscopic image (right)

- Cassava genotypes were screened for post-harvest physiological deterioration (PPD) in 61 cassava genotypes. The HPTLC chromatographic data of methanolic extract of cassava roots with PPD showed several polymorphic bands corresponding to phytoconstituents such as coumarins and flavonoids.
- The polymorphic bands were scored and used for classifying the genotypes. A dendrogram was constructed using Ward's method using squared Euclidean distance. There were some degree of overlapping in I and II main groups having low to moderate PPD, however there was a clear separation of genotypes having high and severe PPD in group III.



Thin layer chromatogram of phyto-chemical profile of methanolic extract of 61 cassava genotypes (A, B, C & D) at 10 days of storage. The image was taken using UV light of 350 nm

EXTENSION AND SOCIAL SCIENCES

- Under the commercial sweet potato production system at Belgaum, Karnataka, the released variety Sree Arun performed satisfactorily producing an average tuber yield of 19 t ha^{-1} with 85 per cent of marketable tubers during 2015 kharif season.
- The Kunbi tribe at Joida, Uttar Kannada, Karnataka grow organically dasheen type of taro and greater yam as the major tuber crops in their homestead and they form an important source of vegetable.

Discussion with the farmers

View of sweet potato field

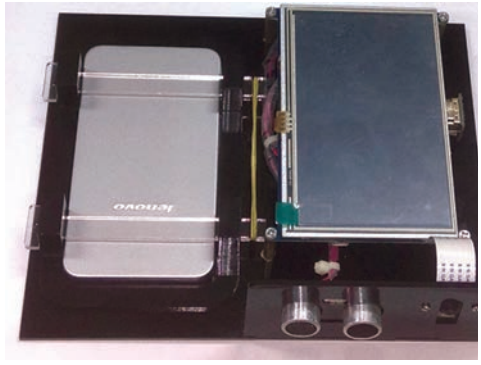
Tuber mela fest

- In the lexicon generation phase of the dry pasta, about 110 experts provided their responses. Sixty per cent of the respondents consumed short macroni pasta once or twice a month. The pasta sensory attributes taste (93%), aroma (82%), chewiness (78%) were most recommended attributes for evaluating sweet potato pasta.
- Livelihood analysis conducted in Thiruvananthapuram and Pathanamthitta districts of Kerala with a sample of 60 tuber crops farmers revealed that the overall human index of tuber crops farmers was more in Pathanamthitta district (0.65), when compared to Thiruvananthapuram (0.63).
- Equal percentage (93.33%) of tuber crops farmers from both the districts had high physical capital index. The overall social index was more for Thiruvananthapuram (0.84) than Pathanamthitta (0.73).
- In Pathanamthitta, 33.33% of the tuber crops farmers had high level of natural capital index than Thiruvananthapuram (40%). In Thiruvananthapuram 46% of the tuber crops farmers were having high financial capital compared to Pathanamthitta (13.33).

- Electronic device called Electronic crop (E-Crop) to simulate the crop growth real-time in the field was developed. This device collects various weather parameters from the field and generates agro-advisory for the crop planted in the field and the advisory is sent to the mobile of the concerned farmer in the form of SMS.

View of E-crop installed in sweet potato field

- A portable electronic device is being developed to identify the varieties of tuber crops from its morphological features.



Variety identifier device

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

- A "Village Incubation Centre for Value Addition of Tuber Crops" was established at Ukhrul, Manipur. A Launching Workshop-cum-Training Programme on "Incubation Centre for Value Addition of Tuber Crops" was also held at Riha village, Ukhrul district .

ALL INDIA COORDINATED RESEARCH PROJECT ON TUBER CROPS

- A total of 251 new collections were made by different centres during 2015-2016. Altogether 4574 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. UHS, Dharwad collected thirty genotypes of minor tuber crops from Northern dry belt of Karnataka and Central Coastal Belt of Karnataka were plenty of minor tuber crops are grown naturally. IC numbers were obtained for a total of 1574 germplasm collections at different centres.
- Molecular characterization was done utilizing three marker systems (RAPD, ISSR and AFLP) and locus specific SSR markers. Seventy six genotypes of taro were characterized and duplicates were found out by DNA fingerprinting at BCKV, Kalyani.
- Pooled data analysis of MLT on Cassava Mosaic Resistant entries showed that TCMS – 2 performed well at Dapoli, Yethapur and Thiruvananthapuram and TCMS-5 at VR Gudem. Under MLT on Bunda, IGB-5 produced maximum yield

BCA – 3 recommended for release in the state of West Bengal

at Jagdalpur and BCB-2 at Kalyani based on pooled data analysis. Under MLT on greater yam, IGDa-2 yielded the highest at Jagdalpur (26.56 t ha^{-1}) and Navsari (17.14 t ha^{-1}). These varieties may be recommended for release in the respective states.

- Six new varieties, one in sweet potato, one in lesser yam, two in taro and two in elephant foot yam were recommended for release during the 15th Annual Group Meeting held at Dr. YSRHU, VR Gudem, Andhra Pradesh during 23-25 April 2015.
- Phenology studies were conducted in cassava, sweet potato, elephant foot yam, taro and greater yam at different AICRP centres located in different agro-climatic zones. Observations recorded over the past three years were used to validate the cassava, sweet potato and elephant foot yam simulation models developed at ICAR-CTCRI, for providing agro-advisory to the farmers of the respective states.
- The gross income and net income increased at both the locations (Gumiyapal-Bastar and Tatirsh-Kondagaon district, Chattisgarh) after intervention of different components under tuber crops based farming system studies from 2012-2013 to 2015-2016. Average B: C ratio increased from 1.87 to 3.36. The model developed has the potential to transform the tribal region of Chhattisgarh, especially the Bastar and Kondabaon districts.
- Studies on micronutrient management in cassava and sweet potato indicated that positive response in terms of tuber yield was obtained with the application of micronutrients ie. Mg, B and Zn.

Distribution of pigs under farming system studies in Car Nic

- Greater yam + maize (1:3) additive intercropping was found to be beneficial with more yam equivalent yield and B:C ratio, hence growing of maize as intercrop in greater yam for staking purpose will be profitable than growing of yams by staking with bamboo poles.
- Under integrated management of sweet potato weevil, the lowest vine infestation at collar region with minimum tuber infestation and maximum marketable tuber yield was recorded with dipping the planting material in 0.02% chlorpyriphos (20 EC) for 10 min, earthing up along with weeding and fertilizer application, spraying 0.02% of chlorpyriphos (20 EC) at 30 and 60 DAP, spraying *Nanma* at 45 and 75 DAP and timely harvest.
- Soil application and tuber treatment with *Trichoderma* and Carbendazim spray (1%) was found effective in reducing the anthracnose incidence in greater yam and increasing tuber yield at all the centres.
- AICRP Centres from 19 states participated in the tuber crops food festival, Tuber Food-Fest 2015, organized by ICAR-CTCRI, Thiruvananthapuram, during 24 - 25 November 2015 along with two tribal farmers of their respective states and displayed ethnic food preparations from tuber crops.

General

TRAINING AND OTHER PROGRAMMES

- Forty one exposure trainings were given on "Production and Processing of Tuber Crops" to 557 farmers, 799 students and 27 teachers/extension officers. The participants were from Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Himachal Pradesh, and other parts of the country.
- Seven training programmes were organized under Tribal Sub Plan Programme involving tribal farmers/farm women at Odisha and Jharkhand during July 2015-January 2016.
- A workshop was organized on "Strengthening Impact Assessment in CGIAR (SIAC)" at ICAR-CTCRI, Thiruvananthapuram on 16 April 2015.
- A state level brain storming session was organized on "Extension Research in NARES of Kerala: Current Progress and Future Perspectives" on 18 April 2015 at ICAR-CTCRI, Thiruvananthapuram. The course was aimed to equip the NARES professionals on critical business planning skills that are essential for developing viable agro-technology enterprises.
- An ICAR sponsored short course on "Business Planning for Developing New Agro-Technology Enterprises" was organized at ICAR-CTCRI, Thiruvananthapuram,

Participants of the Short Course on Business Planning

Participants of the ICAR Short Course on Processing Machineries

Participants of the Speed Programme

during 2-11 September 2015. About 19 participants from different Agricultural Universities, ICAR institutes and Rubber Board attended the programme.

- Students Programme for Excellence in Experimental Design (SPEED) was organized under the Science Enrichment Programme for Prathibha Scholars 2014-15 by Kerala State Council for Science, Technology and Environment (KSCST&E) for 26 UG students from Kerala and two PG students from Karnataka during 19-23 September 2015 to motivate the students to pursue science as their carrier by inculcating a scientific temper among the participating students.
- Eight officials from Nigeria were given three days' training during 21-23 September 2015, at ICAR-CTCRI, as a part of their "Certificate Course on Requisites of Seed Production, Processing and Quality Assurance" at MAU, Uttar Pradesh.
- Hands on Training on " SAS and R for Statistics" was conducted for the Scientists and Research Scholars of ICAR-CTCRI, Thiruvananthapuram, during 15-17 October 2015.
- A Model Training Course on "Tuber Crops Technology Commercialization and Entrepreneurship Development" sponsored by the Directorate of Extension, Ministry of Agriculture, Cooperation & Farmers Welfare, Government of India was organised at ICAR-CTCRI, Thiruvananthapuram, during 2-9 February 2016.
- Village Incubation Centre for Value Addition of Tuber Crops was inaugurated at Ukhrul, Manipur under ICAR-CTCRI-NEH programme on 17 February 2016. A Launching Workshop-cum-Training Programme was held, in which 100 farmers/progressive SHG members and prospective entrepreneurs from Riha village were trained on tuber crops snack food production.
- One-day "Entrepreneurship Orientation Programme for Agricultural Students" was organised at ICAR-CTCRI on 21 March 2016.
- An "Entrepreneurship Orientation Programme on Promoting Tuber Crops Seed Enterprises for Sustainable Seed Security" was held at the Krishi Vigyan Kendra, Sandhiyur, Salem, on 23 March 2016 under the aegis of ICAR-CTCRI.
- Three new Scientists posted at ICAT-CTCRI (on Probation) were given orientation training programme in the institute for a period of one month, 9

October–9 November 2015. Twelve newly recruited Skilled Support Staff were given orientation training for one month in the institute during January 2016.

- In the Techno-Incubation Centre, ICAR-CTCRI, 20 training programmes-cum-practical demonstrations on value added products from tuber crops and entrepreneurship development were organized. Thirteen entrepreneur groups utilized the incubation facility for the production of snack foods and pasta. One young entrepreneur group utilized the incubation facility for developing jack fruit seed-cassava based pasta.
- More than 135 classes on production, protection, processing and value addition aspects were handled by scientists of various divisions under different programmes within and outside the institute beneficial to department officials, subject matter specialists, students and farmers all over the country. The specific topics covered were improved varieties, tissue culture, agro-techniques with special focus on organic management, soil health management, INM, IPM, vermi-composting, bio-pesticides and bio-control strategies, post-harvest management and value addition.
- Ten Scientists of ICAR-CTCRI attended 12 training programmes organized at National level.

TOP EVENTS

Programme	Date
41st Annual Institute Research Council	30 March to 1 April 2015
Sixth H.H. Sree Visakham Thirunal Endowment Lecture–2015	2 June 2015
52nd Foundation Day Celebration of ICAR-CTCRI	25 July 2015
Group Meeting on "*Phytophthora* diseases of horticultural crops and their management"	29 July 2015
13th Institute Management Committee Meeting	31 October 2015
Tuber Crops Day	24 November 2015
Tuber Food Fest-2015	24-25 November 2015
World Soil Day	5 December 2015
ICAR-CTCRI Developed Bio-formulations Technology Transfer Meet	15 December 2015
National Science Day Celebrations-2016	24-25 February 2016
Second Meeting of Research Advisory Committee VII	2-3 March 2016
42nd Annual Institute Research Council	29-30 March 2016

Sixth H.H. Sree Visakham Thirunal Endowment Lecture–2015

52nd Foundation Day Celebration of ICAR-CTCRI

National Science Day Celebrations-2016

Tuber Food Fest-2015

PARTICIPATION IN EXHIBITIONS

ICAR-CTCRI participated in 25 exhibitions organized at Kerala, Tamil Nadu, Odisha, Uttar Pradesh, Nagaland states of India.

VISITS ABROAD

Seven scientists and one JRF visited abroad to participate and present research papers in international conferences/attend project review meetings/be a part of scientific exchange programmes.

PUBLICATIONS

- Research papers in journals: 68
- Book chapters: 7
- Technical bulletins: 4
- Course/training manuals: 5

- Popular articles: 4
- Folders/leaflets/pamphlets: 8
- Papers in conferences/proceedings/seminars: 28
- Lecture notes in short courses: 21
- Other institute publications: 11
- Radio talks: 6

ONGOING PROJECTS

- Institute projects: 10
- Externally aided projects: 25

AWARDS

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

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

- Drs. V.B.S. Chauhan, K. Banerjee, Ahammed Shabeer, D. Oulkar, S. K. Chakrabarti, M.N. Sheela, Archana Mukherjee, K. Pati and R. C. Ray received the Best Poster Award for the work entitled "Profiling of anthocyanin in greater

yam exhibited its potential for nutritional security and source of natural pigments for food industries" at the National Conference on Horticulture in North Eastern Region held at College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh, during 16-18 January 2016.

Award of Ph.D.

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

Award of M. Sc. (Integrated Biotechnology)

- Nine students were awarded B.Sc.-M.Sc. (Integrated) Biotechnology from Kerala Agricultural University under the guidance of Scientists of ICAR-CTCRI.

Recognitions

- Dr. S. K. Chakrabarti was conferred as Fellow, National Academy of Agricultural Sciences 2016.

- Dr. S. K. Chakrabarti was recognized as Chairman, Cassava Breeding Session, Nanning, Guangxi, China, in the World Congress of Root and Tubers held at Nanning, China, during 18-22 January 2016.
- Dr. James George was nominated as Councillor for South Asia of the ISTRC in the World Congress of Root and Tubers held at Nanning, China, during 18-22 January 2016.
- Dr. Archana Mukherjee was nominated as IMC member, ICAR-CIWARI and ICAR-CIWA.
- Dr. M. N. Sheela was inducted as member, Board of Studies, Kerala Agricultural University.
- Dr. C. A. Jayaprakas was nominated as member, expert committee, Scheme for Young Scientist & Technologist (SYST), under the Equity, Empowerment and Development (SEED) division of Department of Science and Technology, Govt. of India.
- Dr. J. T. Sheriff was nominated as IMC member, ICAR-CIAE, Bhopal.

DISTINGUISHED VISITORS

- Shri. Subrato Biswas IAS, Agriculture Production Commissioner, Government of Kerala.
- Smt. K. B. Valsalakumari IAS, Executive Director, State Mission, Kudumbasree, Thiruvananthapuram.
- Dr. N. K. Krishna Kumar, DDG (Hort. Sci.), ICAR, New Delhi.
- Dr. Gurbachan Singh, Chairman, ASRB, New Delhi.
- Dr. T. Janakiram, ADG, ICAR, New Delhi.
- Dr. P. G. Latha, Director, Jawaharlal Nehru Tropical Botanical Garden and Research Institute, Palode, Thiruvananthapuram.
- Shri. Ravi Varma Raja, Member, Travancore Royal family.
- Shri. R. Ajith Kumar, Director of Agriculture (i/c), Kerala.
- Dr. P. Chowdappa, Director, ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala.

- Dr. H. P. Maheswarappa, Project Coordinator, Palms, ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala.
- Dr. Ravi Maruthachalam, Assistant Professor, School of Biology, Indian Institute of Science, Education and Research, Thiruvananthapuram.
- Dr. M. Anandaraj, Director, ICAR-Indian Institute of Spices Research, Kozhikode, Kerala.
- Dr. H. S. Singh, Head, Central Horticultural Experiment Station, Bhubaneswar, Odisha.
- Dr. K. Nirmal Babu, Project Co-ordinator, Spices, ICAR-Indian Institute of Spices Research, Kozhikode, Kerala.
- Dr. Peter J. Mathews, Network Creator and Chief Administrator, National Museum of Ethnology, Senri Expo Park, Suita City, Osaka.
- Dr. Waven William, High Commissioner, High Commission of the Republic of Seychelles.
- Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAARC Agriculture Centre, Dhaka, Bangladesh.
- Prof. V. Ramakrishnan, Director, Indian Institute of Science, Education and Research, Thiruvananthapuram.
- Dr. P. Rethinam, Former ADG, ICAR & Chairman, RAC VII.
- Dr. Umesh Srivastava, Former ADG, Hort. Sci., ICAR & Member, RAC VII.
- Dr. P. S. Naik, Former Director, ICAR-Indian Institute of Vegetable Research & Member, RAC VII.
- Dr. V.G. Malathi, Adjunct Faculty & Emeritus Scientist, Tamil Nadu Agricultural University & Member, RAC VII.
- Dr. Srinivasa Murthy, Principal Scientist, ICAR Indian Institute of Horticultural Research & Member, RAC VII.
- Dr. G.V.S. Saiprasad, Lead Scientist, Agriscience, ITC Limited, Bengaluru & Member, RAC VII.
- Shri. Salim P. Mathew (IMC Rep.), Member, RAC VII.
- Dr. Srikanth Attaluri, Program Director, International Potato Centre (India).

LIBRARY SERVICES

Library continued the information support services to the research activities of the institute. During the period, 14 journals and 107 books were added to the stock at ICAR-CTCRI, Thiruvananthapuram, and five books at Regional Centre, ICAR-CTCRI, Bhubaneswar. A total of 18 ICAR Hindi publications were purchased from the Directorate of Knowledge Management in Agriculture for the libraries of both Head Quarters and Regional Centre. One E-journal and online database software (Indiastat. com) were also procured. Library continued to provide services like ready reference, reading and reference facilities to the research students within and outside the institute, circulation of books, CeRA and photocopying to the users.

INSTITUTE TECHNOLOGY MANAGEMENT UNIT (ITMU)

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

Technologies transferred

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

Patent services

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

AGRICULTRAL KNOWLEDGE MANAGEMENT UNIT (AKMU)

Our Institute has established a fully fledged Local Area Network connecting various Divisions, Administration, Accounts, and farm sections of ICAR-CTCRI through a strong fiber optic backbone. The entire network is supported by state-of-the-art equipments such as Fiber optic Core switches, Routers and Firewalls. The Entire campus is now wifi enabled through access controlled wifi 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. AVPN connectivity is established for Global Access to the servers. Legal Licensed versions of popular software packages are installed for various types of applications.

AKMU was established in an area of 1400 sqft consisting of 17 state of the art work stations with centralized facilities for printing scanning etc. ARIS cell also houses a centralized server room and a power room supplemented with a 10KVA online UPS and supported with centralized generator facility. Our AKMU became one of the nodal point of National Knowledge Network of India (NKN) for effective sharing of scientific resources. A high speed 1Gbps fiber optic connectivity was established for internet communication and can be accessed through the Local Area Network. A 2 mbps broadband connectivity

from BSNL is also established to supplement/backup the internet bandwidth. 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.

PLANTING MATERIAL PRODUCTION

Sl. No.	Crop	Variety	Quantity of planting material produced
1.	Cassava (No. of stems)	Sree Vijaya	25,000
		Sree Jaya	25,000
		Sree Pavithra	1000
		Sree Swarna	1000
		Vellayani Hraswa	1000
		Total	53,000
2.	Elephant foot am (ton)	Gajendra	33
3.	Greater yam (ton)	Sree Keerthi	1.5
		Sree Shilpa	1.0
		Sree Roopa	1.5
		Da-293	8.0
		Orissa Elite	2.0
		Total	14.0
4.	Taro (ton)	Telia	1.5
		Muktakeshi	0.8
		Total	2.3
5.	Sweet potato (No of vine cuttings)	ST-14	2,00,000
		Kishan	3,00,000
		Total	5,00,000
6.	Yam bean (kg)	RM-1	300

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