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Betanin enriched cassava pasta
Carotene rich cassava chips
Alocasia tubers

Back: Cassava, Elephant foot yam & Greater yam, Swamp taro

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PREFACE

The Central Tuber Crops Research Institute (CTCRI) established during third five year plan in 1963 for intensification of research on tropical tuber crops with the aim of harnessing maximum potential of those crops for ensuring food, nutrition, and livelihood security entered into its golden jubilee year during the beginning of XIIth plan, 2012-2013. CTCRI is the only Institute of its kind in the world, doing research exclusively on tropical tuber crops with its regional centre at Bhubaneswar. The research programs of the Institute are carried out by the Divisions of Crop Improvement, Crop Production, Crop Protection, Crop Utilization and Extension and Social Sciences. Since inception, CTCRI has brought about phenomenal progress in the production and processing fronts of tuber crops research. Nearly 50 varieties of different tuber crops with high yield potential were released from CTCRI. The widespread cultivation of high yielding cassava varieties has raised the productivity in India to the highest in the world. The scheme has led to the development of production technologies suited to various agro-ecological zones of India, management packages for the control of pests and diseases of tuber crops and several utilization technologies for enhancing shelf life of harvested tubers and promoting product diversification. Transfer of technology on the production and utilization of tuber crops was achieved through training and outreach programmes, workshops, etc.

The major challenges for this group of crops are their bulky and perishable nature, long growing period, vegetative mode of propagation, and difficulty in genetic improvement. Innovative programs have been planned to address various challenges keeping in view the potential of tuber crops. In this document, an overview of the achievements and progress made during 2012- 2013 is presented.

The institute maintains a large collection of germplasm of 1923 cassava, 1472 sweet potato, 1151 yams 1098 aroids and 407 minor tuber crops accessions. Elite accessions were evaluated and identified for unique traits. Two CMD resistant hybrids, viz., 9S127 and CR35-18 with high drymatter (> 40%) and CR43 - 11 with high yield at sixth month after planting have been identified. Four yam varieties are ready for varietal release. Marker assisted selection and transgenics for CMD resistance are in good progress. Organic farming proved to be equally productive as that of conventional practice in taro, dwarf white yam and cassava. Significant achievements have been made in precision approach, SSNM, fertigation, nutrient management, abiotic tolerance, soil water conservation to manage the crops and resources. A Pilot Plant was installed to scale up the production of biofumigant from the rinds and leaves of cassava which is effective against stored product pests. Novel techniques for diagnosis of DsMV of elephant foot yam and taro, yam viruses and fungal diseases have been standardised. Bio- intensive management of collar rot of elephant foot yam and greater yam anthracnose have been developed. Standardized technologies for many value added food products and feed which have been commercialized through ITMU. Setting up of a Techno Incubation Centre for the commercialization of value added products from tuber crops, was approved by the Department of Agriculture, Govt. of Kerala, under the 'Value Addition Scheme' of Small Farmers' Agribusiness Consortium. Composite biodegradable films and cassava starch based semi-synthetic superabsorbent polymers have been developed. A vibro sieving system for sieving wet starch slurry was also developed. Achievements in impact assessment

of production technologies, TEFR for value added products, interactive information management for tuber crops user system and bioinformatics to genomic analysis are important contributions for the advancement of the mandatory crops.

Events like training programmes for production and utilisation technologies, demonstrations and exhibitions, classes to department officials and farmers, CTCRI-NEH collaborative seminars and TSP are programmes directed towards accelerating the dissemination of technologies and capacity building of human resources. The Institute took special effort to develop and transfer technologies with the support and collaboration with SAUs, NGOs, different Indian and foreign funding agencies and other ICAR institutions.

I express my sincere gratitude to Dr. S. Ayyappan, Secretary DARE and Director General, ICAR for constant support and guidance. It is my pleasure to thank Dr. N. K. Krishnakumar, DDG, Horticulture for his suggestions and encouragement. I would like to congratulate the multidisciplinary team who have facilitated this important compilation and I thank all the scientists, officers and staff members for their contribution in the advancement of the Institute.

Thiruvananthapuram
26th June, 2013

Dr. S. K. Chakrabarti
Director

EXECUTIVE SUMMARY

The Central Tuber Crops Research Institute established in 1963 with its headquarters at Thiruvananthapuram commemorates golden jubilee during 2012 - 2013. CTCRI along with its regional centre at Bhubaneswar is the only Institute in the world doing exclusive research on tropical tuber crops. The division-wise progress of research work under institute and externally funded projects during 2012 - 13 is presented in the report.

A large collection of 1923 cassava, 1472 sweet potato, 1151 yams, 921 taro, 277 elephant foot yam, 28 tannia, 212 yam bean, 130 chinese potato and 37 other minor tuber crops accessions are being conserved as field gene bank. Three hundred and fifty landraces of cassava were characterized and documented based on 12 key traits and 24 morphological duplicates were identified. Elite accessions were evaluated and the clones CI-898 and CI-75 were identified for higher yield and low cyanogens (< 30 ppm); CI - 60 for early bulking, drought tolerance and higher yield; CR43-11 and CR43-7 for drought tolerance; CI-800, CI-802 and CI-859 for better cooking quality.

The sweet potato genotypes ST-10 with high extractable starch (20.8 - 21.2%), ST-14 with high carotene (13.2 - 14.4 mg 100 g^{-1}) and ST - 13 with high anthocyanin (85 - 90 mg 100g^{-1}) were registered at NBPGR, New Delhi. Identified 18 sweet potato accessions with high starch (22.2 - 24.8%) and minimum weevil damage (5 - 10%), five with low sugar content (< 3%) ,13 with early maturity (75 - 90 days) and four with K and P efficiency. Fourteen wild species of sweet potato including *Ipomoea aquatica*, *I. carnea, I. trifida, I. coccinea, I. palmata* & *I. nil* were collected and maintained in the field as possible donors of resistance to sweet potato weevil in pre-breeding programme.

Database of taro germplasm with passport data of 122 accessions, tuber photographs of 161 and disease scoring data of 342 was updated.

Two genotypes of cassava (CR21- 10 and CR20-A2) have been identified as suitable for processing into fried chips after on-farm trial. A new promising clone (CMR-100) suitable for chips was identified along with CMD resistance, middle branching habit, uniform tuber shape (cylindrical), light yellow flesh, non-bitterness and high dry matter (43%). Promising hybrids (9S-127 and CR35-18) with CMD resistance and high dry matter content (> 40%), early maturity (CR43-11), and tolerance to post-harvest physiological deterioration (CI-800 and CR20-A2) have been identified.

Promising greater yam accession (Da-331) with purple flesh and higher yield (28.0 t ha^{-1}); tall white yam hybrids (Dr-657) with higher yield (35.0 t ha^{-1}), good tuber shape and better cooking quality; dwarf white yam hybrids (Drd-1068, Drd-1157) with higher yield (25 t ha^{-1}) and good culinary quality have been identified through on-farm trial.

Molecular markers RME-1 and SSR44/NS136 were confirmed and validated that could differentiate CMD resistant and susceptible lines of cassava.

Draft DUS testing guidelines have been prepared with 53 traits for cassava including 9 grouping traits and 34 traits for sweet potato including 7 grouping traits. Thirty three characters of 37 released sweet potato varieties and 26 characters for 14 released cassava varieties have been recorded. Seventeen pre-harvest characters for sweet potato and 11 characters of cassava have been validated for uniformity and stability. Thirty two pre- harvest morphological characters for elephant foot yam and 31 characters for taro have been recorded for developing DUS testing guidelines.

Six accessions of taro were identified as early maturing types and sixty four percent populations were tolerant to taro leaf blight in a European Union funded participatory trial.

Rice-pulse-short-duration cassava cropping system proved to be feasible at Thiruvananthapuram, Kerala. Green gram, black gram and soybean were equally compatible in rice based cropping systems involving

short-duration cassava. There is a possibility to save half FYM and N and full P for cassava especially when black gram and green gram preceded cassava. Continuous cultivation of cassava for 8 years without any manures and fertilizers (absolute control) could sustain yield to the tune of 14.71 t ha^{-1}.

The low input integrated practice of cultivating NPK-efficient cassava genotype (Ac. No.130) along with the nutrient management practice of application of organic manures, and chemical fertilizers including secondary and micronutrients based on soil test was found effective in sequestering atmospheric CO_2 to soil organic carbon. Organic farming proved to be equally productive as that of conventional practice in taro and dwarf white yam.

Soil test based application of NPK @ 84:0:106 kg ha^{-1} along with FYM @ 5 t ha^{-1} produced yield in cassava (21.32 t ha^{-1}) on par with recommended POP (NPK @ 100:50:100 kg ha^{-1}+ FYM @ 12.5 t ha^{-1})(24.70 t ha^{-1}). Integrated application of organic manures, secondary and micro nutrients along with half of the recommended doses of NPK, significantly enhanced the cormel yield as well as quality of taro. Soil amendment with lime @ 0.5 t ha^{-1} not only enhanced productivity and quality of the produce but also improved soil fertility.

Drip irrigation in cassava at 100% CPE along with NK fertigation @ 50% during 1 - 40 days, 30% during 41-80 days and 20% during 81-120 days gave significantly superior tuber yield. Significant yield could be obtained when 50% fertigation was applied during the first 40 days after transplanting. The recommended doses of fertilizer applied through fertigation in more number of splits has recorded higher corm yield of elephant foot yam while the corm yield with 40 numbers of split of recommended fertilizer was on par with 50 numbers of splits (32.5 and 33.5 t ha^{-1} respectively). Maximum corm yield of 37.3 t ha^{-1} was observed with fertigation at 4 days interval and 40 numbers of split of recommended dose of fertilizer.

Mulching with porous black coloured plastic sheets resulted in complete suppression of weeds of all kinds with 60% additional tuber yield of cassava.

Water deficit stress (WDS) during 4 and 5 or 5 and 6 months crop growth period significantly affected growth and productivity of *Amorphophallus* variety Gajendra. WDS during growth stages A to F, i.e., from the time of sprouting (stage A) to development of full leaf (stage F) suppressed the development of leaf indicating that the initial establishment is a critical period of crop sensitivity to WDS and this crop growth period requires adequate soil moisture. Similarly, crop growth period between 4 and 6 months also is critical period which requires adequate soil moisture for crop productivity.

In sandy clay loam soils, moisture level at 50% water holding capacity (WHC) was on par with moisture at 100% of WHC level on the rate of P mineralized but significantly different and higher as compared to air dry conditions (2.83 against 3.54 kg P ha^{-1} per season). Higher level of P had a significantly higher mineralization rate of 4.53 kg P ha^{-1} per season as compared to control (2.61 kg P ha^{-1} per season) in sandy loam soils.

The three years field experimentation with 6 selected K efficient genotypes of cassava at four different levels of K indicated the efficacy of these genotypes to perform equally well without K as well as at higher levels of K with Aniyoor and 7 III E3-5 as the best for edible and industrial purposes, respectively.

Developed nutrient management plan for Pathanamthitta district of Kerala giving emphasis to tropical tuber crops after analyzing 10,348 soil samples for pH, organic carbon, major, secondary and micronutrients.

In six major hill cassava production systems of Eastern and Western Ghats in Tamil Nadu with different elevations, soil type, soil fertility management levels etc. were characterized for major soil physical properties and nutrient contents.

Prepared a nutrient rich organic manure through composting of cassava starch factory solid waste (thippi) having mean N, P, K, Ca, Mg, Fe, Cu and Mn content of 1.32, 3.82, 0.4, 2.18, 0.96, 1.11, 0.08%, 11.23 and 89.93 ppm, respectively which is 3.5, 49, 7, 3.25, 8.1, 185, 100, 2.5 and 12 times than that in thippi with reduced starch, cellulose, cyanide and fibre and enhanced protein content.

Zeolite materials with high cation exchange capacity were synthesized from fly ash for enhanced soil

nutrient retention. Dose of zeolites for soil application was standardized. Evaluation of its suitability as soil amendment in sweet potato (variety ST-14) indicated 57% tuber yield over control (no zeolite).

Identified salt tolerant sweet potato varieties CIP-440127, Samrat and Pusa Safed suitable for cultivation in salt affected areas.

Malathion, chlorpyrifos and methyl parathion at 0.5% concentration completely controlled adult yam mealy bug (*Rhizoecus amorphophalli*) two days after treatment. A Pilot Plant was installed to scale up the production of bio-fumigant from the rinds and leaves of cassava. Two bio-formulations from the bioactive principles of cassava seed, one effective in controlling pseudostem weevil in banana and the other for management of aphids,were developed.

Elephant foot yam mealybug (*R. amorphophalli*) was successfully controlled in storage by releasing coccinellid *Cryptolaemus montrouzieri* @ 2 beetles per kg of tuber at a temperature of 25 to 30^{0}C. The parasite *Anomalicornia tenuicornis* Mercet (Encyrtidae) gave 15 - 20% control of *R. amorphophalli* in storage.

Two repellents for female sweet potato weevil *Cylas formicarius* was identified as α-Humulene and α-Gurjunene. Feeding deterrents for *C. formicarius* were identified as 2-(2-butylcyclopropyl)-cyclopropanenonanoic acid methyl ester and 9,12-(Z,Z)-octadecadienoic acid released from flowers and storage roots, respectively.

Dasheen mosaic virus (DsMV) in *Amorphophallus* was detected through Lateral flow device and Reverse transcriptase – LAMP techniques. *DsMV*, *Broad bean mottle virus* and *Hibiscus singapore virus* were detected through deep sequencing of virus infected *Amorphophallus* samples. Transcriptome analysis of elephant foot yam revealed differential gene expression in infected and healthy samples. An efficient callus multiplication and shoot regeneration medium was established for *A. paeoniifolius* for the production of virus free plants. *Yam Maclura virus* was detected from leaves and tubers of greater yam using virus specific primers and antibody and diagnosed through NASH technique. The partial genome of the virus was amplified with specific primers. Sequence analysis showed that it is 69% matching with *Chinese yam necrotic virus.* Specific primers were designed using RAS-like, TRP1, GPA1 and ASF-like regions for accurate detection of *Phytophthora colocasiae* causing taro leaf blight. A simple and rapid *in vitro* method was developed for zoospore generation in *P. colocasiae* and screening for taro blight using leaf segments.

A positive correlation between virus titre and CMD symptom severity in cassava like susceptible, recovery and resistant, was established using quantitative PCR. A qPCR protocol was standardized for detection and quantification of *P. colocasiae* inoculum load in infected taro leaves.

Soil and tuber treatment with *Trichoderma* @50 g of 10^7 cfu g^{-1} and 5 g in fresh cow dung slurry per kg of tuber, respectively along with foliar spraying of Carbendazim @0.05% three times at 15 days interval after initiation of the symptom was most effective for management of greater yam anthracnose caused by *Colletotrichum gloeosporioides*. Toxin produced by the pathogen has been purified and partially characterized using TLC and column chromatography. Lesion produced on leaves *in vitro* using crude toxin is positively correlated with field symptoms.

Planting material treatment with cowdung mixed with *Trichoderma* (@5g per kg), use of *Trichoderma*-enriched compost and application of 200 g neem cake per plant resulted into 22% higher corm yield and 80% reduction in collar rot incidence, 15% reduction in leaf blight and 10% reduction in mosaic incidence over control in the farmer's field. ITS and *tef* characterization of 10 isolates of bio-control agents (BCA) against *Sclerotium rolfsii* yielded three different species, viz., *Trichoderma asperellum*, *T. harzianum*, and *T. longibranchiatum*. RAPD analysis showed polymorphism of these isolates, even within the same species.

Potent bio-control agents of vermicompost origin against taro leaf blight and elephant foot yam collar rot were identified as *Bacillus subtilis, B. cereus*, *Providencia rettgeri* and *Trichoderma asperellum.* The bacterial isolates expressed N_2 fixing, P and K solubilizing and growth promotion properties. Disease suppression varied with the origin of vermicompost. Minimum concentration of 10% was required for pathogen suppression. Application of

vermicompost reduced the taro leaf blight incidence (PDI of <5) and collar rot in elephant foot yam (10-30%) in pot culture. Vermiwash reduced the lesion development by *P. colocasiae* on detached taro leaves *in vitro*. Production of resistance inducing enzymes; chitinase, glucanase and total phenols increased with application of vermicompost in taro plants.

Technology standardized for the production of sweet potato spaghetti with low starch digestibility and low estimated glycaemic index (EGI) using legume flour sources and low glycaemic pasta from cassava using commercial resistant starch source, NUTRIOSE®. Low calorie sago with high resistant starch content (35%) compared to 23% in control sago was developed.

Technology for value added fried snack food from cassava was commercialized to five entrepreneurs. Setting up of a Techno Incubation Centre for the commercialization of value added products from tuber crops was approved by the Department of Agriculture, Govt. of Kerala, under the 'Value Addition Scheme' of Small Farmers' Agribusiness Consortium.

Extruded products were developed form blends of cassava with cardamom, black pepper, turmeric, rice-banana, rice-wheat etc. The best fermented cassava-wheat-rice blended extrudate was obtained at 200^{0}C die temperature and 80 rpm of extruder speed. A highly expanded product was obtained from sweet potato turmeric blend at 180°C and 92 rpm of extruder screw speed.

Lacto pickle of orange fleshed sweet potato with carrot and beet root (1: 1: 1 ratio) was developed by lactic fermentation with a probiotic strain *of Lactobacillus plantarum* (MTCC 1477).

Alpha amylase enzyme from *Bacillus subtilis* strain CM 3 earlier isolated from cow dung microflora was purified and used in amendment with the commercial saccharifying enzyme (Palkodex, 10 ml, v/v, M/S Maps Enzyme Ltd, India) for hydrolysis of sweet potato flour and subsequently to ethanol. After 120 h of fermentation, the maximum yield of ethanol was 380 ml per kg flour.

Low cost simplified technique developed for the purification of linamarin (toxic glucoside of cassava) from cassava leaves and rind. Cassava leaf protein concentrate was prepared using cheap methods and its efficiency as fish meal substitute tested in ornamental fish in collaboration with CMFRI, Kochi. Ten percent LPC incorporation gave maximum performance of Black Molly fish. Dehydrated cassava leaf meal was tested as an animal protein supplement in collaboration with the Kerala Veterinary and Animal Sciences University (KVASU). Replacement of concentrated feed with 30% leaf meal gave the highest weight gain in goats.

Recovery of starch from cassava roots could be enhanced through ultrasound sonication at 450 W energy level and 50% pulsation rate for 10 minutes. The whiteness of the recovered starch ranged from 88.50 to 96.22% and maximum whiteness was obtained at 600 W energy level and 70% pulsation rate when treated for 10 min.

Developed modified cassava starch (hydroxypropylated and cross linked)-nano clay (nanocalibre 100 A-Amino silane modified nanokaoline clay) and nanocalibre 100 SD (nanokaoline clay in spray dried form) composite biodegradable films. Hydroxypropylated/crosslinked starch-nanocalibre 100 A film had maximum whiteness index and tensile force with minimum total colour change and solubility. Hygroscopicity of crosslinked starch-nanocalibre 100 A film was minimum with 0.09 g g^{-1} for 4% starch - 0.3% clay and 20% glycerol composites. Among the cassava starch-wax composite films, maximum thickness, whiteness index, tensile force and elongation at break with minimum total colour change, swelling power and solubility obtained for starch-bee wax films. Minimum hygroscopicity was obtained for the films with 0.108g g^{-1} and 0.102 g g^{-1} for 3% starch-10% bee wax/parafin wax and 15% glycerol composites.

The oligosaccharide profile of the maltooligosaccharides synthesized by the dual enzymatic process of cassava, maize and potato starches using a commercial starch debranching enzyme, pullulanase and a thermostable alpha-amylase Spezyme (Genencor), was determined by HPLC analysis. The product contained maltotriose, maltopentaose, maltohexaose and maltoheptaose as major oligosaccharides. The morphology and crystallinity of the enzymatically debranched cassava and potato starches were determined. All debranched products showed higher percentage crystallinity than

the corresponding native starches. After debranching, cassava starch showed a transition from A-type to B-type pattern via type-C. Loss of granular structure was observed in the debranched starches. A comparative study of the structure and properties of the naegeli dextrins and lintnerized starches of cassava (a tropical tuber starch), potato (a temperate tuber starch) and maize (cereal starch) starches was performed. The dextrins of all the three starches showed complete erosion of amylose fraction. The morphology, crystallinity, aqueous solubility, thermal properties and *in vitro* digestibility of the dextrins were determined and compared.

The residual acrylamide content in the porous sample of superabsorbent polymeric gel was determined and no detectable monomer was present. The cassava starch based semi-synthetic superabsorbent hydrogel was evaluated under field conditions, as a soil additive for moisture retention and its effect on physical, chemical and biological properties of the soil as well as on plant growth parameters was studied. The sample with higher percentage of starch showed 78% degradation after 5 months of disposal in soil. The product was tested for its efficiency to remove heavy metal ions from aqueous solutions and the adsorption was maximum for Pb^{2+} ions (about 66%),whereas it was minimum for Zn^{2+} (2%). Cassava starch-g-poly (methacraylamide) having good flocculation efficiency was synthesized and characterized. These grafted starches exhibited good textile sizing properties also. Nanostarch was synthesized from cassava starch, characterized and incorporated in composites for evaluation as matrix for incorporation of curcumin.

A vibro sieving system for sieving wet starch slurry was developed. Industrial evaluation of vibro sieving system was carried out at three deck slopes and two sieve sizes (250 &400 mesh) and the results showed that the concentration of the feed and output were 8.2% and 9.3%, respectively. The whiteness of starch in feed and output were 93.0 and 97.05%, respectively.

Non-monetary practices, *viz.,* land preparation, selection of seed material, seed size, depth of planting, spacing, method and time of fertilizer application and inter culturing operations were adopted by the farmers as per the recommendations in West Bengal for taro and yams and elephant foot yam in Odisha. Farmers of Andhra Pradesh growing elephant foot yam and yams were also adopting fertilizer as per the recommendation. Some farmers indiscriminately used fertilizers, pesticides and fungicides in all the surveyed villages. Average adoption index with regard to the selected sweet potato production technologies in Odisha was estimated as 55.61. Under the rain-fed conditions of Andhra Pradesh, the short duration triploid 3-4 performed well and preferred by the farmers with an average tuber yield of 19 t ha^{-1} and extractable starch content of 27%. Tapioca starch demand in textile sector was 85 lakh tonnes for 2011 and the projected demand for 2016, 2021 and 2026 is 0.9; 1.01 and 1.15 lakh tonnes respectively. Tapioca starch demand in corrugation adhesive sector was 1.15 lakh tonnes for 2011 while the projected demand for 2016, 2021 and 2026 at current growth rate of 10% in the industry is 1.85; 2.98 and 4.36 lakh tonnes respectively.

TEFR was prepared on Pasta from sweet potato and gluten free pasta from cassava. Total capital investment for each unit with a working capacity of 38.4 tonnes sweet potato pasta and gluten free pasta from cassava was at ₹ 44 and 45 lakh respectively.

An EST analysis pipeline developed for the analysis of EST from tuber crops and distribution studies of SSR in EST data of cassava, sweet potato and yams were carried out; 5489, 3373 and 2267 SSR containing sequences were identified for cassava, yams and sweet potato, respectively. An R function developed for SSR prediction, which identifies the location of the SSR in the sequence and the number of repeats. With a view to develop tools for miRNA analysis, an miRNA target prediction tool for the given mRNA and miRNA sequence has been developed in R package incorporating sequence similarity score and energy prediction.

Developed a disease diagnostic system of cassava, an expert pathologist, on the web. This helps the users to clear their doubts regarding various cassava diseases. The potential yield of cassava in all the 15 agro-climatic zones of India was computed using the cassava simulation model SIMCAS. Tuber information café (TIC) was modified by including

more user friendly features. On line facility for early warning about mealy bug was developed using PHP/ MySQL and launched. A simulation model about the dynamics of mealy bug was developed and this is running at the back end to give predictions.

About 20 tuber crops dishes from Nagaland (Konyak tribe – 17 and Aao tribe – 3) were documented. Semi-processed taro products like Teangyakwan (processed taro leaf), Teangwan (dried taro tubers), Fluo (dried taro leaves), Shouhwan (processed taro petioles) and Tunggan (Dried taro tubers) were documented. Several home-based recipes like Teangyakhoi, Teanghoi, Teang, Fluo Curry, Tung Rahak Sui, Tungkungsui, Tungrhak, Tunkhon, and Tung Pai were also documented.

For enhancing food security and sustainable livelihoods in the North-Eastern India through tuber crops technologies under CTCRI- NEH programme a baseline survey was conducted in Manipur, Meghalaya, Nagaland and Tripura to identify the present livelihood status of the tuber crops farmers in the project villages. Besides the livelihood status, the major tuber crops production systems, the farmers' food insecurity status, proneness to shocks and disasters and their coping strategies were also studied. The project partners were equipped in the knowledge and skills necessary for conducting the livelihood survey through training programmes in Manipur, Meghalaya, Tripura and Nagaland.

Under Tribal Sub Plan (TSP), systematic effort was undertaken to improve the productivity of root and tuber crops by careful application of improved technologies. Extensive outreach programmes complemented with need based research modules would be done through support of seed materials development and distribution, knowledge dissemination, production processing linkage, capacity building and entrepreneurship building. During the year 2012 - 13, 465 tribal farmers were identified as beneficiaries from Chatisgarh (Narayanpur district), Jharkhand (Deogarh) and Odisha (Kandhamal and Koraput districts) state and laid out 665 demonstrations on tuber crops technologies. Planting materials of different tuber crops were distributed to them. Capacity building training programmes were organized for the tribal farmers one each in Narayanpur, Deogarh, Kandhamal and Koraput districts on root and tuber crops.

INTRODUCTION

CTCRI (1963-2013)

The Central Tuber Crops Research Institute (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 21.5 ha. Later, an area of 26.69 ha has been added. CTCRI has one Regional Centre (RC) at Bhubaneswar functioning in an area of 20 ha. The All India Coordinated Research Project on Tuber Crops (AICRPTC) was started at CTCRI in 1968 with three centres at Dholi in Bihar, Coimbatore in Tamil Nadu and Acharya N.G. Ranga Agricultural University, Hyderabad, Andhra Pradesh. The AICRP TC which was started for testing and popularization of location specific tuber crop technologies invarious parts of India has presently 17 centres including 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 CTCRI is conducting basic and applied research on various edible tropical tuber crops.

Research Mandate

- To undertake basic, strategic and applied research for generating technologies to enhance productivity and utilization potential of tuber crops (other than potato)
- To act as a national repository of scientific information on tuber crops.
- To coordinate network research with State Agricultural Universities for generating location specific technologies
- To act as a centre of human resources development for various clientele systems involved in tuber crops research and development
- To undertake transfer of tuber crops technology through consultancy, outreach programmes and linkage with developmental agencies

General Achievements

The CTCRI is the only one of its kind in the world dedicated solely to the research on tropical tuber crops. The institute is celebrating its golden jubilee year and

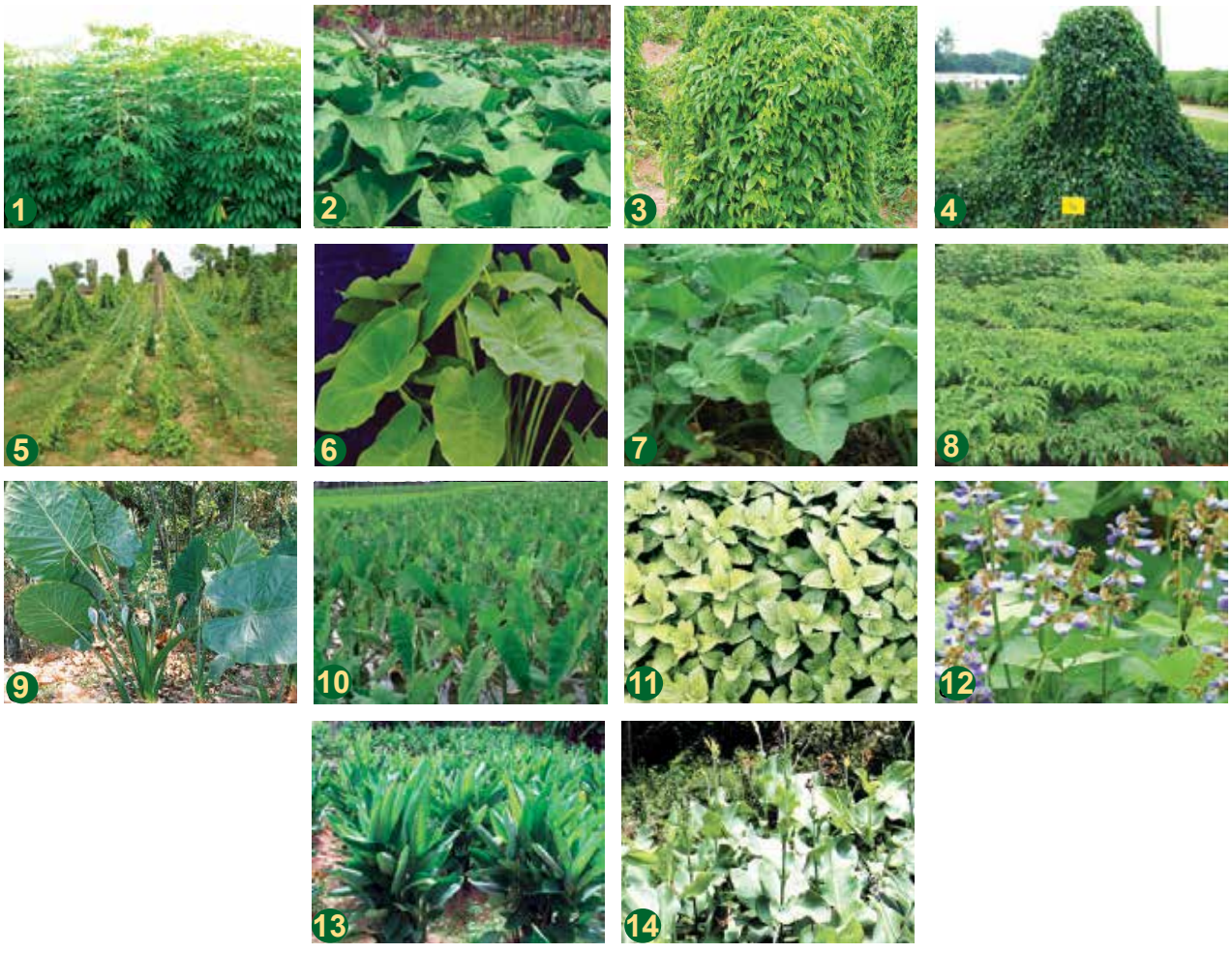
five decades of concerted research have led to the development of several production and processing technologies for tuber crops besides release of nearly 49 improved varieties. The target group of most of the technologies being marginal and resource poor farmers, adequate emphasis is also given for 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.

- CTCRI has a wealth of germplasm of tuber crops, totalling 6151. This has formed the basis of all the genetic improvement and variety development programme. The improvement work was exclusively based on conventional breeding programmes. Pioneering role of CTCRI in tropical tuber crops breeding attracts international collaboration in the breeding and genetic improvement of tuber crops.
- CTCRI has released 50 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 dependant on two major industrial varieties of cassava released from CTCRI, viz., H 165 and H 226. Further new and improved triploids with high extractable starch content were developed which are under farmers' participatory selection process in Tamil Nadu. Two of such varieties, viz., 4-2 and 5-3 are found to be promising and acceptable to farmers as well as industries and these are in the pre-release stage. Thus apart from the table varieties, the industrial varieties of cassava have made a major impact in adoption and utilization by the farmers.
- 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 the development of facilities and formulation of programmes using this advanced technology for the improvement of tuber crops. The Institute presently has very strong programmes in biotechnology which includes the development of diagnostic tools for viral and fungal diseases and transgenic plants for cassava mosaic disease.
- A host of tuber crops production technologies are available for mono crop, intercrop and multi crop cropping systems which help in enhancing the yield, soil fertility, employment opportunities for farm families and income levels. Integrated crop protection technologies developed for cassava mosaic disease and sweet potato weevil would help the farming community in extreme eventualities. Besides, technology has been perfected for organic production of yam and elephant foot yam.
- 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.
- Aroids especially elephant foot yam is gradually gaining importance in different areas like Odisha, Bihar and Uttar Pradesh, Gujarat and north eastern states. Supply of quality planting material is ensured to farmers of all regions though revolving fund scheme and mega seed project. There exists a good research base in the country to sustain root and tuber crops research and development with CTCRI giving the leadership and AICRPTC to plan and coordinate region specific research and testing of technologies on these crops.
- Technology generation and transfer being closely interlinked with the utilization by the clientele system.
- 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 award carries a cash prize of Rs. 5 lakhs, besides a plaque, certificate and citation.
- The Institute has bagged many national and International recognitions in the past that include J.J. Chinoy Gold Medal (1970), three ICAR Team Research Awards (1985, 1996, 1998), D.L. Plucknett Award for Tropical Root Crops, Hari Om 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)

and Vasantharao Naik Memorial Gold Medal (2002).

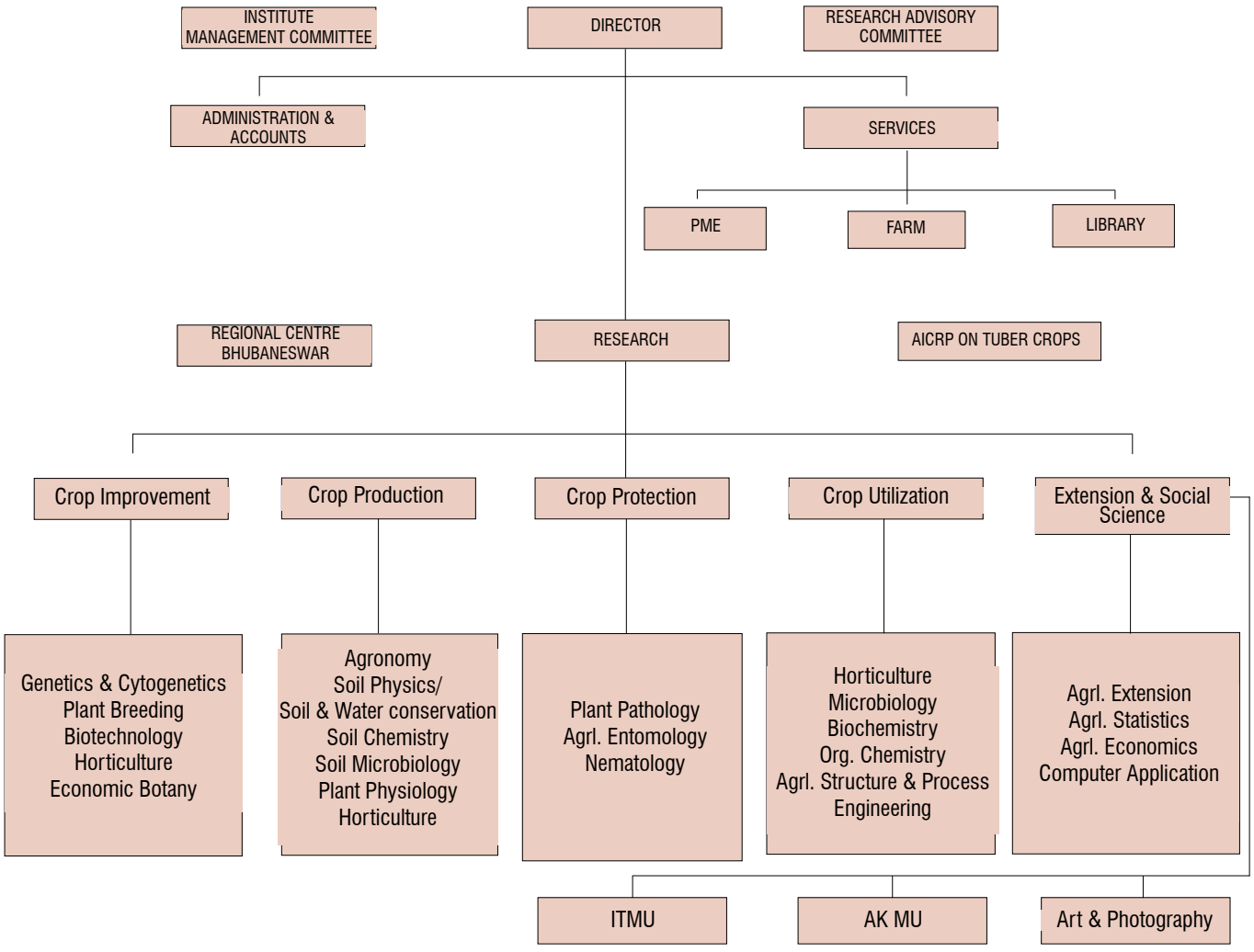
- In recognition of its contribution to cassava growers and consumers worldwide, CTCRI has been rewarded at the First International Meeting on Cassava Plant Breeding, Biotechnology and Ecology organized at Brasilia, Brazil during 11-15 November, 2006.
- The Best Annual Report Award (1997-98) among the category of Small Institutes was conferred to Central Tuber Crops Research Institute for succinctly presenting the research results.
- The Institute has conducted more than 13 National and International Symposia / Seminars / Workshops.
- The infrastructural facilities of the Institute have been tremendously increased during the X and XI Plan periods. Additional laboratories like Food Extrusion Laboratory, Transgenic glass House, Bioinformatics Laboratory, Biodiversity sheds, Modernised Computer Cell, Seed Storage Laboratories, Net Houses etc. have been constructed. The Institute Headquarters has been renovated thoroughly, giving a totally new look to it, with modern laboratories. A number of new and sophisticated equipment have been added to the existing ones to raise the standard of research. These include several imported equipments like the Food Extruder, Texture Analyzer, Differential Scanning Calorimeter, FTIR, Rapid Viscoanalyser, HPLC, Atomic Absorption Spectrophotometer, Autoanalyser, Gel Documentation System, Realtime Quantative PCR, Nitrogen analysers, Fibre analyser etc. The infrastructural facilities of the Regional Centre have also been considerably improved through the creation of additional laboratory space, providing several new equipments.
- Extramural support by way of research schemes from both International (like CIAT, CIP, CIRAD etc) and National agencies (like ICAR, DST, DBT, DRDO, LSRB, JNU, UGC, PPIC, KSCSTE, DSIR,SHM,PVP & FRA etc), was a great boon to the Institute to upgrade the research infrastructure as well as to facilitate detailed studies on frontier areas of research. The Network projects of ICAR have helped the Institute to focus research on priority areas.
- Established a full fledged local area network connecting the various divisions and administration wing. The network consists of windows nt server, internet proxy server, intranet file server and email server, computers, laser printers, inkjet printers, scanners, dtp and multimedia work stations. Legal licensed versions of popular software packages like windows 98, windows, microsoft office 2000, Microsoft XP office, pagemaker 6.5, corel draw 6.0, ism multiscripts, visual studio etc. are installed for various type of applications. In addition to that supporting statistical softwares such as SAS, JMP Genetics and Genomics and R environment for statistical computing, WinBugs Visual Studio 2012 and bioinformatics software DNASTAR, Laser Gene 11 Genomic Suite are installed to meet the computing requirements.
- 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. are available in the site.

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 arrow root *Canna edulis* (Ker-Gawler) Cannaceae.

Organisational set-up



Staff position (2011-12)

Category	No. of posts Sanctioned	Filled	Vacant
RMP	1	1	0
Scientific	49	38	11
Technical	47	46	1
Administrative	31	28	3
Supporting	67	42	25
Total	195	155	40

Progressive Expenditure 2012-13

Plan

₹ in lakhs

SL. No.	Head of Account	RE 2012-13	Progressive Expenditure 2012-13
1	Works		
	i. Office building	17.00	17.00
	ii. Residential building		
	iii. Minor Works	6.50	6.35
2	Equipments	91.00	91.02
3	Information Technology	10.00	10.15
4	Library Books & Journals	10.00	10.00
5	Establishment Charges		
6	Traveling Allowances (Instt.+TSP+NEH)	39.00	39.00
7	Research & Operational Expenses (Instt.+TSP+NEH)	151.50	151.51
8	Administrative Expenses	153.50	153.61
9	Miscellaneous	21.50	21.35
	Total	**500.00**	**499.99**
10	AICRP on TC	384.50	380.00
11	AICRP o n PHT	6.53	3.36
12	Plan Schemes	66.90	53.88

Non-Plan

1	Equipments	10.00	10.09
2	Furniture & Fixtures	2.00	1.91
3	A. Establishment Charges	1050.00	1010.03
	B. Pension & Other Retirement Benefits	181.00	181.00
	C. Loans & Advances	5.00	5.00
4	Traveling Allowances	5.00	5.04
5	Research & Operational Expenses	26.00	25.97
6	Administrative Expenses	71.35	71.32
7	Miscellaneous	2.65	2.65
	Total	**1353.00**	**1313.01**

RESEARCH ACHIEVEMENTS

CROP IMPROVEMENT

COLLECTION, CONSERVATION, CATALOGUING AND EVALUATION OF GERMPLASM OF TROPICAL ROOT AND TUBER CROPS

Cassava

The germplasm of cassava consisting of 1,923 accessions are being maintained as field gene bank. Six high yielding landraces of cassava with good cooking quality were collected which included two accessions from Nagaland and one narrow leafed landrace with high dry matter content (42.7%) from Kerala. One hundred and fifty accessions of landraces of cassava were provided to TNAU for research purpose under MoU.

Totally 350 landraces of cassava were characterized and documented based on 12 key traits and twenty four morphological traits and the duplicates were identified. CI-898 and CI-75 recorded the highest tuber yield with low cyanogen (<30 ppm) content. CI-60 was identified as an early bulking clone with high yield. CI-60, CR43-11 and CR43-7 were identified as drought tolerant genotypes. Tubers of CI-800, CI-802 and CI-859 had excellent cooking quality. Fifteen landraces were free from cassava mosaic disease symptoms.

In cassava, fifty landraces were analyzed for molecular variability and DNA fingerprinting of released varieties was done using RAPD and SSR markers. CI-273 was highly divergent from all other accessions. Among the SSR primers tested, the primer SSRY-28 elucidated maximum polymorphism followed by SSRY-106, SSRY-45, SSRY-100 and MeM SSR-10 and were selected for diversity analysis in cassava.

Sweet potato

A total of 1100 accessions of sweet potato are being maintained as field gene bank at CTCRI (HQ). 372 accessions were conserved at CTCRI (RC). Ten new accessions of sweet potato from Northern India were received during this year. Five accessions of wild *Ipomoea* species from different parts of Kerala were also added to the germplasm. Fifty six accessions were characterised for vegetative and floral characters of which 22 were also assessed for culinary qualities like consistency, undesirable colour, texture and sweetness of boiled root. The catalogue was updated with digital photographs of 70 accessions. Screening and evaluation of 116 sweet potato accessions at CTCRI (RC) resulted in identifying 18 promising genotypes with high starch (22.2 - 24.8%) and minimum weevil damage (5 - 10%). Five of these accessions had low sugar (< 3%) content and 13 showed early maturity (75 - 90 days). Four accessions were found to be nutrient efficient and responded to half doses of K and P.

Yams

In yams, seven accessions comprising five of greater yam, one of wild yam and one of *D.bulbifera* were added to the field gene bank. A total of 1151 accessions of yams are being maintained in the field gene bank. Totally 350 accessions of greater yam were characterized for 10 traits including six quantitative traits. Yield of 51 accessions ranged from 6 to 25 t ha^{-1}. Da-25 recorded the highest yield. Six *Dioscorea* species were provided to SRM University, Chennai for research purpose.

Aroids

A total of 679 aroid germplasm, which includes 414 taro, 27 tannia and 238 elephant foot yam accessions were maintained in the field as well as in pots for conservation and characterization at CTCRI (HQ). Nine new accessions from the North Eastern regions and Southern regions of India were added during this year. CTCRI (RC) holds a field gene bank with 507 taro and 39 elephant foot yam accessions.

A total of 171 taro accessions were evaluated for yield related traits, viz., number of corm/cormel, weight and shape. One hundred and twenty nine elephant foot yam accessions were evaluated for agronomic traits and 26 accessions for 18 above-ground morphological characters at maximum growth period using NBPGR minimal descriptors. Thirty taro accessions were screened against *Phytophthora colocasiae* and 152

taro accessions for virus. Database of taro germplasm was updated with passport data of 122 taro accessions, tuber photographs of 161 taro (Fig. 1) and one tannia accession and disease scoring data of 342 taro accessions. In taro, yield ranged from 4.5 to 14.4 t ha^{-1}. Passport information was also completed for 33 elephant foot yam accessions. Also of the 39 elephant foot yam accessions, 4 lines recorded higher yield in the range of 18.8 to 26.2 t ha^{-1}.

In taro, genetic diversity analysis was undertaken using SSR markers for 47 taro accessions from Kerala. DNA isolation using Amnion kit and PCR conditions for nine SSR markers (Ce1B03, Ce1B12, Ce1D12, Ce1F04, Ce1F12, Ce1H12, uq73-164, uq84-207 and uq110-283) were standardized to obtain sharp bands on 2% agarose gel. Of the 507 taro accessions at Regional centre 20% were found susceptible to blight.

Fifty exotic lines are being maintained *in vivo* and *in vitro* (Fig. 2) at both, HQ, Thiruvananthapuram and RC, Bhubaneswar under INEA taro Programme of European Union. Morphological characterization revealed 39 as dasheen and 11 as eddoe types. Based on the visual characterization, all 50 accessions could be grouped into six categories.

Minor tuber crops

A total of 239 accessions of minor tuber crops germplasm, viz., 125 of Chinese potato, 84 of yam bean, seven of arrowroot, five of queensland arrowroot, one accession each of *Tacca* and *Vigna*, 11 of Curcuma spp., three of *Typhonium* spp. and two species each of *Coleus* and *Costus* are being maintained in the field gene bank at CTCRI (HQ). The field gene bank at Regional Centre holds yam bean (145), *Coleus* (5), arrowroot (2), tannia (1) and *Alocasia* (3).

To the existing germplasm, two accessions of *Coleus* and *Canna*, one each of *Curcuma* sp. and arrowroot were added. DNA fingerprinting in arrowroot and *Coleus* accessions using RAPD and ISSR primers indicated that there was no genetic variation in these accessions. Passport information of 45 yam bean accessions evaluated has been completed (Fig. 3). Among the 145 yam bean accessions evaluated, four recorded higher tuber yield in the

Fig. 1 Variability in taro tubers

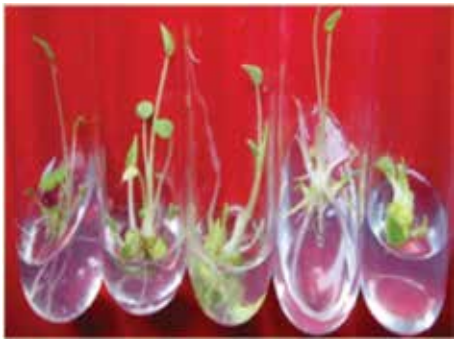


Fig. 2 Taro lines *in vitro*

Fig. 3 Harvested tubers of yam bean

range of 24 to 31 t ha^{-1}. Of the 5 Chinese potato accessions, the highest yield 18.5 t $ha^{-1}$was recorded by tissue cultured plants of Sree Dhara.

In vitro conservation of tuber crops germplasm

Under *in vitro* conservation of tuber crops germplasm, 120 accessions of sweet potato and 10 of cassava were brought under *in vitro* gene bank. 1975 cultures of released and exotic lines are maintained *in vitro* at CTCRI (RC). At the Regional Centre, 275 sweet potato, 14 cassava, 39 elephant foot yam, 145 yam bean and 51 yam accessions have been multiplied for field evaluation.

The micropropagation protocol of *Xanthosoma* was standardized with MS media containing TDZ (0.1 mg l^{-1}) in accession E-14 with 3-4 buds/ explant. Multiple shoot induction protocol was standardized in *Amorphophallus* using axillary bud explants in MS medium containing TDZ and 2,4-D with 4-6 shoots/ explant within 40 days of culture. Thirty three taro lines obtained from NBPGR, New Delhi was successfully transplanted to the field after hardening.

Potentials of aeroponics in tropical tuber crops

Aeroponics chamber was fabricated locally to hold both taro and elephant foot yam plantlets. Explants of hardened elephant foot yam and taro plants were planted and flushed with 4 different nutrient jets containing half doses MS basal salts with growth regulators. Of the different treatments, leaf and root growth was recorded both in nutrient formulation containing ½ MS salts + 0.5 mg l^{-1} each of NAA, BA and GA3. New rooting and emergence of leaves were observed in taro within 3 to 7 days, whereas in case of elephant foot yam similar response was recorded within 5 to 10 days.

VARIETAL IMPROVEMENT IN TROPICAL TUBER CROPS

Cassava

Under genetic improvement of cassava for CMD resistance, earliness, high starch and keeping quality through polyploidy breeding, the CMD resistant hybrids, CR43-11 and 9S-127 were raised in nursery and treated with 0.1% aqueous solution of colchicine for the development of tetraploids. A natural tetraploid clone (Tr2-15) was also identified and used for the production of triploids by crossing with cassava mosaic disease (CMD) resistant diploid clones CR43-11 and 9S-127. Seed set was obtained when tetraploid was used as female and 156 hybrid seeds were collected. In the advanced yield trial (AYT) of triploids, Tr16-6, Tr30-1, Tr11-8 and Tr47-1 recorded high starch content (>30%). Two CMD resistant hybrids, viz., 9S-127 and CR35-18 recorded high dry matter (>40%) and CR43-11 recorded highest yield at sixth month after planting. CI-800 and CR20A-2 recorded tolerance to post harvest physiological deterioration.

To identify the most suitable hybrid varieties of cassava for fried chips production, on farm trial was conducted using six CMD resistant hybrids along with control (M4, local). All the six hybrids were found to be free from CMD symptoms under field conditions. The fried chip quality (taste, texture, colour, shape and peeling quality) was tested by TIERRA FOOD Pvt Ltd. Taste profile and bite feel of the varieties were found good. However, CR21-10 and CR20-A2 were found most suitable for chips production in terms of frying tolerance and bite feel. A new promising clone of cassava (CMR-100) (Fig. 4) was identified for the evaluation of chips

Fig. 4 Tubers and chips of CMR100

quality with CMD resistance, middle branching habit, uniform tuber shape (cylindrical), light yellow flesh, non-bitterness and high dry matter (43%). The uniform, long cylindrical shape of the tuber was ideal for fried chip making. The peeling of the tuber was easy and raw tuber had sweet taste and showed very good cooking quality.

For studying CMD resistance using association mapping, a total of 14 CMD associated SSR markers were selected from the previous studies with 10 CMD resistant (both TMS, TME lines) and 10 susceptible lines. All the markers were amplified and the markers RME-1 and SSR44/NS136 showed clear difference between CMD resistant and susceptible lines. Based on cloning, the fragment of RME1 primer resulted in the identification of 676 bp sequence, 80% similar to *Manihot esculenta* HNL4 gene (AJ2232281). The marker SSR44 gave the amplification length of 194 bp and shows 100% similarity to *Manihot esculenta* clone TME-3 cDNA (604317). Both RME-1 and SSR44 primers were involved in the disease resistance pathway and can be used for molecular breeding of CMD resistance for gene pyramiding to develop highly resistant genotype.

Suppression Subtractive Hybridization (SSH) was done to isolate differentially expressing genes in CMD resistant parent (MNga-1) using cDNA library. Plants were indexed for cassava mosaic virus with the virus specific primers which gave amplification only in the positive control, which confirmed the absence of virus in these meristem derived plants. Viruliferous whiteflies from virus harbouring CMD susceptible plants in the field were released to the tester plants in cage and were allowed to feed on these plants after which the plants were again indexed with virus specific primers and the result showed the presence of virus in tester plants alone and not in control. RNA from tester and driver plants were isolated and used for cDNA construction. Differential screening of tester and driver cDNA libraries was done with Clonetech subtraction kit. The isolated differentially expressed sequences were cloned into pGEM-T plasmid vector for subtracted cDNA library construction.

To develop transgenic cassava with enhanced starch content, a bacterial *glgC* gene was procured from CPRI, and was sequenced. It was then transformed to *E.coli* and again sequenced. Transformation of *Agrobacterium* to cassava was standardized using pBI121 vector via triparental mating method. Further the *glgC* construct was mobilized into *Agrobacterium* LBA4404 strain using tri-parental mating method. The presence of mutated *glgC* gene in transformed colonies were confirmed using a PCR with specific primers. To rule out the presence of an *E. coli* mutant, further biochemical test is being carried out.

Another strategy was adopted to develop waxy cassava through silencing the *gbssI* gene using a hairpin construct development. Primers were designed to amplify *gbssI* gene fragments with restriction sites added, so as to enable its easy cloning to pBinAR construct. Three primer set each of expected amplification size around 600 bp and 400 bp were designed using Oligo3 software. The primers were subjected to *in silico* PCR analysis using the program Fast PCR and confirmed that primers were amplifying the expected size fragments. Further, a 600bp amplicon size fragment was amplified under wet lab conditions by utilizing the primer designed and the PCR conditions standardized through *in silico* primer analysis. The released varieties of cassava H226 and H165 were multiplied *in vitro* for developing embryogenic calli for use in transformation experiments.

Sweet potato

For breeding early maturing, weevil resistant, high starch, high carotene orange-fleshed sweet potato (OFSP) lines for consumption and industrial application, ten improved varieties having good flowering were planted along with S-1, CO3-4 (white fleshed), ST-14 (orange fleshed) and ST-13 (purple fleshed) in isolation to develop hybrid and open pollinated seeds of sweet potato. Fifty nine seedlings with high starch, carotene and good tuber shape were selected for further evaluation. Specific crosses were also made between ST-14 (orange fleshed) and S-1 (white fleshed).

For pre-breeding purpose, a total of 14 wild species including *Ipomoea aquatica, I. carnea, I. trifida, I. coccinea, I. palmata* and *I. nil* were collected and maintained in field for weevil resistance breeding.

A total of 117 sweet potato improved lines were

evaluated for yield performance, dry matter and carotene content, which includes 31 white fleshed lines (WFSP), 46 orange fleshed (OFSP) lines and 40 CIP orange fleshed lines. Out of these 12 WFSP lines were selected for good dry matter content (25-33%) and yield (25-32 t ha^{-1}) and 26 OFSP lines with good dry matter content and carotene were also selected. Biochemical constituents like dry matter, starch and sugar content for 116 sweet potato genotypes were analyzed at different stages of growth (75, 90 and 110 days) for white fleshed types and carotene content for orange fleshed lines.

Screening of 175 sweet potato genotypes, which included 116 indigenous accessions, 15 exotic accessions, 40 open-pollinated (OP) seed raised plants and 4 new accessions showed weevil infestation of 5- 10 % in 31 accessions. Among the 40 OP seedlings evaluated, high yield (> 21.5 t ha^{-1}) was recorded in 8 lines of which, 3 orange fleshed lines recorded high carotene content in the range of 6 – 12.5 mg $100g^{-1}$ and 4 with cream / white flesh recorded starch content of 21-22% and low sugar (<3%).

Registration of high valued sweet potato

The sweet potato genotypes, viz., ST-10 with high extractable starch (20.8-21.2%), ST-14 with high carotene (13.2-14.4 mg 100 g^{-1}) and ST-13 with high anthocyanin (85-90 mg 100 g^{-1}) content were registered with NBPGR, New Delhi (Fig. 5).

Yams

In the on farm trial on purple-fleshed yam accessions, Da-331 recorded the highest tuber yield (28.0 t ha^{-1}). In the advanced yield trial of greater yam accessions, Da-309 recorded the highest yield (37.0 t ha^{-1}) followed by Da-342. Six dwarf hybrids of white yam were evaluated in on farm trials along with Sree Dhanya as control. Among the hybrids, Drd-1068 and Drd-1157 recorded the highest yield (25 t ha^{-1}) followed by Drd-1142. Drd-1060 recorded excellent culinary quality. In the on farm trial of white yam tall hybrids, Dr-657 recorded the highest yield (35.0 t ha^{-1}) followed by Dr-1047 (Fig. 6). Dr-657 also has better cooking quality than the popular released variety, Sree Subhra. It also has good tuber shape similar to Sree Priya.

Fig. 5 Sweet Potato genotypes registered at NBPGR

Dr-657 Dr-1047 Drd-1068

Fig. 6 Pre-release yam hybrids

Participatory trials of taro have been conducted in three different locations of Odisha (Kendrapara, Salepur and Purusottampur) under INEA programme. Six accessions of taro were found to be early maturing. Sixty four per cent populations were found to be tolerant to blight.

As the DUS centre for cassava and sweet potato, 37 released varieties of sweet potato and 22 released varieties of cassava were maintained in field and 205 cultures of sweet potato and 35 cultures of cassava were maintained *in vitro*. Under the PPV & FRA funded project, draft DUS testing guidelines were prepared with 53 traits for cassava including 9 grouping traits and 34 traits for sweet potato including 7 grouping traits. Thirty three characters of 37 released sweet potato varieties and 26 characters for 14 released cassava varieties have been recorded at the Regional Centre. Seventeen pre harvest characters for sweet potato and 11 characters of cassava have been validated for uniformity and stability.

Under the PPV & FRA funded project on Aroids at the Regional Centre, 17 elephant foot yam and 21 taro varieties have been collected and trials laid out for DUS testing. Thirty two pre harvest morphological characters for elephant foot yam and 31 characters for taro have been recorded. Observations on preharvest morphological characters revealed 2-4 individual distinctness (Fig. 7, 8) and 1-4 group distinctness in both the crops.

Fig. 7 IGCOL-8 Purple colour junction

Fig. 8 BCC-38 purple stripe

CROP PRODUCTION

CROP AND WATER MANAGEMENT

Cropping Systems involving Short-duration Cassava and Legumes

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

Rice var. Aiswarya was sown during the first season followed by short-duration pulses, green gram (Co-Gg-7), black gram (Co-6) and soybean (JS-95-60). Thereafter, short-duration cassava was planted with two varieties, Sree Vijaya and Vellayani Hraswa, in main plot and a combination of the three preceding pulses and two fertility levels to cassava (full FYM, N and K; half FYM and N, full K) in subplots. Sole crop of cassava under full dose of manures and fertilizers was also maintained for comparison. The pulse crop was fertilized with P and cassava was not given P. Rice-pulse-short-duration cassava proved to be feasible. Both Vellayani Hraswa and Sree Vijaya were suitable for sequential cropping. Among the pulses, green gram, black gram and soybean were equally compatible in rice based cropping systems involving short-duration cassava (Fig. 9). There was a possibility to save half FYM and N and full P for short-duration cassava, especially when black gram and green gram preceded cassava. The total and tuber biomass production, crop growth rate, tuber bulking rate, mean tuber bulking rate, relative growth rate and harvest index of short-duration cassava were significantly higher when soybean preceded and cassava was fertilized at the full dose. The tuber yield of cassava (34.78 t ha^{-1}), energy equivalent (265.47 x 10^3 MJ ha^{-1}, tuber equivalent yield (52.88 t ha^{-1}) and production efficiency (146.90 kg ha^{-1} day^{-1}) were higher for the system, rice-black gram-short-duration cassava var. Sree Vijaya (at the reduced fertility level).

Precision approach in tuber crops cultivation

Scheduling drip and fertigation requirement of cassava is of utmost importance in order to achieve the twin objectives of higher productivity and significant economic returns. The experiment was repeated during the reporting year in split-plot design with drip irrigation in the main plots and fertigation in the sub-plots. The three treatments of drip were: Drip irrigation at 100, 80 and 60% Pan Evaporation (PE). The fertigation treatments included application of N&K 50:30:20 (50% during 1-40 days, 30% during 41-80 days and 20% during 81-120 days) , N&K 30:50:20 (30% during 1-40 days, 50% during 41-80 days and 20% during 81-120 days) and N&K 50:40:10 (50% during 1-40 days, 40% during 41-80 days and 10% during 81-120 days). At the time of field preparation, FYM was applied @ 12.5 tha^{-1} and full dose of P fertilizer was applied as basal. After ridge formation, drip system was laid out in the field and outlets spaced at a distance of 45 cm on the ridges (spaced at 60 cm) so as to match with the minisett spacing on the ridges at a spacing of 45 cm. Life saving irrigation was given to all the plants invariably

First crop of rice | Second crop of pulse : Soybean JS-95-60 | Third crop of short -duration cassava

Fig. 9 Cropping system involving short- duration cassava

for five days (till establishment). Drip irrigation and fertigation were started from the second week (after establishment) as per the schedule made. Biometric observations were taken at monthly interval and the recorded data had been analyzed. Harvest was done during August 2012.

Biometric observations made at monthly intervals indicated that leaf area index corresponding to drip irrigation at 100 % CPE was significantly higher over that of 60 % and 80% CPE. There was no significant difference among the different fertigation treatments as well as for interaction between drip irrigation and fertigation. The harvest data indicated that drip irrigation at 100% CPE gave significantly superior tuber yield (36.43 t ha^{-1}) over that of 80 and 60 percent CPE (29.19 and 26.53 t ha^{-1}) respectively. No significant difference in yield was observed between irrigations at 80 and 60 % CPE and also with different levels of fertigation. The third year data revealed that drip irrigation at 100 % CPE was the most beneficial for obtaining higher tuber yield. The two controls namely, rainfed and surface irrigation treatments gave significantly inferior tuber yields.

The interaction between irrigation and fertigation, showed that drip irrigation at 100% CPE along with NK fertigation @ 50% during 1-40 days, 30% during 41-80 days and 20% during 81-120 days gave significantly superior tuber yield of 40. 07 t ha^{-1} over the rest of the treatments (26.18 to 36.33t ha^{-1}). The second best interaction was given by the treatment at 100% CPE with NK fertigation 50% during 1-40 days, 40% during 41-80 days and 10% during 81-120 days. The interaction effects also indicated that significant yield could be obtained when 50% fertigation is applied during the first 40 days after transplanting.

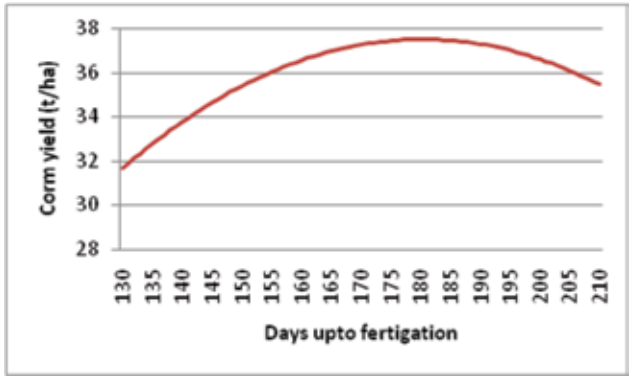


Fig. 10 Effect of duration of fertigation on corm yield of elephant foot yam

Management of fertigation in elephant foot yam

Experiment was conducted during 2012-13 at Regional Centre of CTCRI, Bhubaneswar, to study the effect of frequency / interval, dose and duration of fertigation on growth and yield of elephant foot yam. The experiment was laid out in split plot design with fertigation interval (2, 3 and 4 days) in main plots and in sub plots the recommended fertilizer (Soluble fertilizer N- P_2O_5-K_2O 120-60-120 kg/ha) was split into 30(N- P_2O_5-K_2O 4-2-4 kg/ha/dose), 40 (N- P_2O_5-K_2O 3-1.5-3 kg/ha/dose) and 50 (N-P_2O_5-K_2O 2.4-1.2-2.4 kg/ha/dose) doses and applied through drip irrigation. A control/Check IW/CPE: 1.0; P_2O_5 60 kg/ha basal application; N-K_2O 120-120 kg/ha soil application at 1st (40%), 2nd (30%) and 3rd (30%) months after planting (MAP)). The treatments were replicated three times. The treatments were imposed 10 days after planting. Farmyard manure @10 t/ha was incorporated in the last plough in all the treatments. The crop was drip irrigated at 80% CPE. The irrigation was stopped 10 days before harvesting.

The maximum plant height at three and five MAP was recorded in treatments received at higher fertigation. The treatment fertigation at two days interval with 40 split doses recorded higher plant height at three MAP whereas fertigation at three days interval with 50 split doses registered taller plants at five MAP. The control/check treatment recorded plant height 75 and 90 cm at three and five MAP, respectively.

Corm yield increased with increasing fertigation interval from two to four days. The maximum corm yield was observed (34.7 t ha^{-1}) in fertigation at four days interval. Perhaps, the plant is unable to utilize nutrients if supplied in quick successions. The recommended fertilizer applied in more number of splits has recorded higher corm yield and the corm yield with 40 numbers of split of recommended fertilizer was on par with 50 numbers of splits (32.5 and 33.5 t ha^{-1} respectively). Maximum corm yield of 37.3 t ha^{-1} was observed with fertigation at 4 days interval and 40 numbers of split of recommended dose of fertilizer. The treatment fertigation at 4 days interval with 50 numbers of split of recommended dose of fertilizer recorded lesser corm yield (35.5 t ha^{-1}). Interpolation of fertigation duration indicated

that the crop responded upto 180 days after planting (Fig. 10). Starch content was significantly influenced by the fertigation interval, dose and duration of fertigation. Starch content increased with fertigation upto 160 days after planting and then decreased whereas calcium oxalate content was found increased with increase of fertigation duration.

Studies on water requirement and scheduling of irrigation in elephant foot yam

An experiment was initiated to study the water requirement and scheduling of irrigation in elephant foot yam. The field experiment was laid out in split plot design with two main plots and eight sub plots in three replications. Two methods of irrigation viz., drip irrigation and flood irrigation were included in the main plots. Sub plots comprised of two levels of irrigation applied at different frequencies,viz., irrigation at 75% CPE for 1-12 weeks after planting, irrigation at 75% CPE for 13-24 weeks, irrigation at 75% CPE for 1-24 weeks, irrigation at 100 % CPE for 1-12 weeks, irrigation at 100% CPE for 13-24 weeks, irrigation at 100 % CPE for 1-24 weeks, irrigation at 75% CPE for 1-12 weeks & 100% CPE for 13-24 weeks and irrigation at 100 % CPE for 1-12 weeks & 75% CPE for 13-24 weeks. A rainfed crop was also included as control.

Irrigation facilities were installed in the field as per treatments. Initial soil samples were collected and analyzed for physical and chemical parameters including micro nutrient status. The field is medium in soil organic carbon (0. 57%), available nitrogen (380 kg ha^{-1}) and potassium (169.3 kg ha^{-1}) and high in Bray extractable P (59.3 kg ha^{-1}). The crop was planted during February 2013. Drip irrigation was given daily considering the pan evaporation value and crop factor. Flood irrigation was given at weekly intervals. Germination was started 30 days after planting of corms. About 77 % of the corms germinated within 45 days with drip irrigation at 100% CPE and 56 % sprouting occurred with flood irrigation at 100% CPE. Only 22% of the corms germinated after 45 days without irrigation. The experiment is in progress.

Weed management in cassava

To identify the best weed management practice in cassava using black plastic mulch (weed control ground cover), a field experiment was conducted at CTCRI farm with six treatments and four replications in Randomized Block Design under rainfed conditions using the cassava variety Sree Jaya.

Fig. 11 Black porous plastic mulch in cassava

Complete suppression of weeds of all kinds was observed in plots from planting till harvest where black plastic mulch (weed control ground cover) was used (Fig. 11). Sixty per cent additional tuber yield was obtained in plots where black plastic mulch was used. Soil moisture content was higher in those plots and the soil micro flora population was not affected.A net income of upto Rs.93,000 / ha was obtained from the plots where plastic mulch was used.

SOIL MANAGEMENT

PLANT NUTRITION AND SOIL HEALTH

Fertilizer management practices by site specific nutrient management (SSNM)

The calibrated QUEFTS model for site specific nutrient management of Amorphophallus was tested in a field experiment conducted at CTCRI farm. There are six treatments and four replications per treatment. There was good agreement between the predicted and measured yields which indicated that the calibrated model can be used to improve NPK fertilizer recommendations for Amorphophallus in India. The indigenous supply of N, P and K in the experimental field were 142.41, 17.42 and 132.35 kg ha^{-1} respectively. There were significant increases in NPK uptake and agronomic, physiologic and recovery efficiencies of N, P and K in SSNM plot

compared to present recommended on plot (Table 1). To study the sustainability of SSNM technology of cassava, the field experiment was conducted for the 4th consecutive season and data were recorded.

Table 1. Effect of site specific nutrient management (SSNM) on corm yield, nutrient uptake and nutrient use efficiency parameters

Parameter	Unit	SSNM	Present Recommendation	Difference (Δ)	Probability level
Corm yield	t/ha	36.20	27.60	8.60	0.005
N uptake	kg/ha	195.45	172.24	23.21	0.002
P uptake	kg/ha	26.75	20.62	6.13	0.020
K uptake	kg/ha	226.82	198.75	28.07	0.030
AE_N	kg/kg	84.50	67.40	17.10	0.002
AE_P	kg/kg	85.40	71.25	14.15	0.003
AE_K	kg/kg	125.42	84.75	40.67	0.030
RE_N	kg/kg	0.51	0.39	0.12	0.004
RE_P	kg/kg	0.18	0.12	0.06	0.008
RE_K	kg/kg	0.39	0.27	0.12	0.040
PE_N	kg/kg	165.50	88.60	76.9	0.010
PE_P	kg/kg	295.30	210.65	84.65	0.017
PE_K	kg/kg	74.50	49.60	24.90	0.025

Long term effect of manures and fertilizers in an acid Ultisol growing cassava

The effect of continuous application of different levels of fertilizers, viz., NPK@ 125:50:125, 100:50:100, 50:25:50 kg ha^{-1},soil test based fertilizer (STBF) recommendation and absolute control, different combinations of secondary nutrient (Mg) and micronutrients (Zn, B) as Mg, Zn, B alone, Zn +Mg, Mg + B, B + Zn and Mg + Zn + B, different sources of organic manures, viz., FYM, green manuring in situ with cowpea, coir pith compost, vermicompost and crop residue alone and in combination along with recommended dose of NPK @ 100:50:100 kg ha^{-1} was studied under a long term fertilizer cum manurial trial in cassava laid out for the 8th season in the third phase of the experiment. The parameters studied were tuber yield, tuber quality (cyanogenic glucosides and starch), plant (leaf, stem, tuber and total plant) dry matter production, plant nutrient concentration and nutrient uptake

Continuous application of NPK @ 100:50:100 kg ha^{-1}+FYM @12.5 t ha^{-1} (POP)resulted in a tuber yield (24.70 t ha^{-1}) on par with NPK @ 125:50:125 kg ha^{-1} + FYM @12.5 t ha^{-1} (29.79 t ha^{-1}). Soil test based application of NPK @ 84:0:106 kg ha^{-1} + FYM @ 5 t ha^{-1} produced yield (21.32 t ha^{-1}) on par with POP (24.70 t ha^{-1}). Absolute control could sustain yield to the tune of 14.71 t ha^{-1} even after eight years of continuous cultivation without any manure and fertilizers. Different sources of organic manures, viz., vermicompost (25.88 t ha^{-1}), coir pith compost (24.22 t ha^{-1}) and green manuring *in situ* with cowpea (24.19 t ha^{-1}) are found as alternate source to FYM (24.70 t ha^{-1}). No significant effect of independent and combined application of secondary and micronutrients was noticed over POP on yield. Cyanogenic glucoside content of cassava tubers were significantly influenced by levels of fertilizers and NPK @ 125:50:125+FYM @ 12.5 t ha^{-1} resulted in the maximum HCN concentration (242.7ppm). Among the different levels of fertilizers, NPK @ 125:50:125 kg ha^{-1} resulted in significantly higher tuber N% (0.6%) and absolute control, the lowest

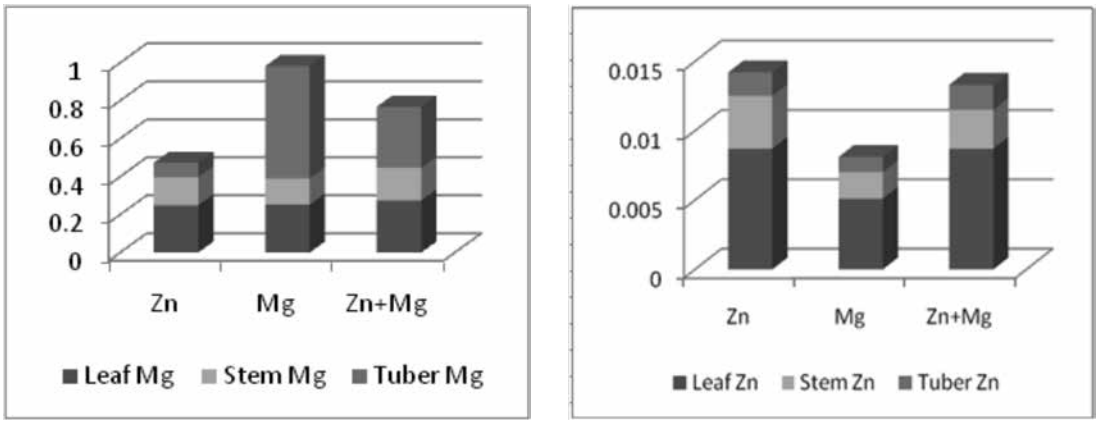


Fig. 12 Effect of Mg and Zn on tuber, stem and leaf Mg and Zn contents (%)

(0.424%). Application of Mg resulted in considerable increase in Mg concentration of tuber whereas Zn application resulted in enhanced level of Zn in leaves (Fig. 12). Significant effect of treatments was seen in the post harvest soil status of pH, P, Ca, Mg, Mn and Zn. Among the different levels of fertilizers, NPK @ 125:50:125 kg ha^{-1} resulted in significantly the highest pH, Ca, Mg and Mn which in turn was on par with that of NPK @ 100:50:100 kg ha^{-1}. In the case of P, in STBF where P was not applied, a significantly lower P than POP was noticed. Application of ash resulted in a significantly higher pH due to higher content of Ca and Mg in ash. Among the different organic manures, green manuring *in situ* with cowpea and coir pith compost caused a significant reduction in Ca and Mg status of the soil.

Organic Farming of Yams and Aroids

Varietal response to organic farming in elephant foot yam

A field experiment was carried out in split plot design with five varieties (Gajendra, Sree Padma, Sree Athira and two locals (Peerumade local and VFPCK local) in main plots and 2 practices (conventional and organic) in subplots for three seasons. Chemical analysis of soil samples at the termination of the experiment indicated that there was significant improvement in pH under organic farming in elephant foot yam. Varieties x production systems interaction were significant for organic C status and it was significantly higher under organic practice for Gajendra and Sree Padma.

Organic farming of dwarf white yam

Dwarf white yam var. Sree Dhanya was tested under four production systems, viz., conventional, traditional, organic and integrated farming for the second season. Organic farming (12.28 t ha^{-1}) was on par with conventional practice (13.01 t ha^{-1}). There was significant improvement in available K and pH under organic farming during the first and second seasons respectively. Biochemical parameters of tubers were not significantly influenced by the various practices.

Organic farming of taro

Three varieties of taro (Sree Kiran, Sree Rashmi and a local) were tested under three production systems, viz., conventional, traditional and organic farming

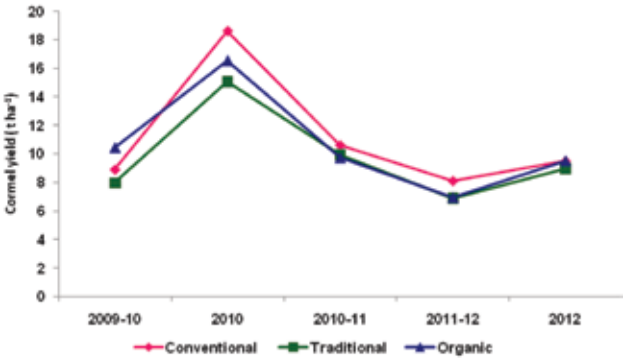


Fig. 13. Yield trend over the years in taro as affected by production systems

in split plot design for the fourth and fifth years. Organic farming proved to be equally productive as that of conventional practice during the fourth (6.93 and 8.09 t ha^{-1} respectively) and fifth seasons (9.49 and 9.47 t ha^{-1} respectively). Yield trend over the five years and pooled analysis also indicated similar results (Fig. 13 and 14). In taro the elite varieties, Sree Kiran, Sree Rashmi and the local (Palakkad local) produced same yield under organic and conventional practice. There was significant improvement in pH and available P under organic practice at the end of the fifth season. Biochemical parameters were not significantly affected in taro. However, organic cormels had higher dry matter, starch and total sugars; Conventional cormels had higher phenol, fibre and ash. The microbial count of soil remained unaffected.

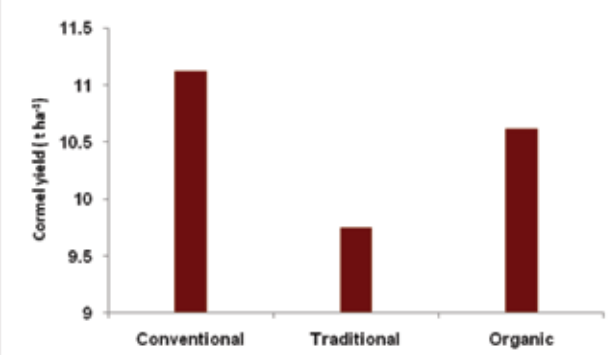


Fig. 14 Effect of production systems on cormel yield in taro (pooled mean of five years)

Nutrient Management in Tuber Crops based Cropping Systems

Effect of integrated use of inorganic, biological and organic sources on soil fertility, yield and quality of Colocasia

A field experiment was conducted consecutively for the second year during kharif, 2012-13 in an acidic

Alfisol at Regional Centre of CTCRI, Bhubaneswar, to study the effect of integrated use of lime, biological, organic sources, secondary and micro nutrients on yield and proximate composition of Colocasia and its residual effect on soil quality. The effect of different treatments on cormel yield, nutrient uptake and quality parameters is presented in Table 3.

Single application of N, P, and K showed a yield response of 45, 43, and 65 %, respectively, whereas the increase in cormel yield was pronounced to be 65, 108 and 128 % with respect to 50, 100 and 150 % of the recommended doses of NPK over control. The per cent yield response was found highest with respect to Zn (13) followed by Mg (11) and B (10) over that of lime (0.5 t ha^{-1} + FYM + ½ NPK. Among the organic sources, green manuring showed highest uptake of NPK in Colocasia.

The soil pH after harvest of Colocasia during 2011-12 ranged from 4.97 to 6.10. Application of NPK alone showed decreasing trend of pH, whereas integrated use of inorganic and organic sources considerably improved the soil pH. The organic C and total N ranged from 0.29 - 0.69 and 0.0762 - 0.0937%, respectively. Significantly the highest available N (233 kg ha^{-1}) was observed due to integrated application of lime + FYM + ½ NPK + $MgSO_4$, while the available P was the highest due to integrated application of lime + FYM + ½ NPK + VAM (128.1 kg ha^{-1}). The available K was found the highest (274.3 kg ha^{-1}) due to combined application of FYM and optimum doses of NPK based on soil test. The integrated application of lime + FYM + ½ NPK + $ZnSO_4$ has recorded the highest dehydrogenases activity (2.012 µg TPF hr^{-1} g^{-1}) followed by 150% NPK (1.981 µg TPF hr^{-1} g^{-1}). The inoculation of VAM combined with lime + FYM + ½ NPK has recorded highest FDA (1.986 µg g^{-1} hr^{-1}) followed by lime + FYM + ½ NPK + $MgSO_4$ (1.832 µg g^{-1} hr^{-1}). The application of ½ NPK in combination with lime + FYM + VAM recorded the highest acid phosphatase activity (78.19 µg PNP g^{-1} soil h^{-1}) and alkaline phosphatase activity (52.16 µg PNP g^{-1} soil h^{-1}). The application of lime had a positive effect on both acid phosphatase and alkaline phosphatase activities as it improves the soil pH, which can limit the enzyme-mediated reaction rates by affecting the maximum activities of enzymes, and the solubility of substrates and cofactors.

Integrated application of organic manures, secondary and micro nutrients along with half of the recommended doses of NPK, significantly enhanced the cormel yield as well as the quality traits. Incorporation of lime is customary for not only to enhance the crop productivity, the quality but also to improve the soil fertility.

Soil- based plant nutrient management plan for agro eco-systems of Kerala

The multi institutional project involving 15 agricultural institutions of Kerala with the intention of evolving plant nutrient management plan for all crops at panchayat, block, district and state levels and nutrient advisory cards to individual farmers (2.3 lakh farmers) was launched during July 2010. CTCRI as a partner of the project has the objectives to analyse the samples from Pathanamthitta and Kottayam district for pH, organic carbon, major (P,K), secondary (Ca,Mg,S) and micronutrients (Fe, Cu, Mn, Zn & B) and also to prepare nutrient management plan for these districts. The chemical analysis of the entire samples (10,348) received from Pathanamthitta district was completed and the data was uploaded on the website of IIITMK and the generated fertilizer recommendation in the form of soil health cards were issued to 9956 farmers of the district. Based on the data, soil based nutrient management plan was prepared for the district for all crops giving special emphasis to tuber crops. A total of 6942 samples from Kottayam district belonging to 32 panchayats were analysed for the above parameters and the data of 4820 soil samples were uploaded on the IIITMK website for generating fertilizer recommendation.

Development of eco-friendly technologies for quality cassava production and to safeguard soil health and environment

A field experiment was laid out in split plot design with three varieties,viz., H-165, Sree Vijaya and Vellayani Hraswa in main plots and five production systems,viz., traditional, conventional, integrated and two types of organic in sub plots for the second season. Organic farming produced the highest yield (29.32 t ha^{-1}) on par with conventional practice (27.18 t ha^{-1}). Both domestic and industrial varieties responded equally well to organic farming. However, the industrial variety (H-165) produced higher yield

under organic management than under conventional practice. The soil temperature, soil moisture, soil CO_2 and photosynthetically active radiation (PAR) were unaffected, but slightly higher PAR and soil CO_2 were noticed under organic farming. The soil physico-chemical properties of the previous season were not significantly affected by the various production systems. There was a slight improvement in the water holding capacity, porosity, pH (by 0.35 units), organic C (by 10.70%), available N (by 13%), exchangeable Ca (by 30.86%) and Mg (by 25.94%) contents of soil under organic management over conventional practice. Production systems significantly influenced the soil microbial biomass C. Organic management had significantly higher microbial biomass C (860 µg g^{-1}) than integrated practice (449 µg g^{-1}). However, it was on par with that of conventional practice (601 µg g^{-1}). The count of bacteria was significantly higher, and fungi and actinomycetes were also promoted under organic management.

Soil carbon sequestration potential of hill cassava production systems

At Kadambur and Bargur hills, soil infiltration studies were conducted under 10 different situations each (7 agriculture and 3 forest) using the Guelph permeameter. At Kadambur hills, the mean steady state infiltration for agriculture systems (at 5 cm water head) was 0.36 cm/minute whereas for forest land use it was 0.32 cm/minute. The infiltration rate at high water head (10 cm) for agriculture and forest land use was 1.34 and 0.43 cm/minute respectively. The per cent water stable aggregates are the major soil physical quality indicator of the soil strength and the resistance capacity of soils against erosion. Representative soil samples, analyzed for water stable aggregates (WSA), revealed that agricultural soils had a lower value of 45-50% whereas forest soils were found to have higher per cent (Fig. 15). Analysis of labile C content using potassium permanganate oxidation revealed that the average values ranged from a minimum value of 139 mg kg^{-1} for Kadambur hills to a maximum of 278 mg kg^{-1} for soils of Kolli hills. In all the five hills, forest soils had the highest content of labile C indicating the high organic C content and the ready release of this fraction for the microbial utilization.

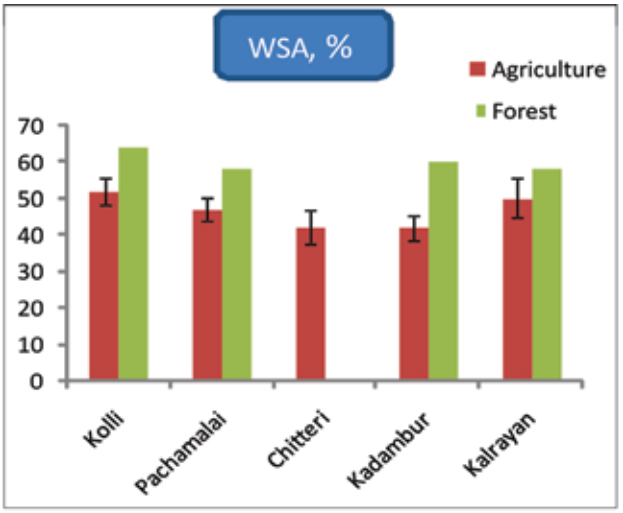


Fig. 15 Water stable aggregates (%) in hill soils of Eastern and Western Ghats under agriculture and forest land use

IMPROVING INPUT USE EFFICIENCY IN TROPICAL TUBER CROPS

Screening potassium efficient cassava genotypes for industrial and domestic uses

The results of the third season field experiment conducted in a split plot design with six selected genotypes,viz., Aniyoor, W-19, 7 Sahya-2 (edible purpose) and 6-6, CR 43-8, 7 III E3-5 (industrial use) as main plot treatments and levels of K, viz., control (0), sub optimal (50 kg ha^{-1}), optimal (100 kg ha^{-1}) and super optimal (150 kg ha^{-1}) as sub plot treatments with 2 replications to identify the most efficient lines are given below. Observations were recorded on biometric characters (plant height, stem girth, number of fallen and retained leaves), LAI, plant (leaf, stem and tuber) dry matter production, plant K content at 3 critical growth stages of the crop, viz., tuber initiation, tuber enlargement and tuber bulking stage. Physiological parameters,viz., crop growth rate (CGR), relative growth rate (RGR), tuber bulking rate (TBR) and harvest Index (HI) and NUE parameters, viz., agronomic efficiency (AE), physiological efficiency (PE), agro-physiological efficiency (APE), apparent recovery efficiency (ARE), utilization efficiency (UE), harvest index (HI), K harvest index (KHI), K uptake ratio (K Up R), K utilization for biomass (K Ut B) and K utilization for tuber (K Ut B) were computed. The post harvest soil K and tuber quality parameters, viz., starch and cyanogenic glucosides were also determined.

The interaction effect of tuber yield and K levels was significant in the case of tuber yield, HI, KHI, stem K%, tuber K uptake and % K utilization for tuber (Fig. 16). Tuber yield was significantly influenced by genotypes, but not affected by levels of K indicating the efficacy of these genotypes to perform well even without K which was on par with K @ 150 kg ha^{-1}. Tuber yield indicated significant interaction effect of genotypes and K levels, with Aniyoor @ 100 kg ha^{-1} (32.08 t ha^{-1}) and 7III E3-5 without K (27.29 t ha^{-1}) and at 50 kg ha^{-1} (23.92 t ha^{-1}) performing better. Aniyoor had the lowest HCN (50.1 ppm) on par with CR 43-8 (98.4 pm). K @ 150 kg ha^{-1} had the minimum HCN (114.3 ppm) which was on par with K @ 100 kg ha^{-1}(125.9 ppm). Starch was significantly influenced by genotypes with W-19 having the maximum (33.27%) on par with Aniyoor (32.49%) and the industrial genotypes were on par and it varied from 27.7-29.1%**.** Physiologic parameters viz., RGR, CGR, TBR, LAI and HI supported the potential of the selected genotypes. NUE parameters viz., K efficiency ratio, K utilization for tuber, K utilization for biomass, K uptake ratio, K HI also justified the K utilization efficacy of the selected genotypes. Domestic genotypes and industrial genotypes were on par with respect to tuber K and were increasing with increase in K levels. Increase in soil K with increase in K levels was observed.

Integrated soil and water conservation strategies for hill cassava production systems

The quantity of nutrients available from applied fertilizers is largely determined by the soil physical properties especially texture and moisture content. Lack of adoption of suitable soil conservation measures and imbalanced fertilization especially P and K are widely prevailing in hill cassava production systems of eastern and Western Ghats of Tamil Nadu. Hence a wide scope exists in those regions to improve the nutrient use efficiency of fertilizer nutrients under rainfed cassava conditions. To find out the relationship of nutrient retention of P and K and release patterns of P at different soil moisture and prevailing fertility levels, soils were collected from Kadambur hills, Tamil Nadu. Analysis of initial physico-chemical properties of sandy loam and sandy clay loam soils showed considerable variations in bulk density (1.54 and 1.38, Mgm^{-3} respectively), water holding capacity (32 and 39 %), soil organic carbon (2.9 and 4.2, g kg^{-1}), pH (5.6 and 6.2), available P (146 and 147 mg kg^{-1}) and exchangeable K (175 and 226 mg kg^{-1}) contents. A laboratory incubation study was carried out for eight weeks in two predominant soil textures, viz., sandy loam and sandy clay loam each at three soil moisture levels viz., air dry, 50% of water holding capacity (WHC) and 100% WHC and 3 levels of P viz., 0, 28 and 56 kg P/ha. Two kg soils were taken for each treatment and samples from different treatments were drawn at weekly intervals and the mineralizable P content was determined. The crop season was assumed to be ten months and the mineralizable P (kg per ha per season) was calculated. Likewise, the P and K fixation studies were conducted at three levels of soil moisture as above, by treating soils with graded doses of P and K and incubated for definite period of time and the soil was then extracted and the P and K content was determined and the retained or fixed P and K was calculated as per cent of the added quantity.

In sandy clay loam soils, 50% WHC moisture level was on par with the higher moisture level on the rate of P mineralized but significantly different and higher

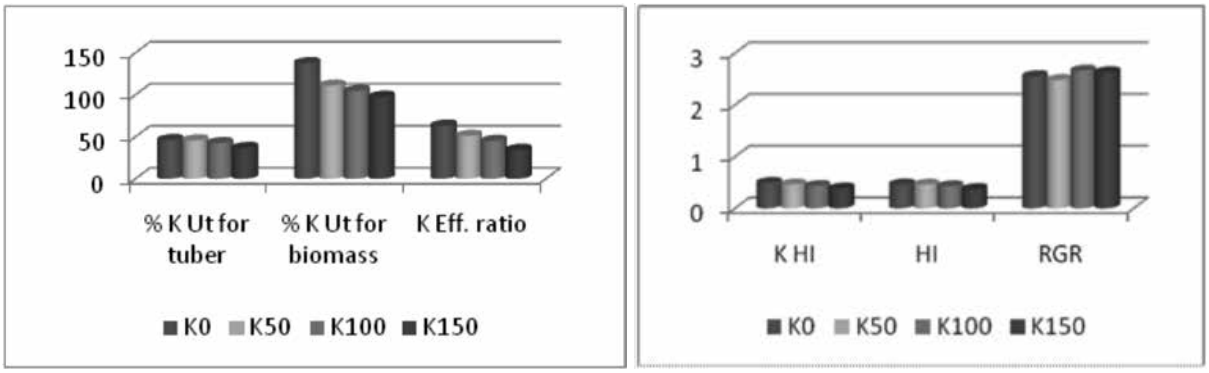


Fig. 16 NUE and physiologic parameters of the genotypes at different levels of K

as compared to air dry conditions (2.83 against 3.54 kg P/ha/season).Higher level of P had a significantly higher mineralization rate of 4.53 kg P/ha/season as compared to control (2.61 kg P/ha/season) in sandy loam soils. In sandy clay loam soils, there was significant difference in P mineralized with respect to low (1.72) and high P levels (3.99). Soil P fixation was reduced with increase in soil moisture (84 against 71%) but there was no significant difference among 50% and 100% soil moisture on P fixation in both the soil types. Soil K fixation increased significantly with increase in soil moisture levels in both soil types (42% against 62% in sandy loam and 41% against 57% in sandy clay loam soils).

Nutrient Use Efficiency of zeolites in Sweet Potato

Zeolites are effectively controlled nutrient release materials that improve the soil nutrient use efficiency because of its high cation exchange and water retention properties. Different types of zeolites amendments, viz., fly ash based synthetic (FAZ) and commercial (CZ) zeolites were studied for their effect on volumetric soil water retention, exchangeable potassium, exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) etc. at initial (before planting) and final (after harvest) stages of sweet potato crop (variety ST-14) and to find out the effectiveness of zeolites on tuber yield and on nutrient use efficiency with respect to NPK. A pot study was conducted in farm soils of CTCRI (acidic, sandy loam soils) with six treatments each replicated thrice in a completely randomized design. The treatments are soil amended with FAZ at 1% (w/w) and 2% levels, pH treated CZ at 1% level, potassium and zinc impregnated CZ at 1% and control (with out zeolites). Organic, inorganic nutrients and irrigation water applications to the crop were given uniformly to all the treatments. Data was analyzed for its statistical significance using SAS package. Results showed that 1% zeolite amended soils had higher mean water retention (19.2%) over control (15.8%) and registered a tuber yield increase of 57% over control. CZ has been found superior in terms of cation exchange capacity and soil water retention properties but not on final yield. Soils amended with both FAZ levels are well below the critical limits in terms of ESP and SAR. The NPK use efficiency of FAZ 1% and 2% is on par and but significantly higher over control. The study also suggested that 1% FAZ will be the ideal rate for soil application under sweet potato crop.

ABIOTIC STRESS MANAGEMENT IN TROPICAL TUBER CROPS

Studies on Production Physiology of Elephant Foot yam

During the reporting period of the second experiment in this project, i.e., the effect of water deficit stress (WDS) on growth and productivity of elephant foot yam, was conducted during 14 May 2012 to 15 February 2013. The objectives of the experiment were to identify the critical period of crop sensitivity to WDS or water requirement and to assess the effect of WDS at different growth period on growth and productivity of *Amorphophallus*. For this experiment, the variety Gajendra was planted in RBD with 4 replications on 14.05.2012 in the farm of CTCRI. There were 4 treatments, viz., T_1 - Control (without water deficit stress), T_2- WDS during 4th and 5th months, T_3- WDS during 5th and 6th months and T_4 - WDS during 6th and 7th months. Control plots were irrigated when the soil moisture reached 50% of field capacity whereas WDS was imposed by withholding water. Observations on gravimetric soil moisture content, plant and petiole height, number of leaflets per plant and leaf area index were recorded at monthly intervals. Number of leaves per plant was recorded at 3rd and 6th months after planting (MAP). Total dry matter production and partitioning per plant was observed at 5th and 8th MAP. Corm yield per plant was recorded at final harvest at 9th MAP. At field capacity, soil moisture content varied between 10.4 to 18.2% with an average of 14.3%. Among the control and three WDS treatments, the average plant height and petiole height during 3rd to 8th month's growth period varied between 66.7 and 77.1 and between 51.6 and 52.4 respectively. The difference in plant height and petiole height among the control and three WDS treatments was not significant. The differences in canopy spread and total number of leaflets per plant among the control and three WDS treatments were significant. While maximum canopy spread and total number of leaflets per plant were observed in

control WDS free plants, these two parameters were significantly reduced by WDS during 4th and 5th and 5th and 6th months. At three MAP, the differences in the total number of leaflets per plant among the control and three WDS treatments were also reflected in the leaf area and leaf area index (LAI). The differences in plants with 1/2 leave among control and treatment plants were not significant. In plants subjected to WDS during 4th and 5th month, the per cent of plants with one leaf was maximum (70%) whereas per cent of plants with two leaves was minimum (20%). Thus, WDS during 4th and 5th month's crop growth period significantly affected the leaf production. The significant reduction in leaf area in WD stressed plants resulted in significant reduction in corm dry matter and hence corm yield per plant. Corm yield was significantly reduced due to water deficit stress (WDS) at 4-5 MAP. As compared to control plants, the reduction in corm yield was 38% more due to WDS at 4-5 MAP (77%) than at 6-7 MAP (39%). These results indicate that WDS during 4th and 5th or 5th and 6th month's crop growth period significantly affected growth and productivity of *Amorphophallus*. WDS during growth stages A to F, i.e., from the time of sprouting (stage A) to development of full leaf (stage F) suppressed the development of leaf indicating that the initial establishment is a critical period of crop sensitivity to WDS and this crop growth period requires adequate soil moisture. Similarly, crop growth period of 4th and 6th month also is a critical period that requires adequate soil moisture for crop productivity

Analysis of gene expression during tuber formation and development in sweet potato

The objectives of this project were to explore the global gene expression, identify the differentially expressed genes in tuber forming roots as compared to non-tuber forming roots and the genes regulating tuber formation in sweet potato and how these genes are regulated under heat stress conditions. For this, sweet potato variety Sree Arun, *Ipomoea trifida*, and *Ipomoea cornea* were planted in pots and maintained. At third week after planting, four sweet potato plants were subjected to heat stress (40 ± 2°C day temperature for 7 hours per day and 23± 1°C night temperature) for seven days. Total RNA was extracted by lithium chloride and trizol method from tuber forming root, fibrous root and leaf of sweet potato variety Sree Arun, (grown under ambient temperature (30 ± 2°C day 23 ± 1°C night) and heat stress for 7 days (40°C day and 23 ± 1°C night), fibrous root of *Ipomoea trifida*, and *I. cornea* grown underambient tempeartue. Quality of total RNA was checked by bioanalyzer. The quality of RNA extracted by trizol method was good and used for further microarray experiment using Agilent microarray.

The results indicated that in ambient temperature 9,030 genes were upregulated while 8,750 genes were downregulated in tuber forming root of sweet potato as compared to fibrous root. 16,384 genes were upregulated while 13,404 genes were down regulated in tuber forming root of sweet potato as compared to fibrous root of *I. trifida*. Heat stress upregulated 1,877 genes and downregulated 30,928 genes in tuber forming root of sweet potato. Heat stress upregulated 7,204 genes while downregulated 9,984 genes in tuber forming root of sweet potato as compared to fibrous root of sweet potato. Heat stress upregulated 8,012 genes and downregulated 6,723 genes in the leaf of sweet potato. Heat stress upregulated 10,281 genes and downregulated 7,677 genes in the fibrous root of sweet potato.

Studies on salt tolerance in sweet potato

A pot culture experiment was conducted during rabi season 2011-12 at the Regional Centre of CTCRI, Bhubaneswar to study the mechanisms of salt tolerance in sweet potato. The study was undertaken with 8 levels of salinity (0, 8, 10, 12, 14, 16, 18 & 20 dS m^{-1}), 5 genotypes (Samrat, Pusa Safed, CIP-440127, Kishan & Sree Bhadra) in 9 replications in a two factorial CRD. The results revealed that salinity levels had no significant effect on total dry matter accumulation and the root biomass varied from 2.38 to 4.07 g pot^{-1} at 40 DAP. However, increased levels of salinity showed significantly decreasing trend of dry matter with the advancement of crop growth stages. Among the genotypes, CIP-440127 recorded highest total dry matter and root biomass (29.96 and 13.06 g pot^{-1}, respectively) irrespective of

salinity levels, indicating that it had greater tolerance to salinity up to 16 dS m^{-1}. Total uptake of N and P at initial stage (40 DAP) showed no significant variation to salinity levels up to16 dS m^{-1}, whereas, it decreased with the advanced crop growth stages. However, the total uptake of K from initial to harvest stages progressively decreased due to increased levels of salinity. Among the genotypes, Pusa Safed recorded highest total uptake of N and P irrespective of salinity levels at 120 DAP followed by Samrat and CIP-440127, whereas the total K uptake was highest in Samrat followed by Pusa Safed and CIP-440127. Thus, the study indicated that CIP-440127, Samrat and Pusa Safed showed tolerance to salinity up to 16 dS m^{-1} and these varieties have greater potential for livelihood and nutritional security in salt- affected areas.

Promotion of Sweet potato in coastal saline soils

A total of 100 demonstrations were laid out with salt tolerant genotypes of sweet potato at Misimisia, Ambadia, Pimparkani, Patana, Chaulia, Mahua, Sunadia, Chasapada, Anandpur, Sankha, Kendumath, Muslimpada, Siali, Padmapur, Olarah, Mayurlanji, Gadaharishpur and Suakunda villages of Erasama Block, Jagatsinghpur district of Odisha under the NABARD sponsored project during rabi season of 2011-12 to increase cropping intensity, livelihood enhancement and nutritional security. The soils had wide range of physico-chemical properties in which pH varied from 4.08 - 5.72, EC from 1.02 - 4.63 dS m^{-1}, organic carbon from 0.175 - 1.29 % (mean of 0.67%), and having 112 - 349, 11.2 - 192.6, and 64.3 - 1082.6 kg ha^{-1} of available N, P_2O_5, and K_2O ha^{-1}, respectively. The crop was harvested at maturity and the tuber yield ranged from 1.667 to 19.375 kg ha^{-1} with an average productivity of 8.757 kg ha^{-1}. Wide variations in tuber yield may be due to variations in salinity build up during crop growth period, nature of salts existing in the soil, organic matter status, native soil fertility, performance of genotype under the saline environment, availability of good quality irrigation water during the tuber initiation, awareness of the farmers for sweet potato cultivation.

PLANTING MATERIALS PRODUCTION

Rapid multiplication of disease- free planting materials in tuber crops

The major objective of this sub-project is to generate and multiply disease- free planting materials in tuber crops. The work was initially started with cassava and *Amorphophallus* and later other important tuber crops will be covered. The project conceived is inter-disciplinary in nature and involved Regional Centre of CTCRI also. The major targets of the project would be indexing and *in vitro* multiplication with the following phases, viz., micro propagation and hardening, multiplication of planting materials under protected cover, multiplication of planting materials in field and harvest observations and storage. The salient results that emerged during the reporting period in cassava include 110 indexed plantlets micropropagated and a total of 468 sub culturing was done (H-226: 270, Sree Vijaya: 32, H-165: 166). The steps involved are selection of apparently disease- free cassava plants, meristem dissected raised in tissue culture medium, plantlets indexed and would be used as *in vitro* mother plants, while hardening, 10% of the batch will be randomly indexed, hardening of the i*n vitro* grown plants in Green house/protected net house, hardening under protected cover, minisett multiplication of stems in nursery, transplanting sprouted minisetts to the main field, repetition of the process and storage/ distribution of planting materials.

In *Amorphophallus*, the steps involved in disease-free planting materials are selection of apparently disease free plants, dissect the meristem and grow in tissue culture medium or else, raise minisetts/ microsetts under protected cover, meristem or bud cultured plantlet will be PCR indexed and would be used as *in vitro* mother plants, micro propagation of the mother plants, while hardening, 10% of the batch will be randomly indexed, hardening of the i*n vitro* grown plants in green house/protected net house, raising of the hardened plants in protected area, harvesting corms at maturity, minisett multiplication of corms in nursery/straight planting, transplanting sprouted minisetts to the main field and repetition of the process.

CROP PROTECTION

MANAGEMENT OF INSECT PESTS OF TUBER CROPS

Eco friendly techniques for the management of insect pests

Effect of organophosphate insecticides on mealybug, *Rhizoecus amorphophalli*, of the tubers of elephant foot yam.

Organophosphate insecticides, viz., malathion, quinalphos, dimethoate, dichlorovos, chlorpyrifos and methyl parathion at the concentrations of 0.5, 0.1, 0.05, 0.01, 0.005 and 0.001% when treated on mealy bug, *Rhizoecus amorphophalli*, cent percent mortality was observed on one day after treatment (DAT) due to methyl parathion at 0.5% conc., and it was statistically on par with the treatments with malathion, chlorpyrifos and quinalphos. Treatment effect of dichlorvos and dimethoate 0.1% on mealy bug was significantly lower than the other insecticides used. On 2 DAT, cent percent mortality was observed in the treatment with malathion and chlorpyrifos at 0.5%, and it was on par with the dimethoate.

Efficacy of petroleum ether extract of cassava seed extract on *Rhizoecus amorphophalli*

Petroleum ether extract of cassava seed (CSE) in six concentrations (3, 2, 1, 0.5, 0.05, 0.005%) with a few drops of soap solution was treated on the first instar larvae and adult females of *R. Amorphophalli* and found that all the first instars were killed at a con. of 0.5% on 1 DAT. Application of early instars with the lower concentration of CSE (0.005%) also caused 86.7% mortality on 1 DAT, nevertheless adult females were not as sensitive as first instar, and treatment with a con. of 2% of CSE only killed all the females. Surfactant at 0.1% was also highly toxic to early instars and the mortality was 50%.

Identification and formulation of insecticidal active principles of cassava seeds

Effect of petroleum ether extract of cassava seed extract on *Spilosoma obliqua*

Petroleum ether extract of cassava seed at seven concentrations (1.0, 0.5, 0.3, 0.1, 0.05, 0.05 and 0.005%) with 0.1% of soap solution was applied on *Spilosoma obliqua* and found that the early instars were highly susceptible to the treatments (Fig. 17) when compared to late instars, however, aqueous extract of cassava seed had no toxic effect on early or later instars.

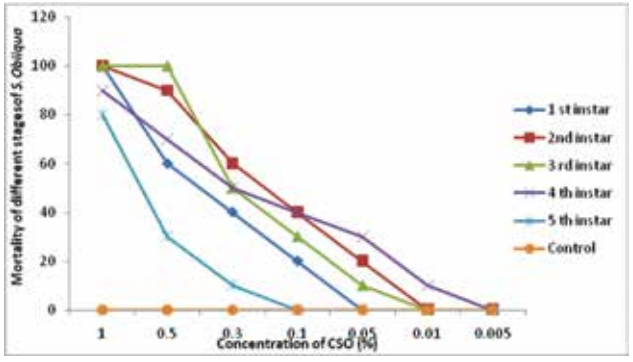


Fig. 17 Toxicity of petroleum ether extract of cassava on different instars of *Spilosoma obliqua*

Effect of biofumigant isolated from different varieties of cassava on stored product pests

Biofumigants isolated from 10 varieties of cassava were tested on *Callosobruchus maculatus, Sitophilus oryzae* and *Rhyzopertha dominica*. The result revealed that *C. maculatus* and *R. dominica* were more susceptible to the cassava biofumigant. The biofumigant from all varieties caused cent percent mortality of *R. dominica* and *C. maculatus* at one day after treatment, where as mortality of *S. oryzae* ranged from 7.67% in the variety *Sree Rekha* to 100% in variety H226 and M4 (Fig. 18).

Optimisation of the quantity of cassava leaf distillate for the mortality of *Callosobruchus maculatus*

Application of 100 µl of the distillate showed 50% mortality of *C. maculatus* at 15 minutes after treatment (MAT) and it increased to 100% at 25 MAT.

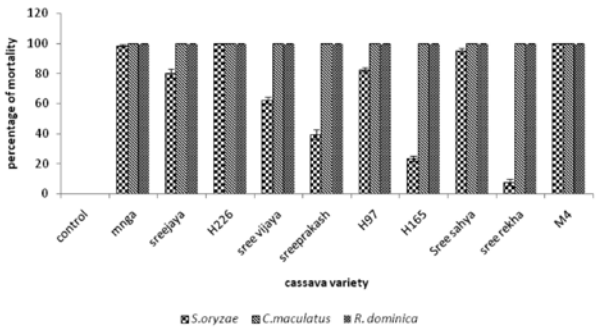


Fig. 18 The action of cassava biofumigant isolated from different variety of cassava on stored product pests

As the dose of the extract increases, the mortality of *C. maculatus* was also found increased. In the case of *S. oryzae,* 82.2% and 22.2% weevil died on 1 DAT with 100 µl and 300 µl respectively, but at 800 µl, cent percent mortality was noticed at 55 MAT.

Novel molecules produced by unique bacteria and their bioactivity

A bacterium was isolated from the dauer juveniles of a novel entomopathogenic nematode *Rhabditis (Oscheius)* sp. from diseased sweet potato weevil, *Cylas formicarius.* Cell free culture filtrate of the bacterium exhibited strong antimicrobial activity. The ethyl acetate extract (TSB medium) of the bacterial culture filtrate was purified by column chromatography and two bioactive compounds were isolated and their chemical structures were established based on spectral analysis. The compounds were identified as 3,4'5-trihydroxystilbene (1) and 3,5-dihydroxy-4-isopropylstilbene (2). The presence of 3,4'5-trihydroxystilbene (resveratrol) is reported for the first time in bacterium. Cell free extract of the bacterium and isolated stilbenes demonstrated high antibacterial activity against bacteria and fungi especially against plant pathogenic fungi. The antifungal activity of the compounds against the plant pathogenic fungi, *Rhizoctonia solani* is reported for the first time. TLC profile of the organic extract of LB showed the presence of 10 compounds. Three compounds were identified as Cyclo-(L-Pro-L-Met), Cyclo-(D-Pro-L-Phe) and Cyclo-(L-Pro-L-Tyr)

Physical and chemical interactions between plant insect interface in tuber crop ecosystem

Pest Risk analysis of sweet potato weevil and mealybug on tuber crops

Sweet potato weevil (SPW), *Cylas formicarius,* was found to be the single and most important insect pest in sweet potato production in Orissa. The areas with intensive and continuous cultivation of sweet potato over the years contributed to serious pest status of *C. formicarius*. Several generations of SPW were found in Regional Centre farms of CTCRI, Bhubaneswar. After the crop harvest in December, it was observed that the vines and sweet potato fields were left without any chemical interventions, hastening the process of buildup of the SPW. The SPW from these fields were migrating to blocks with planting material production, ovipositing them and becoming key factor for spread of SPW in the areas wherever these planting materials were supplied. Though seedling root dip of vines with systemic insecticide was recommended, it was not adopted leading to mass multiplication and spread of SPW. After the harvest, the storage roots were left in the field also lead to the multiplication of SPW. Banned pesticides were used for control of SPW, thus these pesticides partially responsible for outbreak of SPW in Bhubaneswar. With absence of resistant sweet potato varieties, non-adoption of IPM practices, SPW shall continue to a serious pest of sweet potato in the coming years in sweet potato growing states. A laboratory experiment indicated that one pair of SPW took 31 days to kill the sweet potato plant while two and 16 pairs took 27 days and 15 days respectively to kill the plant.

Two species of mealybugs *Paracoccus marginatus* (Fig. 19) and *Ferrisia virgata* (Fig. 20) were found as dominant species on cassava and yambean. *F. virgata* was not recorded in storage of tuber crops. *F. virgata* and *P. marginatus* were found parasitised by unknown wasps upto 40-50% in field conditions. *Rhizoecus amorphophalli* infests 10-15% of elephant foot yam tubers and occurred only in storage of elephant foot yam tubers under storage conditions in Orissa. It was parasitized by *Anomalicornia tenuicornis* Mercet (Encyrtidae) upto 15-20% and activity of the biocontrol agent was higher during December to March. Approximately 120 numbers of *A. tenuicornis* were emerged from one kg of elephant foot yam tuber fully infested with R. *amorphophalli*. A coccinellid *Cryptolaemus montrouzieri* Mulsant (Fig. 21 & 22) successfully controlled this pest in storage. The growth and reproduction of mealybugs were favoured by hot and humid conditions during February to April in the storage. The optimum temperature for *C. montrouzieri* to control

R. amorphophalli was found to be between 25 to 30°C. In storage, it was successfully controlled by 2 numbers of *C. montrouzieri*/kg tuber coupled with natural parasitization by *A. tenuicornis*. During the months of low parasite activity, 4 coccinellids were found sufficient for their control. Both these bioagents consumed the mealybugs within 3 to 4 days.

Differential plant volatile emission against sweet potato weevil

A four chamber 'Headspace volatile collection system' was developed to trap the volatile compounds emitted by flowers and tubers of sweet potato. This system cleans the incoming air through hydrocarbon traps and also fitted with traps to collect volatiles. The system is completely glass-fabricated.

Headspace volatile extracts were collected from sweet potato varieties Kishan, Kalinga, 'Howrah', BX86, C-14. Among these varieties 'Kishan was highly preferred by male and female SPW, whereas 'Howrah', BX-86, C-14 were found least preferred, in bioassay experiments. GC-EAD analysis of Howrah, BX-86 and C-14 indicated that, these varieties release α-Humulene (2,6,6,-9-tetramethyl-1,4-8-cycloundecatriene) which is also called α-caryophyllene. α-Humulene is a monocylic sesquiterpene. Another volatile compound, α-Gurjunene also got emitted from flowers of C-14. Both these compounds have shown 70-75% repellency to female sweet potato weevil. In addition to this, a compound, 2-(2-butylcyclopropyl)-cyclopropanenonanoic acid methyl ester from flower headspace volatiles of 'Howrah' genotype emitted as 9,12-(*Z,Z*)-octadecadienoic acid from the storage root periderm in ester form. 9,12-(*Z,Z*)-octadecadienoic acid is a precursor for production of several short chain aromatic compounds through lipoxygenase (LOX) pathway, presumed to be operated in the storage roots. These compounds were absent or expressed in very low quantities in SPW susceptible genotype 'Kishan'. These compounds presumably plays a role in SPW resistance in 'Howrah' and 'BX 86' genotypes by

Fig. 19 Mealybug *Paracoccus marginatus* infesting cassava leaves

Fig. 20 Mealybug *Ferrisia virgata* infesting twigs of cassava leaves

Fig. 21 Grub of *Cryptolaemus montrouzieri* feeding on mealybug *Rhizoecus amorphophalli*

Fig. 22 Adult beetle *Cryptolaemus montrouzieri* feeding on *Rhizoecus amorphophalli*

producing repellent compounds. Genotypes of sweet potato can be screened for SPW resistance based on the levels of expression, presence/absence of these cyclopropane fatty acid esters. Cyclopropane fatty acid esters can now be used as 'diagnostic marker' for weevil resistance in sweet potato.

INTEGRATED DISEASE MANAGEMENT OF FUNGAL DISEASES OF TROPICAL TUBER CROPS

Taro leaf blight, collar rot of elephant foot yam and greater yam anthracnose caused by *Phytophthora colocasiae, Sclerotium rolfsii* and *Colletotrichum gloeosporioides* respectively are the major limitations to the profitable and sustainable production. The diseases are widespread every year in all tuber crops growing areas. Characterisation of the pathogens are being done to formulate management strategies and attempts are being made to manage the disease through bio intensive methods

Taro leaf blight

Genetic diversity of *P. colocasiae*

Genetic diversity of *P. colocasiae* populations obtained from different taro growing regions were studied using AFLP marker. The results showed the presence of high levels of genetic diversity and isolates was clustered together irrespective of their geographical origin.

For the first time, *P. colocasiae* isolates obtained from fine spatial scale (multiple leaf blight lesion on the single taro leaf (Fig. 23) were analyzed for the presence of phenotypic (Colony morphology, Pathogenicity, Mating type) and molecular diversity (ITS characterization and RAPD). Phenotypic characters showed no variation. RAPD assay displayed polymorphism among the isolates. ITS sequencing and analysis revealed considerable variation in the ITS1 region of all the isolates examined. These variations reinforce that the populations of *P. colocasiae* are highly heterogeneous and the existence of significant level of genotypic variability indicates that these pathogens are continuously evolving in nature.

Development of *P. colocasiae* specific primers from evolutionary conserved regions

P. colocasiae specific primers were developed from

Fig. 23 Multiple leaf blight lesion on the single taro leaf

evolutionary conserved regions, viz., RAS-like, TRP1, ASF-like and GPA1. The specificity and sensitivity assay showed the reliability of the designed primers in amplifying *P. colocasiae* genome.

Real-time PCR-based assay was performed to detect and quantify *P. colocasiae* inoculum load in infected propagules, to develop a reliable method for quantifying disease progression in infected taro plants.

Development of rapid and efficient method for pathogenicity assay for *P. colocasiae*

Young leaves of taro (cv. Sree Kiran) were collected, surface sterilized using 0.8% mercuric chloride, rinsed twice with sterile distilled water and blot dried with sterile paper towels. The leaves were cut into fragments of equal length (5cm x 5cm) and were allowed to float to the abaxial surface in a pertiplate (20cm diameter) flooded with sterile water. Zoospore suspension (20µl) was placed on the center of the leaf fragments and a drop of plain agar was overlaid to maintain high moisture. The plate was incubated at 25°C and observed daily for disease symptoms.

The leaves started developing disease symptoms 48-72 hrs of incubation depending upon the aggressiveness of the isolate. Floating the leaves over the water allowed the leaf to be in the fresh state during the incubation period. During infection, mycelial growth was observed over the lesions as in field conditions and results obtained showed a greater degree of correlation to that of the field disease scores. This clearly shows the reliability of the method and could

be adapted for rapid and efficient screening of taro accessions.The floating leaf disc method was able to discriminate the isolates based on the aggressiveness also.

The survival of *P. colocasiae* was evaluated in sterile moist soil and on sterile water containing taro leaf fragments. The results showed that the latter supported the survival of the pathogen when compared to soil.

Host resistance

The floating leaf disc method previously described was used for assaying the level of resistance in twenty five taro accessions. Briefly, five leaf discs (5x5 cm) of taro accessions were floated on sterile distilled water in 200 mm diameter Petri plates and inoculated with a mycelial disc excised from the margins of actively growing cultures of *P. colocasiae*. After two days of incubation at 25 °C in the dark, the leaf discs were examined visually for disease symptom. Subsequently, the lesion diameter was calculated. There were five replicates for each accession.

The results categorized the accessions to varying levels of resistance (Fig. 24). The leaves produced lesions similar to field conditions and were able to discriminate the accessions based on the levels of resistance.

Exploitation of vermicompost for disease management

Characterization of bio control agents of vermicompost origin

Fungal and bacterial isolates which showed consistent high inhibition to *Phytophthora colocasiae* and *Sclerotium rolfsii* were characterized by biotechnological tools. Four fungal isolates were identified as *Trichoderma asperellum* by amplification and sequencing of ITS region. Six bacterial isolates were identified as *Bacillus subtilis,Bacillus cereus* (3 nos) and *Providencia rettgeri* (2 nos) based on16s r RNA amplification.

Isolates showed good Nitrogen fixation (12B3, 2B13 and 20B1), P solubilisation (8B3) and K solubilisation (2B17) and growth promotion properties. In general, all the treatments promoted growth of cow pea seedlings. Out of 25 tested combinations, 15, 17 and five treatments showed statistically significant increase in terms of shoot length, number of leaves and root length respectively.

Compatibility of potent bio-control agents

Compatibility of AMF (*Glomus microcarpum)* with potent bacterial and *Trichoderma* isolates were studied in pots. Bacterial + AMF triggered plant height but fungal+ AMF resulted in height reduction. The bacterial population was not affected by AMF, whereas 10% reduction in population was noticed in *Trichoderma* + AMFcombination. Hyphal colonization, vesicles and arbuscules formation of AMF were affected by the presence of fungal and bacterial isolates. Compatibility of potent bacterial and fungal isolates of vermicompost origin was evaluated under *in vitro* condition. Sixty six fungi x fungi, 128 bacteria x fungi and 90 bacteria x bacteria combinations were screened and 86.6% combinations are compatible.

Pot culture study- testing of vermicompost against taro leaf blight and collar rot of EFY

In EFY, there was no collar rot incidence in treatments incorporated with vermicompost in soil. However, the treatments with vermiwash drenching and seed treatment showed disease incidence (10.0 -30.0%). In EFY, soil application combined with spraying and drenching of vermiwash after 90 and 120 days of planting resulted in yield increase of 44.0% and

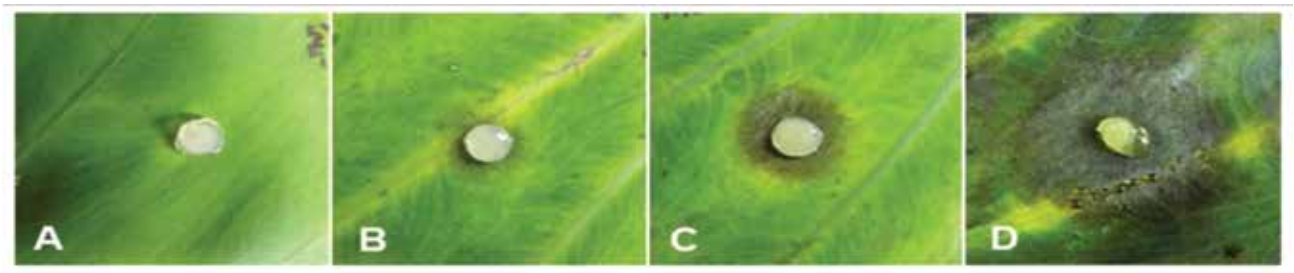


Fig. 24 Levels of resistance depicted by taro accessions. (A) Highly resistant, (B) Moderately resistant, (C) Moderately susceptible, (D) Highly susceptible

121.4 % over POP recommendation and control respectively.

Variability in pathogen suppression potential by different vermicompost/vermiwash

Ten vermicompost/vermiwash samples were tested for their variability in pathogen suppression potential. In general, all the vermicompost showed inhibitory action towards the pathogens. But, the suppression varied with the source. Highest and lowest inhibition to *Phytophthora colocasiae* was exhibited by vermicompost obtained from Vellayani (55.9%) and Kollam (7.69%) respectively (Fig. 25). Highest and lowest inhibition to *Sclerotium rolfsii* was shown by Thiruvananthapuram (100%) and Calicut (33.3%) samples respectively (Fig. 26). It was also found that a minimum concentration of 10% is required for disease control.

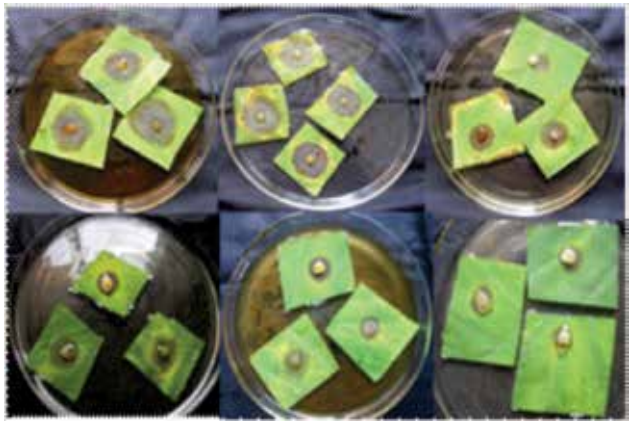


Fig. 25 Inhibition of lesion development in taro by various vermitea

Fig.26 Inhibition of *S. rolfii* (slices of amorphophallus) by various vermitea

Induction of enzymes in taro plants by vermicompost

Changes in resistance inducing enzymes and total phenols in taro plants due to incorporation of vermicompost were studied. Taro plants were treated with vermicompost and inoculated with *Phytophthora colocasiae*. Enzyme analysis was done at 0, 1, 2, 4 and 8 days after inoculation. Chitinase, β 1, 3 glucanase and total phenol production increased by the application and maximum production was noted in treatment vermiwash drenching+ pathogen after 24h followed by vermiwash drenching (Fig. 27 and Fig. 28). In the case of soil application of vermicompost, the highest activity was noted after 48 h of application. In pathogen alone also, all three have showed an increase but it was less in quantity at 96h.

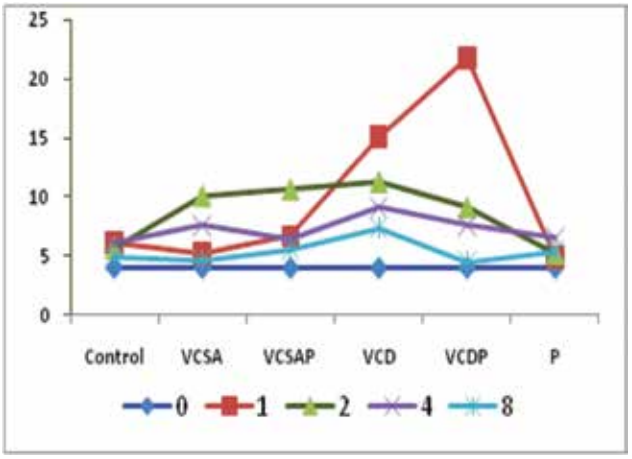


Fig. 27 Chitinase production in terms of mg of N acetyl glucosamine released /g of fresh leaves/h

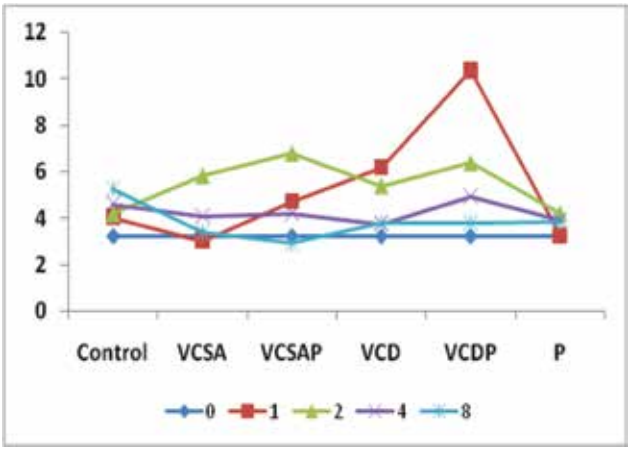


Fig. 28 Glucanase production in terms of mg of glucose released /g of fresh leaves/h

APPLICATION OF MICROBES FOR DISEASE MANAGEMENT AND SUSTAINABLE PRODUCTION OF TROPICAL TUBER CROPS

Bio control of collar rot of Elephant foot yam

Polyphasic Characterization of *Trichoderma* Isolates

Ten *Trichoderma* isolates were selected based on their antagonistic activity against *S. rolfsii* causing collar rot of elephant foot yam as weak, moderate and high for Morphological, biochemical and molecular characterization.

For morphological characterization quantitative and qualitative parameters were considered. Quantitiative (morphometric) parameters include size of conidia, time of initiation of spore production, radial growth rate at 30°C and 40°C and at pH 3, 7, and 9, percentage reduction of radial growth rate of *S.rolfsii* on dual culture while the qualitative (phenotypic) parameters include spore colour and ornamentation, colour of excreted pigment, presence of coconut like odour, texture of colony.

ITS and tef characterization of the 10 isolates yielded three different species, *Trichoderma asperellum*, *T. harzianum*, *T.longibranchiatum*. RAPD analysis showed polymorphism of these isolates, even among the same species.

Molecular mechanism of antagonism by *Trichoderma harzianum* against *Sclerotium rolfsii*

cDNA - RAPD was done with OPA, OPG and OPT series to study the differential gene expression in Tr9 on contact with *S.rolfsii* and 7 differential expressed bands were obtained Subtractive hybridization was used to isolate differentially expressed genes in Tr9 on mycoparasitism on *S.rolfsii*. 12 of the subtractive clones were sequenced. The sequences were compared with those in GenBank using blastx searches and in the GenBank EST database using blastn. Sequence analysis revealed that some have same sequence as each other and yielded five gene family, *viz.*, Methyl transferase, Dehydrogenase / reductase, Fungal transcription factor, N acetyl β glucosaminidase glucoside hydrolase and heat shock protein

Management

Fifteen isolates of *Trichoderma* and four isolates of rhizobacteria were isolated from soil samples collected from Odisha, Meghalaya, Tripura, Jharkhand and Chattisgarh.Field trials were conducted at RC of CTCRI, Farm, Bhubaneswar and in the farmers' field at village Kadarua, District Jalaun, Bundelkhand, UP on application of microbes for disease management and sustainable production of Amorphophallus (Fig. 29 and 30). Planting material treatment with cowdung mixed with *Trichoderma* (@5g/kg), use of *Trichoderma* enriched compost and application of 200g neem cake/plant resulted into 22% higher corm yield and 80% reduction in collar rot incidence, 15% reduction in leaf blight and 10% reduction in mosaic incidence over control in the farmer's field .

Fig. 29 Field view of the field trial and demonstration in farmers' field in U.P.

Fig. 30 Harvesting of the experimental crop in the farmer's field

Greater Yam anthracnose

Management

A field trial has been conducted at CTCRI Farm with thirteen different treatments and three replications for the management of greater yam anthracnose which includes a biocontrol agent (BCA) *Trichoderma asperellum* (Tr 15), biopesticide and fungicide

application for the third season with planting of healthy and diseased tubers without any treatment as control.Soil and tuber treatment with *Trichoderma* have been done@50 g of 10^7 cfu g^{-1} and 5 g in fresh cow dung slurry per kg of tuber respectively and foliar spraying of Carbendazim (Bavistin), Mancozeb (Indofil M-45) and combination of both (SAAF) @0.05% , 0.2 % and 0.1 % respectively three times at 15 days interval after initiation of the symptom *Trichoderma* was applied two times ,viz., at the time of planting and after two months when there was a reduction. Population of *Trichoderma* has been quantified at monthly interval in all the treatment plots. The result showed the survival in *Trichoderma* treated and untreated plots planted with healthy and diseased tubers (Fig. 31).

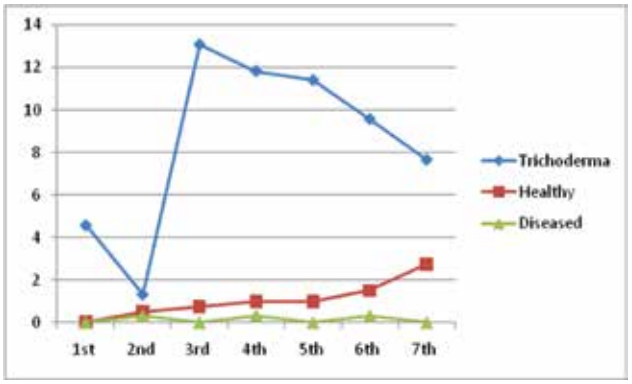


Fig. 31 Population of *Trichoderma* (10^4) at monthly intervals

The number of vines, leaves and vine length have been recorded in control, *Trichoderma* and biopesticides treated plots.The statistical analysis showed that there was no significant difference between treatments. However there is a slight increase in vine length and number of leaves in the *Trichoderma* treated plants

The maximum reduction in the anthracnose intensity was by spraying of Carbendazim alone (18%) which is on par with soil application with Tr15 + Tuber treatment with Tr 15+ Spraying Carbendazim; Soil application with Tr15 + Tuber treatment with Tr 15+ Spraying Mancozeb; Soil application with BP+ Tuber treatment with BP; Spraying Mancozeb and Carbendazim alone separately. But the disease intensity was not significantly different between treatments. The yield was significantly different between treatments whereas the tuber number was not significant.The maximum percentage of increase in yield has been observed in soil application with Tr15 + tuber treatment with Tr 15 + spraying carbendazim (60.5%) over control which was followed by soil application with Tr15 + Tuber treatment with Tr 15 + Spraying mancozeb and carbendazim (SAAF) (58 %) .

Charcterisation of toxic metabolites

Diethyl ether fraction which produced necrosis in greater yam leaf similar to the pathogen was subjected to TLC using different solvent combinations, i.e., Hexane : Ethyl acetate (3:1), Butanol : Acetate: water (3:1:1), Hexane : Methanol (3:1). Hexane : Diethyl ether (3:1) was the appropriate solvent system than the other. Several bands were obtained on TLC plates and the bioassay of these bands individually on yam leaves shows that some bands cause symptoms of anthracnose disease and other bands does not produce any necrotic effect . The combination of all bands on yam leaves produced significant changes which indicated that the phytotoxic effect of toxin is due to synergism or combined activity of different components present in the crude extract. The spectrum of the the diethyl ether and aqueous fraction of toxic metabolites of five different isolates was measured and scanned using a UV/Visible spectrophotometer (T70/ T80 series, P. G. Instruments, Alma Park, Wibtoft, Lutterworth, U.K) which produced three to five peaks between 200 to 360 nm in UV spectroscopy (Fig. 32). The column chromatography was done using the silica gel and ten different fractions were eluted out. The development of band in TLC and the necrotic symptoms on greater yam leaves are positively correlated with the concentration of diethyl ether in the elution solvent . The young leaves of greater yam accessions were screened with crude toxin which developed different size of necrosis.

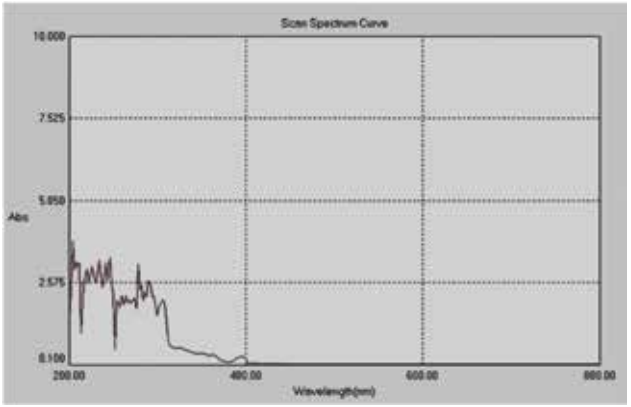


Fig. 32 Spectrum of the diethyl ether fraction of toxic metabolite

CHARACTERISATION, DIAGNOSIS AND MANAGEMENT OF VIRUSES INFECTING TUBER CROPS

Tropical tuber crops are infected by different viruses. Major viruses are Srilankan Cassava mosaic virus, Dasheen mosaic virus in elephant foot yam and taro and yam mild mosaic virus and yam maclura virus in yams. The crops are vegetatively propagated and the viruses are spread through tubers. Charcterisation and diagnosis plays a major role in mining new viruses and also indexing to get virus free planting materials. Work is also being carried out for ecofriendly management of the diseases

Cassava Mosaic Disease

Studies on symptom recovery phenomenon and qPCR

Totally, 15 selected varieties of susceptible, resistant and recovery types were planted in field and observations were taken at every month based on different grades of symptoms. In these, resistant varieties showed grade 1 symptom and susceptible varieties showed grade 3&4 symptom during the growth period. But recovery types showed grade 2&3 symptoms up to third month of growth and then it was found to be decreased and almost all plants showed grade 1 symptom at the sixth month.Observations revealed, susceptible cultivars, viral load and symptoms did not show much variation throughout the growth period. qPCR studies revealed that, even though there was no symptom expression in resistant varieties, a very low concentration of viral DNA was found at early stages of growth. In recovery type, although there was severe infection at early stages, the symptom score as well as the virus titre decreased over the growth period. Virus concentration was positively correlated with severity of symptoms.

Four rhizobacteria (viz., RB9 (*Pseudomonas areuginosa*), RB26 (*Bacillus pumilus*), EN16 (*Bacillus subtilis*) and EN22 (*Enterobacter cloacae* var *dissolvens*) and eleven different combinations were tested for their effectiveness in CMD containment. Observations showed CMD incidence was less in all the treated plants compared to control. About 53 % CMD incidence was noticed in case of EN 22 treated plots compared to control which showed 90 % disease incidence. There was significant increase in plant height, girth and tuber yield in all the treated plots compared to control plots. Among the combinations EN16+EN22 showed significant reduction of CMD (31%), but it is less than that of EN22 (47%).

Molecular analysis of putative cassava transgenic lines with biotinylated *NPT II* probe & GUS probe showed that out of nine plants screened, three plants were positive with GUS probe and two with *NPT II* probe. New transformation of cassava events are in selection medium and the previous ones are different stages of selection. Friable embryogenic callus (FEC) of cassava production for H226 is in progress.

The transformed *N.benthamiana* plant having SLCMV constructs (Rep_IV2, SLC/IC_Syn gene, SLCMV Trap_IV2) and ICMV_Antisense Rep were subcultured in specific antibiotic (Kan_{80}) medium and molecular analysis for gene incorporation was done by PCR and RT-PCR using *Npt II* primer and gene specific primer (SLCMV Rep, SLCMV TrAP, IC/SLCMV Synthetic gene specific primers, ICMV Rep1/Rep2). These transgenic plants were hardened and their F1 seeds were collected and will be further used for analysis of these transgene in next generation

Dasheen mosaic virus (*DsMV*) in Elephant foot yam and taro

Detection

Virus indexing of Taro leaf samples of various accessions

Out of 180 samples indexed with ELISA, 53 were positive for *DMV* and 25 were positive for potyvirus.

Out of 110 samples from Bhubaneshwar, 71 samples were *DsMV*-Taro *(DsMV*-T*)* positive, 34 were *DsMV*-T / *DMV-Amorphophallus* (*DsMV*-A) positive while only one was found to be *DsMV*-A alone positive. Out of 20 samples from Salem, Tamil Nadu, 2 were *DsMV*-A positive. Out of 70 samples from Kerala, 60 were potyvirus positive while 15 were *DsMV*-A positive and 30 were *DsMV*-T positive.

About 25 samples of amorphophallus were detected with Lateral Flow Devices within10-15 minutes time. The *DsMV* positive samples gave purple lines in both control and test lines while the negative samples gave colouration in control lines alone (Fig. 33 & 34). The test was found to be highly sensitive and was capable of detecting virus with very low titre.

Fig. 33 Dipstick for detecting DsMV infection

Fig. 34 Detection of DsMV using lateral flow device

RT- LAMP proved to be rapid way of detecting virus in less time. The primers designed were found suitable for genus (potyvirus) and species (*DMV*) detection.

Deep sequencing of suspicious samples for detection of mixed viral infection in *Amorphophallus*

Two virus infected samples of *Amorphophallus* (1a, 2a) having confirmed mixed infection and two virus free healthy samples (3a & 3b) were subjected to transcriptome using next generation sequencing with Illumina platform. Analysis of sequences showed possible association two suspected virus viz., Bean mottle virus and Hibiscus Singapore virus. Apart from this we have obtained gene expression in virus infected and healthy samples, totally 405349 transcripts which included up and down regulated genes with some unique gene present only in infected or healthy samples (Fig. 35).

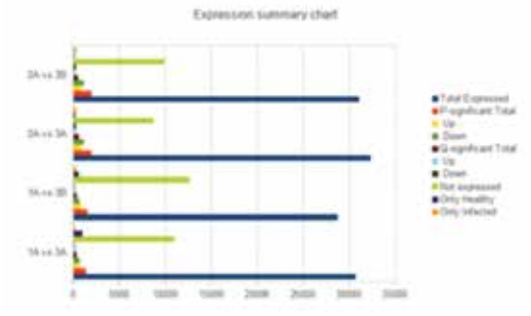


Fig. 35 Gene expression profile in Amorphophallus in comparison of healthy with virus infected one

Friable embryogenic callus of elephant foot yam was developed from lateral bud, petiole and leaf explants on modified MS medium supplemented with 0.5 mg/L each BA, NAA and 2,4-D (CI medium). Shoot regeneration was optimal on modified MS medium supplemented with 5.0 mg/L BA and 1.0 mg/L NAA (SR medium) (Fig. 36). Modified MS medium supplemented with 5.0 mg/L IBA was found to be the most potent rooting media which recorded 100% rooting (Fig. 37). Survival rate of 100% was observed when the plantlets were transplanted to soil: sand: coir pith mixture. Mass propagation of callus and microshoots were done in CI and SR medium respectively. Out of 150 hardened plants obtained from tip of lateral bud used as explant, 95 (tested with both *DMV*-A and *DMV*-T antisera) were virus free. The virus free plants are maintained in Net house, CTCRI.

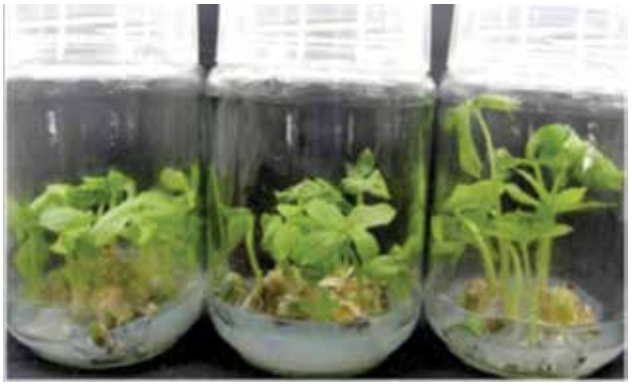


Fig. 36 Shoot induction of *Amorphophallus*

Fig. 37 Root induction of *Amorphophallus*

Yam viruses

Leaves and Tubers were collected from virus infected *D.alata* plants showing mosaic and prominent puckering symptoms and total RNA was isolated from leaves using Ambion kit. Since the greater yam tuber contains high mucilage isolation of RNA with good quantity and quality is difficult. Using different manual (Trizol, Lithium chloride and method described by Mohankumar et al., 2008 and kit method (Ambion, Sigma and Qiagen Rneasy). Among all Lithium chloride and Mohankumar et al., 2008 methods gave reasonably good RNA.

The RNA isolated from the leaves and tubers was subjected to RT-PCR amplification using virus specific Maclura 1s and 1c primers. The amplified product was checked in agarose gel electrophoresis. Analysis of PCR showed amplification product of Maclura at 200bp size. This confirmed the presence of Maclura virus in tubers. The Amplified product from leaf was eluted and sequenced. The sequence analysis showed that it is 70% related to Chinese yam necrotic virus

Since the amplified product of Yam Mild Mosaic Virus (YMMV) through RT-PCR was not of good quality and concentration, the amplification was done by two steps. Initially cDNA was prepared and then RT-PCR has been done using virus specific primers (YMMV S and YMMV C) which gave ~ 500 bp amplicon of good quality (Fig. 38)

Nucleic acid spot hybridization technique

Biotinylated non-radioactive probes of YMMV and Maclura viruses have been developed using the specific amplified products. The quality of the probes was confirmed. In separate tests RNA of the test samples were spotted onto the nylon membrane and hybridised with the developed probes. After hybridization the membrane was processed according to the NEB Phototope star detection kit and finally the presence of viruses were confirmed by spots developed by exposing the chemiluminescence from membrane to X-ray film

DAS-ELISA

YMMV and Maclura virus have been diagnosed from greater yam leaves through DAS ELISA using virus specific antibodies. Among twenty, 35 % of the samples showed positive to Maclura virus, 55% to YMMV mixed infection was observed in 20%.

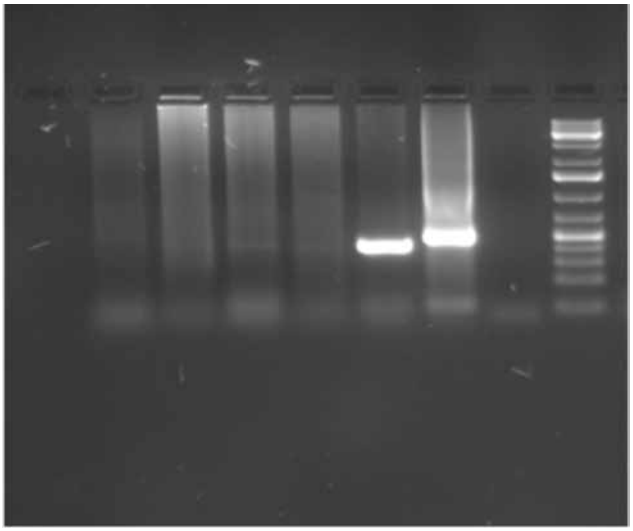


Fig. 38 PCR with cDNA using YMMV specific primers

CROP UTILIZATION

DEVELOPMENT OF FUNCTIONAL FOODS FROM TUBER CROPS

Developing technology for nutritionally fortified pasta and designer food products from tuber crops

The project was started in 2007 with the objective of perfecting the technology for making nutritionally fortified pasta from tuber crops and for making designer foods having specific nutritional or dietetic value. During the year under report, three experiments were undertaken: (i) effect of legume flour fortification in reducing the starch digestibility of cassava spaghetti, (ii) pigment retention studies on betanin and carotene enriched cassava and sweet potato pasta and (iii) studies on cassava fortified with NUTRIOSE® - a high dietary fiber source.

Effect of legume flour fortification in reducing the starch digestibility of cassava spaghetti

Legume flours were incorporated at 15% level to cassava flour: maida blends (50.9:13.0), with whey protein concentrate (10%), gelatinized cassava starch (5%), oil (5%) and guar gum (0.5%) as other major additives. Studies on the cooking characteristics of the spaghetti showed that cooking loss was significantly reduced for the legume flour fortified spaghetti, possibly due to the better binding of legume proteins with starch. Lowest cooking loss (8.26 %) was observed for bengal gram fortified spaghetti, as compared to the control spaghetti. Swelling Index (SI) was significantly low (1.71) for the green gram flour fortified spaghetti, while the control and other fortified samples had SI of 2.0. Significant elevation in protein content (14-18%) compared to 9.6% in the control was a major advantage of legume flour fortification. Time course release of glucose from the cooked spaghetti (as gram glucose released per 100g starch in cooked spaghetti on dry basis) showed that only 42.9g glucose was released from black gram fortified spaghetti at 120 min, while 51 and 54g were released from bengal gram and green gram fortified spaghetti respectively as against 61.3g from the control. The total of rapidly digested starch (RDS) and slowly digested starch (SDS), representing the starch fractions that could be digested in the intestines within 2h was the lowest (38.65 %) in the black gram fortified spaghetti. Resistant starch, representing the undigested starch fraction was elevated for all the legume fortified samples, with a concomitant decrease in the estimated glycaemic index (Fig. 39).

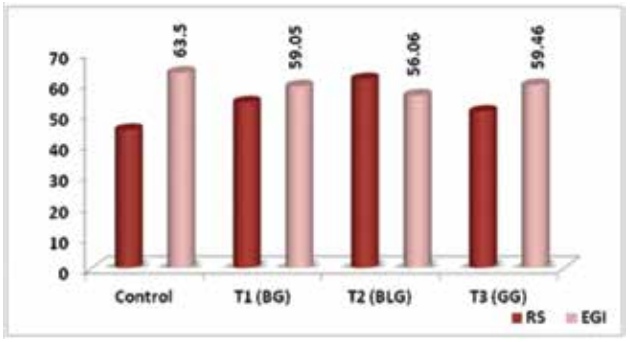


Fig . 39 Resistant starch content and estimated glycaemic index (EGI) of legume flour fortified cassava spaghetti (RS expressed as gram per 100g starch in cooked spaghetti on dry wt. basis; EGI as Units)

Cooking brought about a sharp reduction in the firmness (N) and toughness (Ns) of the spaghetti. Firmness and toughness of the cooked spaghetti were the highest for bengal gram fortified spaghetti.

Pigment retention studies in betanin and carotene enriched cassava and sweet potato pasta

The formulations contained 60% cassava/sweet potato flour, 15% rice flour, 10% carrot/beet root powder and common ingredients such as whey protein concentrate (10%), oil (2%) and gelatinized cassava starch (3%). Retention of carotenoids and betanin in the fortified cassava and sweet potato pasta stored in plastic pouches was studied under ambient conditions up to one month. It was found that only 65% and 85% of total carotenoids were retained after one month in carotene enriched cassava and sweet potato pasta respectively. Betanin was retained to the extent of 74% and 61.2% in betanin enriched cassava and sweet potato pasta respectively. The study showed that efficient packaging systems have to be developed that permit only minimal loss during storage.

Experiments on cassava pasta fortified with NUTRIOSE®, a high dietary fiber source

Cassava pasta enriched with NUTRIOSE®, a dietary fiber rich material (having 85% dietary fiber) was prepared. Two levels of NUTRIOSE, viz., 10% (T1) and 15% (T2) were added to cassava – maida blends (60:10 for T1 and 57.5: 7.5 for T2) along with other ingredients such as whey protein concentrate, oil and gelatinized cassava starch (GCS) as binder. It was found that the cooking loss (7.02 %) and swelling index (1.91) were reduced for 10% NUTRIOSE fortified cassava pasta, with gelatinized cassava starch as binder compared to the respective values of 8.16 % and 2.25 for the control pasta. *In vitro* starch digestibility showed that after 2h (120min) of digestion, only 43.8g glucose was released from 100g starch in the 10% NUTRIOSE enriched pasta, compared to 73.6g for the control. Accordingly, the resistant starch fraction was 33% in control *viz-à-vis* 60% in 10% NUTRIOSE enriched pasta. Addition of gelatinized cassava starch led to slightly higher stickiness in the pasta. Hence, cassava pasta fortified with NUTRIOSE alone without gelatinized starch was prepared and its characteristics were compared with the former. It was found that the swelling index of NUTRIOSE enriched pasta was significantly higher when compared to its counterpart with gelatinized starch as binder. This indicated the less firm structure of the pasta, leading to higher water uptake by NUTRIOSE. *In vitro* starch digestibility kinetics showed that in the NUTRIOSE fortified samples without gelatinized starch, the digestible starch fractions were significantly less than the former, coupled with high resistant starch values. Estimated glycaemic index of 54 could be obtained for 10% NUTRIOSE fortified pasta with gelatinized cassava starch (Fig. 40). The study showed that NUTRIOSE is a highly preferred additive for making cassava pasta with low glycaemic index and addition at 10% level was optimum.

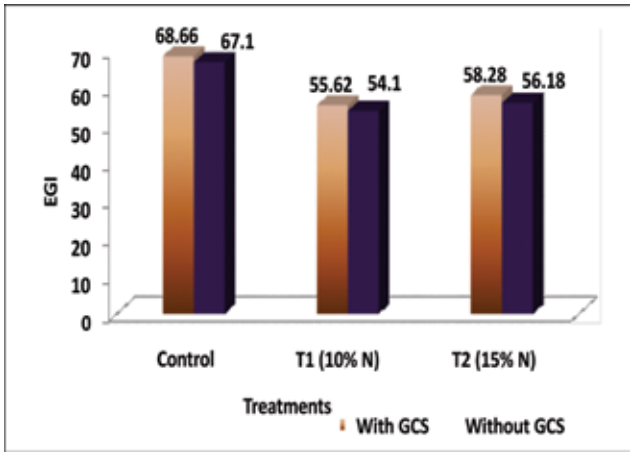


Fig. 40 Estimated glycaemic index (EGI) of cassava pasta fortified with NUTRIOSE®

Development of low glycaemic noodles from sweet potato and low calorie sago from cassava as anti-diabetic foods

Experiments with starch sources like banana, lentil, black gram and sweet potato with reported high resistant starch content, as additives for sweet potato spaghetti showed that the estimated glycaemic index could not be significantly reduced (62-66) compared to control (68). Hence, studies were made to find out the effect of commercial gum sources such as guar gum, Xantan gum and locust bean gum in reducing starch digestibility. It was found that gums generally and xanthan gum especially reduced the cooking loss of fortified sweet potato spaghetti. Swelling Index was significantly higher for all the gum fortified spaghetti samples. Starch digestibility kinetics showed significantly slower glucose release at 120 min, for all the gum fortified samples, compared to the control. Accordingly, elevation in resistant starch content was significantly higher for the gum fortified samples and among the gums, maximum effect was produced by xanthan gum. However, estimated glycaemic index was minimum [58.69 for the guar gum (1.5%) and 58.65 for Xanthan gum (1.5%)] fortified sweet potato spaghetti. Ultra structural studies done using scanning electron microscopy showed that xanthan gum (1.5%) gave better binding with starch than others (Fig. 41).

The effect of fortification of sweet potato flour with fiber sources such as apple, wheat and oats in reducing the starch digestibility and glycaemic index was also studied. Fibers were fortified at 10 and 20% level and it was found that the swelling index of pasta was higher for all the fiber fortified samples. Starch digestibility was also significantly reduced for all the fiber fortified sweet potato spaghetti, with the highest reduction in glucose release for the oat fiber and wheat (20%) fortified samples. Estimated glycaemic index was 57.29 for oat (20%) and 58.24 for wheat (20%), suggesting further improvements in the formulations to bring it down to <55. Ultra

structural studies using SEM showed that starch granules were closely spaced in the dry sweet potato control spaghetti. However, in all the fiber fortified samples, starch granules were widely dispersed and many ruptured granules were seen. Cooking led to the formation of starch-fiber protein layer over the surface, leading to less accessibility of amylase to starch (Fig. 41). Legume flours were incorporated at 15% to sweet potato-maida blends and spaghetti was prepared. Legume flours reduced the cooking loss, with maximum reduction in the case of black gram flour. Least release of glucose into *in vitro* system was observed in the case of black gram fortification. Reduction in estimated glycaemic index was significant in the case of black gram fortification. However, the EGI values could not be brought down to < 55. Hence the legume flour sweet potato starch blends were exposed to low temperature aided retrogradation of starch and this mix was then mixed with other flours and spaghetti extruded. Swelling Index was more for the pretreated legume flour fortified spaghetti. Besides, starch digestibility could be considerably reduced. The estimated glycaemic indices for the legume fortified spaghetti were black gram (53.13)<bengal gram (55.6)<green gram (56.2). Ultrastructural studies conducted in the case of all the samples substantiated the cooking loss observed for the various spaghetti samples.

Rapidly digested starch which was only 43.7% in native starch increased to 79% and 68.6% in the heat moisture treated starch and annealed starch respectively. In the native cassava starch, the rapidly digested (RDS) and slowly digested (SDS) fractions were nearly equal; but in the case of modified starches there was a considerable decrease in the SDS content. Resistant starch increased to 7.38% and 8.18% respectively for HMT and annealed starches as compared to only 1.65% in the native starch. The scanning electron microscopic analysis showed that the granules in native as well as treated starches appear almost similar in morphology and spherical granules containing a pit at one end were observed. The resistant starch content of sago prepared from heat-moisture treated starch and annealed starch were found to be comparatively higher than that made from native starch and other treatments.

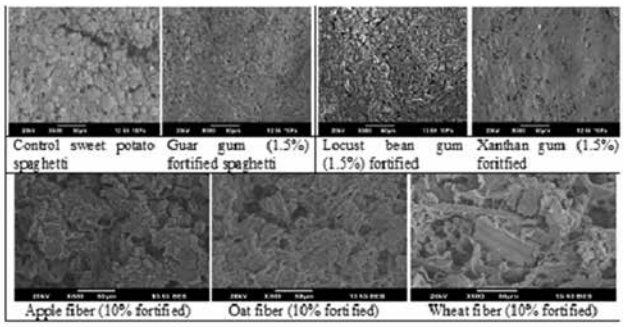


Fig. 41 Scanning electron micrographic photographs (x 500) of gum and fiber fortified sweet potato spaghetti

Development of protein and nutrient concentrate from cassava and sweet potato leaf

Nutritional evaluation of leaf protein

The amino acid and fat composition of the cassava leaf protein concentrate (CLPC) was determined. The crude fat content was high in CLPC in which palmitic acid was found to be the dominant fatty acid among the saturates. Among the amino acids, lysine was found to be high which merits its consideration as a fish feed ingredient. CLPC was incorporated in ornamental fish feed and evaluated for its propensity to replace fish meal. LPC was incorporated at 0, 10, 20, 30, 40 and 50 percent levels replacing fish meal in the formulations. Black molly (*Poecilia sphenops*), a popular freshwater ornamental fish was chosen as the model fish for testing the feed. The acceptability of the feed was found to be good and growth of the fish was higher in all the treatments as compared to the control group (fed with commercial shrimp feed from the Amalgam) as well as to the LPC0 group. Cassava leaf protein concentrates could replace the fish meal component in feed without deleterious effects and the optimum performance was observed for 20% replacement of fish feed by CLPC.

Nutritive evaluation of cassava leaves in animal feed using goats as an experimental model

The upper leafy portion of cassava stems from 10 month old cassava plants were harvested and allowed to dry in shade for 24h. The leaves were then coarsely powdered and packed in gunny bags. Sixteen Malabari goat kids of 3-4 months age were selected from Kerala Veterinary and Animal Sciences University (KVASU) Goat farm and were fed for 3 weeks with normal goat feed and green forage which served as the control period. After three weeks of

feeding, the kids were divided into four groups of 4 animals with similar average body weight. The dietary treatment involves 0, 10, 20 and 30% cassava leaf meal. Replacement of concentrated feed with 30% leaf meal gave the highest weight gain in goats.

Bioactive principles from tuber crops

Analysis of bioactive principles and antioxidant activity in *Dioscorea alata*

Twenty accessions of *Dioscorea alata* with differing flesh were analyzed for total phenols, flavonoids, proanthocyanins, anthocyanins and carotenoids (last two in relevant accessions only). Further, they were assayed for antioxidant potential by determining DPPH RSA, FRAP, SOSA and reducing power.

IC50 determination in high performers in comparison to established standards

Based on pooled data of analysis from present and previous years, fifteen top performing varieties were selected for determination of IC 50 values with respect to their radical scavenging activity. Along with these samples, established standards such as quercetin, catechol, ascorbic acid and trolox were also subjected to IC 50 determination for comparison. IC 50 values for *D.alata* varieties varied from 150 µg to 2 mg, where as the standards gave values ranging from 15µg to 800µg. Based on the encouraging results, antiproliferative activity of two of these varieties are in progress.

Evaluation of prospects of *D.alata* anthocyanins as a viable natural colourant

Colour stability in various drink models

By virtue of the unique property of colour stability across a wide pH range (brought out by previous years work), there is immense scope for *D. alata* anthocyanin as a natural colourant. For practical evaluation of colour stability of *D. alata* anthocyanins, they were purified, concentrated, freezedried, reconstituted and aliquots were used for preparation of different model drinks such as an isotonic system of pH 2.5, three sugar containing buffered systems of pH 3.5, 4.5 and 5.5, each with a sugarless variant and another sugarless system buffered at 3.5 pH. The prepared drinks were distributed into sterilized tubes and incubated with or without additives such as ascorbic acid, catechin or sucrose in various regimes of light, gaseous environment and temperature (light/dark/,-20°C, 4°C, 10°C, or RT, N_2/Air etc). Every month a set of tubes were withdrawn and observations taken, till 4 months.

From the results, the isotonic model drink system was found to be the best to retain color. In this system, up to two months, even in RT exposed to florescent light, anthocyanin color decrease was minimal, but beyond 2 months, there was gradual fading of color. However, when stored at 4°C both in nitrogen and in air, there was no loss of color compared to the control at zero day. Ascorbic acid addition led to loss of anthocyanin color. Addition of sucrose also led to loss of color in the sugarless system.

Studies on encapsulation

For use as a handy colourant, it is essential to store anthocyanin protected from light and air till use. Encapsulation with sodium alginate and PLGA was experimented with. In both cases, though encapsulation could be achieved, color tended to ooze out into the medium within half an hour. The method is being modified using second coatings and also change of encapsulants.

Estimation of different phytochemicals and bioactive properties in tubers of sweet potato varieties

Fourteen varieties of sweet potato were analysed for various beneficial phytochemicals and antioxidant activity for confirming results obtained in previous years. The trend obtained was the same though there were some differences in range of values obtained. ST-13, the red fleshed variety showed largest content of phenols, flavonoids, anthocyanins and proanthocyanins and displayed far superior antioxidant activity than all others.

Changes in biochemical and bioactive properties after processing of sweet potato tubers by different methods

The study involving seven sweet potato varieties with varying flesh colours employing three processing methods, *viz.,* boiling, baking in combo mode in a microwave and microwave cooking brought out interesting results. All three processing methods resulted in sharp increase in bioactive properties (DPPH RSA and reducing power) with associated

increases in total phenols indicative of an increased health protective effect on cooking of the tubers.

Both boiling and baking resulted in large increase in reducing sugar fraction with reflected increase in total sugars along with a concomitant decrease in starch content. This phenomenon unique to sweet potato tubers is brought out by hydrolysis of starch mediated by the endogenous β-amylase with demonstrated thermotolerant properties. Therefore, it was very interesting to note that the sugar shoot up is arrested when the dices are processed by microwave cooking, a processing procedure which is known to inactivate the enzymes almost instantaneously. Comparison of HPLC sugar profile of raw tubers with the processed ones clearly showed that the *de novo* formation of maltose on boiling and baking get suppressed during microwave cooking.

Characterization of anthocyanins and carotenoids in tuber crops

Anthocyanins from *D.alata*, sweet potato variety ST 13, leaves of sweet potato violet variety, and sweet potato tuber skins were purified and their HPLC profile was done. Cyanidin glycoside was found to be the common anthocyanin in all the tuber crops. In sweet potato, peonidin glycosides were also present in tuber flesh and leaves along with cyanidin, whereas in tuber skin, pelargonidin was found present in all the varieties analyzed.

Analysis of carotenoids in sweet potato tuber showed xanthophylls to be the major carotenoids in cream fleshed varieties as opposed to OFSP, where β carotene was the major carotene. In sweet potato leaves, xanthophylls were the major carotenoids and a carotenoid tentatively identified as lutein formed the major one among the xanthophylls.

Retention of carotenoids in variously colored sweet potato tuber chips after deep fat frying

Sweet potato varieties with flesh colours varying from cream to deep orange were investigated for retention of carotenoids after deep fat frying. Frying led to 19-26% loss in carotenoids though the visible appeal was very good. Blanching before frying stemmed the loss only slightly. Comparison of HPLC profile showed some conversion of trans β-carotene to its cis isomer in fried chips, which reduces its provitamin-A activity.

Oligosaccharides and maltodextrins from starch/ tuber slurry using endogenous enzymes from sweet potato and *Dioscorea esculenta*

Endogenous amylases were purified by ammonium sulfate precipitation from two identified high amylase sweet potato varieties and one *D. esculenta* variety and used for liberating maltooligosaccharides from their own starch or tuber slurry as also from other sources of starch. TLC and HPLC profile studies showed that the major oligosaccharides formed were maltose and maltotriose and traces of maltotetraose. The liberated oligos were purified by column chromatography and crystallized. Other extraneous enzymes were tried along with or after/prior to amylase addition, and it was found that amyloglucosidase added after or along with amylase gave rise to large conversion to glucose.

Refinement of technologies for fermented food products and transfer of technology

OFS were pickled with carrot and beet root (1: 1: 1 ratio) by lactic fermentation with a probiotic strain of *Lactobacillus plantarum* (MTCC 1477) for 15 days in 10% brine at ambient temperature. The product had a pH of 3.8- 4.0, titratable acidity 2.5- 3.0 g, LA of 2.6- 3.2g and starch of 5.8- 6.4g/kg pickle on fresh weight basis.

Production of food extrudates from tuber crop flour/starch

Extrusion trials on cassava-cardamom and cassava-black pepper blends

Cassava-cardamom (24:1) and cassava-black pepper (24:1) blends were prepared, conditioned to 16% moisture content and extruded. The feed zone, compression zone and metering zone temperatures of the extruder were set at 60, 70 and 80°C, respectively. The die size was 2mm and the feeder screw speed was 20 rpm. The die temperature varied from 170-190°C and extruder screw speed varied between 70-90 rpm. Nine trials were carried out under SmallHartley Statistical Method. Second order regression models were developed for the physical properties with respect to process variables.

Properties of extrudates w.r.t extrusion parameters

- $ER = 105.44 - 1.046T - 0.14307R + 0.002T^2 + 0.001TS - 0.0004S^2$ ($R^2 = 0.99$)

- PD = -19.62 + 0.193T + 0.058R - 0.0004T^2- 0.0004TS + 0.0001S^2 (R^2 = 0.98)
- BD = 2.02 - 0.022T + 0.01R + 0.00008T^2 - 0.0001TS + 0.00007S^2 (R^2 = 0.99)
- P = 3411.7 - 33.76T - 7.18R + 0.084T^2 + 0.034TS + 0.009S^2 (R^2 = 0.98)
- WAI = -52.267 + 0.60T + 0.063R - 0.002T^2 + 0.002TS - 0.002S^2 (R^2 = 0.96)
- WSI = 1644 - 16.931T - 1.67R + 0.04T^2 + 0.007TS + 0.002S^2 (R^2 = 0.98)
- ER is the expansion ratio; PD is the product density (g/mm^3)
- BD is the bulk density (g/mm^3); P is the porosity (%)
- WAI is the water absorption index; WSI is the water solubility index
- T is the die temperature (°C); S is the screw speed (rpm)

Extrusion trials on Fermented cassava, wheat and rice flour blends

Fermented cassava, wheat and rice flour (2:1:2) were blended, conditioned to 16% moisture content and extruded (Fig. 42). The feed zone, compression zone and metering zone temperatures of the extruder were set at 60, 70 and 80°C, respectively. The die size was 2mm and the feeder screw speed was 20 rpm. The die temperature varied from 180-200°C and extruder screw speed varied between 80-100 rpm. Nine trials were carried out. The moisture content of the extrudates ranged from 9.36-11.49%, expansion ratio 2.97-3.69, bulk density 0.11-0.17g.ml^{-1} and product density 0.00027-0.00031 g.mm^{-3}. Effect of die temperature and screw speed on moisture content, expansion ratio and functional properties such as water solubility (WSI) and water absorption indices (WAI) of the extrudates are shown in Fig. 43. The WSI and WAI values ranged between 8.57- 12.85% and 5.5-6.21 g.gel/g powder, respectively. The hardness, toughness and crispness of the product were between 37.6-64.2N, 27.4-51.02N.S and 13-16.8 (no.of peaks) (Fig. 43). The best product was obtained at 200°C of die temperature and 80rpm of extruder screw speed.

Extrusion of fermented and partially de-starched cassava for high fibre content extrudates

The peeled cassava tuber was grated, fermented and pressed at 10, 20 and 30 kg.cm^{-2} for 2, 12 and 22 minutes. The moisture, starch and sugar content values of cassava before pressing were 45.87-53.89%, 34.43-40.82% and 1.24-4.88% and the values after pressing were 43.74-53.66%, 35.0-45.02% and 1.12-3.45%, respectively. The moisture, starch and sugar contents of dried cassava flour were 9.6-12.2%, 66.2-83.3% and 1.2-3.3%, respectively. The moisture oozed out along with starch during pressing varied from 1.2-5.48% during the application of load (3.5-11.5 kg) through textural analyzer.

Extrusion trials on sweet potato and turmeric blend

Sweet potato and turmeric (24:1) were blended and extruded (Fig. 44). The feed zone, compression zone and metering zone temperatures of the extruder were

Fig. 42 Fermented cassava, wheat and rice flour extrudates

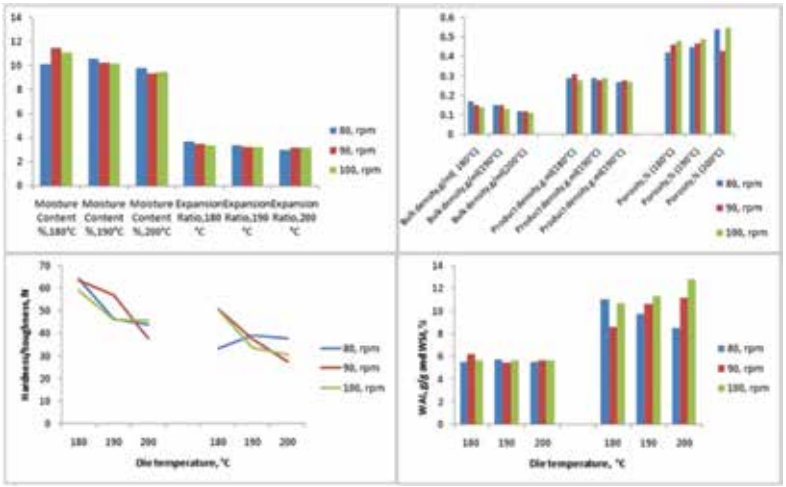


Fig. 43 Effect of extrusion conditions on the physicochemical properties of fermented cassava, wheat and rice flour extrudates

set at 70, 80 and 90°C, respectively. The die size was 2mm and the feeder screw speed was set at 20 rpm. The die temperature varied between 170-190^{0}C and screw speed 70-90 rpm. Small composite Hartley statistical method was adopted. The expansion ratio, bulk density and moisture content of sweet potato and turmeric powder blended extrudate ranged from 1.44-2.11, 0.53-0.59 g/cc and 8.04-14.39%, respectively. The effect of extruder screw speed and die temperature on moisture content of the extrudate is given in Fig. 45. Hardness, toughness and crispiness of the extrudate ranged from 85.48-166.80 N, 93.13-203.50 Ns and 1.94-8.84 number of peaks respectively. The best product was obtained at 180°C of die temperature and 92 rpm of extruder screw speed.

Extrusion trials on cassava, rice and banana flour blends

Cassava, rice and banana flours were mixed at different proportions (20:70:10, 40:50:10, 60:30:10 & 80:10:80) and conditioned to 16% moisture content. Extrusion trials were carried out in a single screw food extruder. The temperatures of feed zone, compression zone and metering zone were maintained at 70, 80 and 90°C, respectively. The die zone temperature (170,180, 190, 200°C) and extruder screw speed (80, 100 and 120 rpm) were varied. The feed rate was varied between 1.4 to 2.28 kg per. The extrudates with a higher expansion ratio (3.2-3.7) was obtained at high temperature-speed combinations (180°C-120rpm). Higher amount of cassava (60-80%) in the feed yielded highly expanded products (expansion ratio 3.4-3.7). The bulk density of the extrudates was lower (0.11g/cm^3) at high temperature-speed (180-190^{0}C, 120 rpm) and higher (0.18-0.24g/cm^3) at low die temperature. At higher temperature range (190-200^{0}C) porosity was found to be low (15-25%) whereas at low temperatures (170-180^{0}C) it was higher (36-47%).

Development of bioprocess for the production of functional oligosaccharides from tuber starches

Determination of oligosaccharide profile of the maltooligosaccharides synthesised from cassava and potato starches

The HPLC analysis of the oligosaccharides synthesized by the dual enzymatic treatment which involved debranching and liquefaction of cassava,

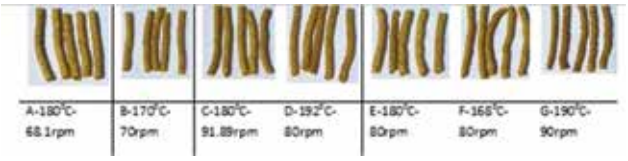


Fig. 44 Sweet potato and turmeric powder blended extrudates

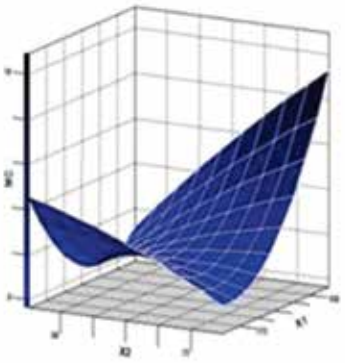


Fig. 45 Effect of extruder screw speed and die temperature on moisture content of the extrudates

maize and potato starches showed that maltotriose, maltopentaose, maltohexaose and maltoheptaose were formed in major quantities, along with traces of maltose and glucose for cassava starch, whereas, maltopentaose, maltotriose, maltose, and traces of glucose were formed in the case of maize and potato starches.

Structural characterization of enzymatically debranched cassava and potato starches

The enzymatically debranched cassava and potato starches were characterised by studying the surface morphology and crystallinity. Pullulanase hydrolysis frees short linear α-(1, 4) polymers that favor crystallization, the longer amylose chains associate much faster and form networks that impede propagation of substantially ordered crystallites. Consequently an increase in crystallinity was observed after debranching in the case of both starches. Cassava starch exhibited A-type pattern, whereas potato starch exhibited B-pattern. After debranching cassava starch showed a transition to B-type pattern, indicating peaks at 2-theta of 24°, 22.5°, 17° and 5.5°. The structure changes to the type-B crystallites via type-C (peaks at 2-theta of 19.6° and 5.5°) and a mixture of the V- type (13°). Debranched potato starch also exhibited a similar pattern. Morphological analysis of the debranched starches by scanning electron microscopy showed the destruction of granular structure in debranched

starches. A continuous non-uniform and non-planar surface morphology was obtained for the debranched starches from cassava as well as potato.

Production of Naegeli dextrins and lintnerized starches of cassava, potato and maize starches

Acid hydrolysis of native starch granules has been used to study the crystalline structure of starch. Sulfuric acid and hydrochloric acid are used for the purpose, and the remaining starch residues after a prolonged hydrolysis at a moderate temperature are known as the Naegeli dextrin and Lintnerized starch, respectively. A comparative study of the structure and properties of the Naegeli dextrins of three starches with different origins, viz., cassava (a tropical tuber starch), potato (a temperate tuber starch) and maize (cereal starch) starches synthesized under similar conditions was performed. Naegeli dextrins with different levels of hydrolysis (ranging from 35 to 98%) were synthesized from the above starches. The percentage hydrolysis was larger for potato and smaller for maize at the same conditions of treatment. The Neageli dextrins of all the three starches showed complete erosion of the amylose fraction.

The morphological characterization done by scanning electron microscopy showed that the granule surface of the Naegeli dextrins was degraded by erosion, followed by degradation of amorphous areas (Fig. 46). On 10th day of hydrolysis, starch granules had faceted structures, characteristic of crystalline material and the partially eroded granules appeared as embedded in the matrix. After 55 days of hydrolysis, no intact starch granules could be found and all the fragments were conglutinated together due to acid erosion and the surface morphology appeared almost similar for the dextrins derived from cassava, potato and maize starches. The Naegeli dextrins of cassava and potato starches showed A-type crystalline pattern after 10 days of hydrolysis, whereas, potato starch showed a B-type pattern (Fig. 47). There was a significant increase in the % relative crystallinity of the dextrins in comparison to the corresponding native starches after 10 days of hydrolysis, indicative of the erosion of amorphous regions in the granules, whereas, there was a tremendous decrease in crystallinity after 55 days, for all the starches (Fig. 47).

There was a significant increase in the gelatinization temperature of the Naegeli dextrins in comparison to that of native starch in all cases. The melting temperatures of the Naegeli dextrins, determined by differential scanning calorimetry, were significantly lower in comparison to that of the corresponding native starch for cassava, whereas, in the case of potato, a slight increase was noticed. In the case of dextrins of maize starch, the melting temperature was lower up to 31 days of hydrolysis, after that an increase was noticed.

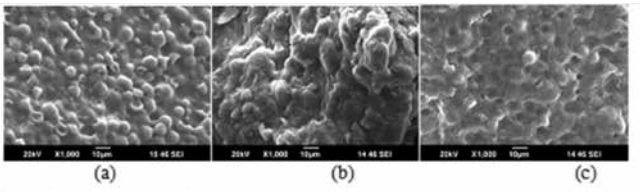


Fig. 46 Scanning electron micrographs of Naegli dextrins of cassava, potato and maize starches

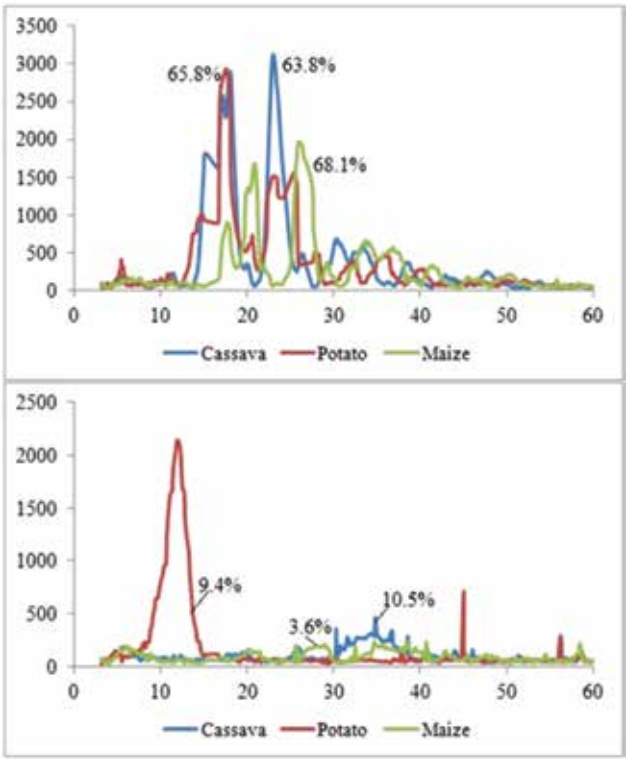


Fig. 47 X-ray diffraction patterns of Naegli dextrins of cassava, potato and maizestarches

Lintnerized starches were synthesized by the hydrochloric acid hydrolysis of cassava, potato and maize starches, for different time durations and the degree of hydrolysis was determined in each case. Complete degradation of the amylose fraction was noticed in all starches due to the lintnerization process. In the case of lintnerized starch also, scanning electron microscopy showed that granules were irregular on the surface in the initial period of hydrolysis, indicating that most of the starch granules were damaged by the acid treatment (Fig. 48). On sixth day of hydrolysis, granular appearance was visible in dextrins from all the three starches, but the granular surface appeared rough and degraded due to acid hydrolysis. After 30th day of hydrolysis, no intact starch granules could be found and all the fragments were conglutinated together due to acid erosion. Only the fractured surface could be found in the SEM photographs of the dextrins in the later stages. The surface morphology appeared almost similar for the dextrins derived from cassava and maize starches, compared to that from potato starch.

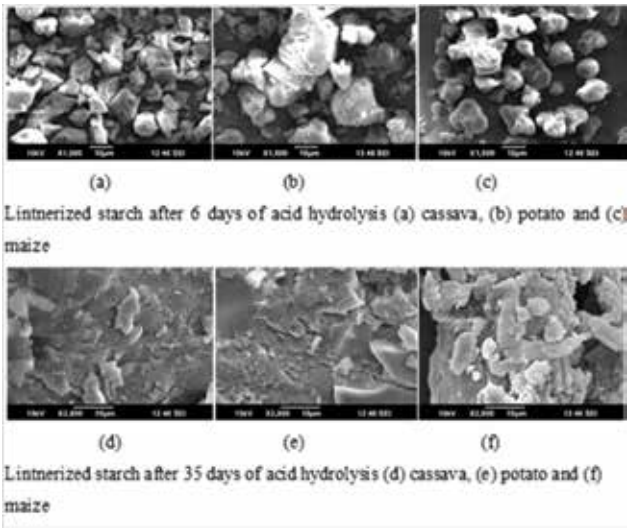


Fig. 48 Scanning electron micrographs of lintnerized starch of cassava, potato and maize

The XRD analysis indicated that there was an increase in relative crystallinity for the lintnerized starches of all the three starches in comparison to the corresponding native starches (35.0%, 52.4% and 39.2% respectively for native cassava, potato and maize starches) (Fig. 49). Lintnerized cassava starch showed higher melting temperature than lintnerized potato and maize starches. The melting temperature showed a decrease with increase in extent of

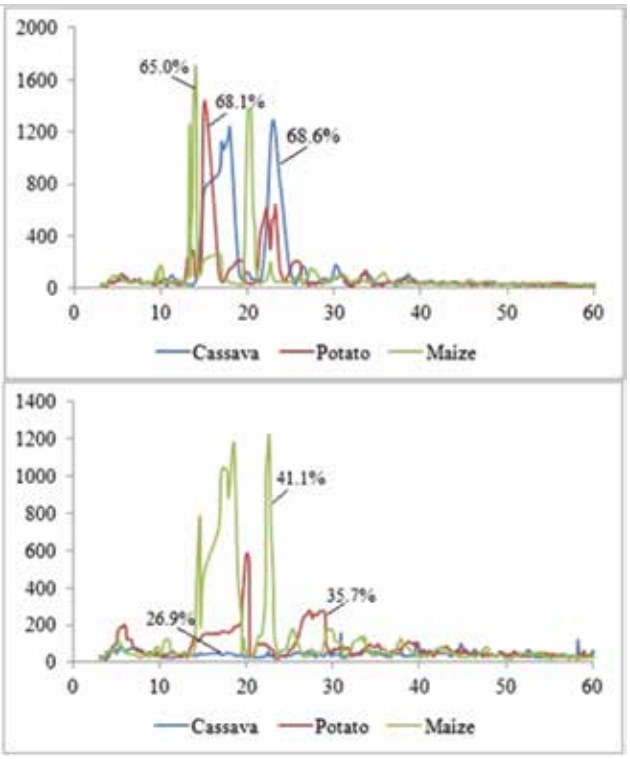


Fig. 49 X-ray diffraction patterns of lintnerized starch of cassava, potato and maize

hydrolysis. In the case of potato and maize starches, the melting temperature was slightly higher than that of the corresponding native starches.

INNOVATIVE APPROACHES FOR THE DEVELOPMENT OF TUBER CROP BASED INDUSTRIAL PRODUCTS

Bio-ethanol Production from Sweet potato

Alpha amylase enzyme from *Bacillus subtilis* strain CM 3 earlier isolated from cow dung microflora. The enzyme had the following characteristics: thermostability, 60- 70°C; optimum pH for growth and enzyme production, 5-9; molecular weight (in two forms), 18.9 and 43.0 kDA (Fig. 50). This strain was used for production of indigenous α- amylase for liquefaction of sweet potato flour. The enzyme was purified by 60% ammonium sulfate saturation at 4°C. The precipitated protein was collected by centrifugation at 8000 rpm at 4°C followed by dialysis. The dialyzed enzyme solution was used as a source of purified enzyme for liquefaction of sweet potato flour. The purified enzyme in amendment with the commercial saccharifying enzyme (Palkodex, 10 ml, v/v, M/S Maps Enzyme Ltd, India) was used for hydrolysis of sweet potato flour and subsequently to

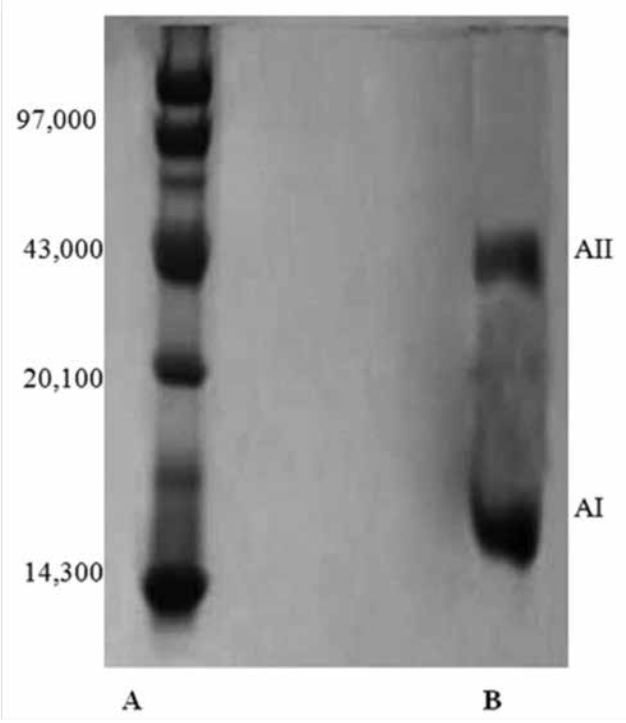


Fig. 50 Determination of molecular weight by SDS-PAGE. (A) molecular weight markers: (97,000-14,300 Da) (B) α-amylase(s) AI and AII from *B. subtilis* strain CM3

ethanol. At the end of fermentation period (120 h), the maximum yield of ethanol was 280ml, 320ml and 380ml/kg flour, when treated with 1%, 5% and 10% *B. subtils* enzyme, respectively. The efficiency of *B. subtilis* α- amylase was compared to that of Palkolase (HT) (liquefying enzyme). Almost same amount (370- 389 ml/kg flour) of ethanol could be obtained with only 1% palkolase HT. The commercial enzyme was found superior to *B. subtilis* enzyme because of higher thermostability (90°C) as compared to the latter (60^0C).

Development of biofilms from native and modified tuber starches

Biodegradable films made from modified starch-nanoclay composites

Modified starches, viz., hydroxypropylated and cross linked starches were prepared and films were developed with these starches (3,4 and 5%) blended with different nano clays viz., Nanocalibre 100 SD and Nanocalibre 100A (0.1, 0.3 and 0.5%) and glycerol (15, 20 and 25%).Physico-mechanical properties viz., thickness, moisture content, swelling power, solubility, total colour change, whiteness index, tensile force, elongation at break, hygroscopic properties of the films were studied.

Hydroxypropylated starch/nanocalibre 100SD/ 100A composites

For hydroxypropylated starch – nanocaliber 100SD biodegradable films, moisture content of the film was highest (18.75%) for 3% starch with 0.1% clay and 20% glycerol and least (11.87%) for 4 % starch with 0.5% clay and 20% glycerol. Thickness of the film was strongly influenced by the starch content and it was linearly increased with increase in starch content. The total colour change of the film was found to increase linearly with the starch content and clay had positive and glycerol had negative quadratic effect and whiteness index values were just reverse of the total colour changes. The swelling power decreased linearly with increase in starch content and had no significant effect with clay and glycerol content. Solubility of the films had positive quadratic effect with the increase in starch and glycerol whereas clay had negative quadratic effect. Maximum tensile force of 3.62 N was obtained for the film made with 5% starch-0.3% clay-25% glycerol composite where as minimum of 0.64 N for 3% starch-0.1% clay-20% glycerol (Fig. 51). Elongation at break was maximum (244%) for 3% starch-0.1% clay-20% glycerol where as minimum (38.44%) for 4% starch-0.3% clay-

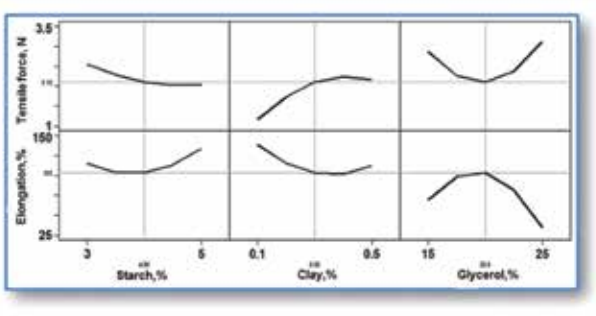


Fig. 51 Prediction profiler showing the effect of variables on mechanical properties of the films

20%glycerol composites. In hygroscopic studies, at 95% relative humidity, films made from 3% starch - 0.5% clay -20% glycerol composite absorbs minimum water (0.183g/g) were as for the 4% starch -0.1% clay-25% glycerol composite films maximum value of 0.285 g/g was observed.

For hydroxypropylated starch –nanocaliber 100 A biodegradable films, starch content have apparently high effect on the moisture content of the film when

compared to clay and glycerol. Thickness of the films was highest (0.155 mm) for film with 0.1% clay and 20% glycerol and lowest (0.095mm) with 0.3% clay and 20% glycerol. Whiteness index was highest (37.19) for 3% starch with 0.5% clay and 20% glycerol and least (32.79) for 3 % starch with 0.5% clay and 25 % glycerol. The highest total colour change was 66.65 for film with 3% starch 0.3% clay and 15% glycerol and least (62.24) for 3 % starch with 0.5% clay and 20% glycerol. Maximum tensile force of 4.14 N was obtained for the film made with 5% starch-0.3% clay-15% glycerol composite whereas minimum of 1.32 N for 3% starch-0.3% clay-15% and the elongation force of the film was found to be highest for 0.1% clay with 20% glycerol (189.08) and least for 0.3% clay with 25% glycerol (0.72) for films with 5 % starch concentration (37.12).The swelling volume was found to be decreased with increase in starch and clay content. Solubility of the films decreased linearly with the increase in starch content. The amount of starch and clay had no effect.

Cross linked starch-Nanocalibre 100 SD/100A composite films

Moisture content of the crosslinked starch-nanocalibre 100SD films increased slightly at the lower levels of starch and clay and then had a negative quadratic effect whereas glycerol had a just opposite effect. Starch and clay had a positive quadratic effect on thickness whereas glycerol had both positive and negative effect. Tensile force was influenced only by glycerol whereas elongation had negative quadratic effect with starch and glycerol whereas with clay it had both positive and negative effect depending upon the concentration. Solubility decreased quadratically with starch, clay and glycerol whereas swelling power linearly increased with glycerol. Total colour change increased with starch and decreased with glycerol whereas clay had both positive and neagative quadratic effect. Whiteness index increased linearly with clay and had both positive and negative effect with starch and glycerol. The range of values of various physic mechanical properties of the cross linked starch-nanocalibre 100SD film are as follows with the starch(S)-Clay (C) and Glycerol (G) combinations given in brackets. Thickness varied from 0.084 (4S-0.5C-15G) to 0.164 mm (5S-0.3C-15G); moisture content from 6.32 (5S-0.5C-20G) to 14.21% (4S-0.1C-25G) , total colour change from 63.86 (4S-0.1C-15G) to 65.90 (4S-0.3C-20G), whiteness index from 33.43 (4S-0.1C-25G) to 43.95 (4S-0.3C-20G), tensile force from 1.87 (4S-0.1C-25G to 6.06 N (4S-0.3C-20G), elongation at break from 20.24 (5S-0.3C-15G) to 47.56%(4S-0.1C-15G),swelling power from 3.04 (5S-0.3C-15G) to 7.22 g/g (4S-0.5C-25G) and ssolubility from 20.39 (3S-0.5C-20G) to 37.14%(3S-0.3C-15G)

Moisture content of the crosslinked starch-nanocalibre 100A films increased linearly with starch and glycerol and clay had no effect. Thickness had negative quadratic effect with clay, whereas starch and glycerol had negative and positive quadratic effect. Mechanical properties were decreased quadratically at the initial levels and then increased as the concentration of the ingredients increased. Swelling power increased quadratically with glycerol whereas having negative and positive effect with starch. Starch and clay had both positive and negative quadratic effect on solubility and swelling power. Total colour change increased linearly with starch whereas glycerol had negative effect on both the colour properties. With cross linked starch-Nanocalibre 100A composite films, the variation in physico-mechanical properties are as follows**.** Thickness from 0.077 (3S-0.1C-20G) to 0.154 mm (5S-0.3C-25G), moisture content from 8.05 (4S-0.3C-20G) to 16.89% (3S-0.3C-25G), total colour change from 59.66 (4S-0.3C-20G) to 62.90 (3S-0.5C-20G), whiteness index from 36.69 (3S-0.5C-20G) to 56.56 (4S-0.1C-15G), tensile force from 2.66 (4S-0.1C-25G) to 8.27 N (4S-0.5C-15G), elongation at Break 20.00 (3S-0.5C-20G) to 73.60%(5S-0.3C-15G),swelling power from 3.32 (4S-0.3C-20G) to 5.09 g/g (4S-0.5C-15G) and solubility from 11.82 (4S-0.3C-20G) to 37.69% (3S-0.5C-20G)

Starch -wax composite biodegradable films

Native starch-wax composite films were developed with starch (3, 4 and 5%) blended with paraffin and bees wax (5, 10 and 15%) and glycerol (15, 20 and 25%). Physico-mechanical and hygroscopic properties of films were analyzed (Fig. 52).

For starch-bees wax composite biodegradable films, starch content and wax had no significant effect on the moisture content whereas it increased with the glycerol content in the film. The addition of starch

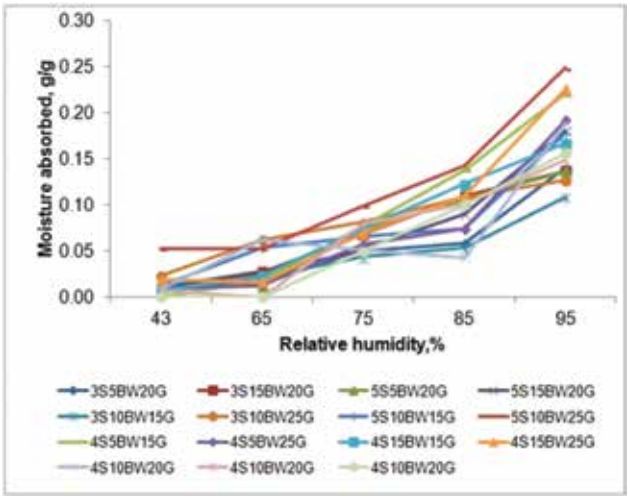


Fig. 52 Hygroscopic properties of cassava starch-beeswax composite films, S-starch, BW-beeswax, G-glycerol and the numerals in the composites represent the percentage of the respective materials

and wax had positive quadratic effect on the thickness of the films where as glycerol addition had negative quadratic, but not that significant. The total colour change and whiteness index of the film was not affected by the starch and glycerol content whereas waxes had a negative linear effect on total colour change and positive linear variation to whiteness index. Tensile force and elongation at break of the films decreased with the increase in the wax content whereas starch and glycerol had no significant effect. The swelling volume decreased with increase in starch content whereas glycerol had a negative quadratic effect and wax had no significant effect.

In the case of starch-paraffin wax biodegradable films, moisture content of the film was highest with 3% starch, 10% wax and 25% glycerol (13.89%) and lowest with 5% starch, 10% wax and 25% glycerol (10 %). Thickness of the film was strongly influenced by the starch and wax content and linearly increased whereas glycerol did not have any effect. The thickness of the film was highest for film with 3% starch, 15% paraffin wax and 20% glycerol (0.189 mm) and least with 5% starch, 5% wax and 20% glycerol (0.14 mm). The total colour change of the film was highest with 5% starch, 10% wax and 25% glycerol (65.41) and least with 10% wax and 15% glycerol (63.22). The whiteness index of the film was highest for film with 3% starch, 10% wax and 15% glycerol (36.17) and least with 5% starch, 10% wax and 25% glycerol (34.06). The tensile force of the film was highest with 5% starch, 10% wax and 15% glycerol (9.35 N) and least with 4% starch, 15% wax and 15% glycerol (1.6 N). The elongation of the film was highest with 5% starch, 10% wax and 15% glycerol (37.4) and least with 4% starch, 15% wax and 15% glycerol (6.4N). The solubility was found to be highest for film with 5% starch, 10% wax and 25% glycerol (45.27%) and least for the film with 5% starch, 5% wax and 20% glycerol (18.09%). The swelling power of the film was found to be highest for the film with 5% starch, 15% wax and 20% glycerol (6.08%) and least for the film with 5% starch, 10% wax and 25% glycerol (3.25%).

Starch-protein composite films

Films were developed with starch (3, 4 and 5%) blended with whey protein concentrate (5, 10 and 15%) and glycerol (15, 20 and 25%). Physico-mechanical and hygroscopic properties of films were analyzed The range of values of various physico-mechanical properties of the starch-whey protein film are as follows with the starch(S)-whey protein concentrate (WPC) and Glycerol (G) combinations given in brackets. Thickness varied from 0.099 (3S5WPC20G) to 0.1758 (5S10WPC15G); moisture content from 9.38 (5S10WPC15G) to 15.58 (5S15WPC20G), total colour change from 59.00 (5S10WPC25G) to 64.33 (5S10WPC15G), whiteness index from 35.8 (4S5WPC25G) to 55.61 (S10WPC15G), swelling power from 0.65 (4S10WPC20G) to 3.25 (4S5WPC25G).

Development, process optimization and characterization of superabsorbent polymers from cassava starch

The residual acrylamide content in the porous sample was determined by gas chromatography and it was found that no detectable monomer was present.

Mechanical and thermal analysis of superporous hydrogels

Compression analysis was performed to find out the mechanical properties of the porous superabsorbent hydrogels under the following conditions:pre test-10mm/s, post test-10mm/s, test-2mm/s and distance-50%, probe size -75mm. Among the 27 samples with different absorption capacities, the firmness of the hydrogels ranged from 1.9 to 10.5N

and the toughness from 3.2 to 17.0Ns. The melting temperature of the xerogels was determined by scanning electron microscopy. The samples exhibited melting temperature in the range 119.1-165.9°C and the enthalpy of melting was 134.0 - 452.7J/g.

Soil biodegradability studies

The biodegradability study was performed by burying the film samples made from the superabsorbent polymer in soil and taking the samples at different intervals to determine the weight loss by degradation. After two weeks of burial in soil the % degradability was about 30-40%. After 2 months about 50% of the sample degraded and after 5 months, the degradation was almost 60%. For the sample, which contains higher percentage of starch, about 78% of the polymer degraded after 5 months of disposal in soil.

Heavy metal ion absorption

The porous superabsorbent hydrogel was tested for its efficiency to remove heavy metal ions from aqueous solutions and the adsorption was maximum for Pb^{2+} ions (about 66%), whereas it was minimum for Zn^{2+} (2%).

Isolation of linamarase and linamarin from cassava and development of linamarin nanoparticle

Linamarase was isolated from cassava leaf, rind and latex and the enzyme activity was measured as β-glucosidase activity using p-nitrophenyl β-D-glucoside as substrate and linamarase activity using linamarin as substrate. Comparison of the activity and yield of linamarase from different tissues showed that latex was the best source of the enzyme. The heat stability of latex linamarase was determined and it was observed that 100% activity was retained up to 50°C with 60 min incubation. At 70°C enzyme activity decreased by 65% after 15 min and retained less than 10% initial activity after 60 min of incubation. Latex linamarase was immobilized on Whatman No. 3 filter paper and the activity of the enzyme was found to be stable for > 6 months at room temperature.

Isolation and purification of linamarin from cassava

Linamarin was isolated from cassava leaf and rind tissues by extraction with boiling methanol as well as using boiling water. There was no signioficant difference in the yield and purity of linamarin obtained in the two methods. The yield ranged from 100-150mg rind and 70-100 mg/100g leaf, indicating that the rind was a better tissue for linamarin extraction. The purified linamarin was characterized by FTIR and ^{1}HNMR analyses and determination of molecular weight.

Linamarin nanoparticles were prepared using PLGA, chitosan and starch nanoparticles. The morphological characteristics of different preparations were examined by SEM analysis. Only chitosan nanoparticles appeared to be satisfactory, however, the loading efficiency of linamarin in chitosan nanoparticles was very low.

PRE- AND POST HARVEST MACHINERY FOR COST EFFECTIVE CULTIVATION AND PROCESSING OF TUBER CROPS

Technology upgradation for starch processing machineries

Design and Industrial Evaluation of vibro sieving system

A vibro sieving system for sieving wet starch slurry was developed. The machine consisted of a frame work assembly, vibro motor, deck assembly of size 4'x2' and replaceable sieves. A pipe line and pumping arrangements (0.5hp pump) were provided to spray the water jet. The deck was made using stainless steel of 304 grade. The machine was installed at M/S T.A.Perumal Starch Industries, Salem for industrial evaluation (Fig. 53). A wooden frame was made and a stainless steel 350 mesh sieve was fitted. A concrete bed was constructed near the setting tank in the industry and the equipment was

Fig. 53 Industrial evaluation of vibro sieving system at M/S T.A. Perumal Starch Industries, Salem

mounted in the bed. Different sizes of brackets were made for inserting between deck and stand frame for altering deck slope. Modifications were carried out by changing the vibro motor position and changing deck slopes. The equipment was evaluated at three deck slopes and two sieve sizes (250 &400 mesh). The concentration of the feed and output were 8.2% and 9.3%, respectively. The whiteness of starch in feed and output were 93.0-97.05% respectively.

Ultra sound experiments with cassava tubers

Ultra sound experiments were conducted with peeled and sliced cassava tuber. Response surface of three variables through Box Behnken statistical method was analyzed. The process parameters selected were 3 energy levels (300W, 450 W, & 600W), 3 pulsation rates (50, 70 & 90%) and 3 levels of process time (10, 15 and 20 minutes). The starch recovery ranged from 15.04-26.34% and the maximum recovery was obtained when treated under 450W energy level and 50% pulsation rate for 10 minutes. The percentage of dry *thippi* obtained was between 2.49-9.67%. The viscosities of the samples (2% solution) were measured in Brookfield viscometer varied between 2.42-36.09 Cp. The whiteness of the recovered starch ranged from 88.50 to 96.22% and maximum whiteness was obtained at 600W energy level and 70% pulsation rate when treated for10 minutes. The total colour change of the starch ranged between 3.77-10.96%.

EXTENSION AND SOCIAL SCIENCES

TUBER CROPS TECHNOLOGY ASSESSMENT, TRANSFER AND MARKET STUDIES FOR SUSTAINABLE DEVELOPMENT

Dissemination and adoption status of tuber crops technologies: a cross sectional analysis

Data and information on the adoption of recommended technologies of taro from West Bengal and yams and elephant foot yam from Odisha were collected through PRA techniques and interviewing the farmers. Information on Taro in West Bengal was collected from three districts Nadia, North 24 Parnagas, Hoogly and for yams and elephant foot yam survey were conducted in Andhra Pradesh in two districts, viz., East Godavari and West Godavari.

Taro

Taro is cultivated in all the three districts in West Bengal (Fig. 54) as a commercial crop in an intensive way. Other major crops forming part of cropping system in the selected districts are rice, banana, vegetables, mustard, elephant foot yam, cauliflower, potato, elephant foot yam etc. Taro is cultivated under irrigated production system and planted in the months of December to February. The information gathered from the farmers clearly showed that local taro varieties were prominent and the popular variety was Beldenga. It was observed that in Nadia district few farmers were found cultivating BCKV varieties. Traders play a major role in deciding the variety as they supply the seed materials. All the farmers were found adopting the non monetary practices, viz., land preparation, selection of seed material, seed size, depth of planting , spacing, method and time of fertilizer application and inter culturing operations as per the recommendations. Regarding seed materials production only 50% of farmers practiced their own production. None of the farmers were found adopting any processing techniques. All the farmers market their produce.

Regarding monetary practices like manures and fertilizers, while a small proportion of farmers (12%) were adopting full dose of FYM with two thirds of farmers not applying organic manures, a large majority (75 to 85 %) of the farmers applying full dose of N, P and K .The main reason stated for limited application of FYM is that taro is normally cultivated after vegetables in which excess FYM is applied. It was found that farmers applied 125 N, 185 P and 184 K ha^{-1} which is much above recommended dose. Regarding plant protection it was found that all the farmers applied plant protection measures both pesticides and fungicides. It was observed that there is indiscriminate handling of plant protection methods.

Fig. 54 Taro in West Bengal

Yams

Yam farmers in Andhra Pradesh cultivate yams on commercial basis (Fig. 55). It is cultivated under irrigated or partial irrigated conditions in heavy soils. The other major crops grown in the surveyed districts arerice, banana, sugar cane, elephant foot yam, turmeric, tobacco, papaya etc. Yam is cultivated both as mono crop as well as inter crop and planted during july and harvested around march. Two varieties were found cultivated, viz., Orissa or Andhra local which is released as Orissa Elite and Bombay yam (violet in colour). Farmers believe that these varieties are suitable to this region and have market demand. Farmers adopted non monetary input practices like land preparation (ridges), selection of seed material,

Fig. 55 Yam field in Andhra Pradesh

seed size (100-150 gms) and depth of planting. However farmers (100 %) were found adopting less spacing (60 cms), main reason quoted are more population, less seed size. All the farmers were adopting correctly the method and time of fertilizer application and inter culture operations. Farmers were found practicing their own seed production. FYM was not applied by the farmers as recommended. On an average only 1.75 tonnes of FYM was applied. Full dose of nitrogen and phosphorus were applied by a large majority (80- 100%) of farmers. It was found out that 235 kg of N, 162 kg of P and 91 kg of K were applied by the farmers. However, with regard to potassium application only 50 % of the farmers were found adopting the correct level. Pest management was adopted by 66% of farmers; where as only 33 % of farmers were found adopting disease management practices. None of the farmers were found adopting any processing techniques and all the farmers were marketing their tubers to the traders.

Elephant foot yam (EFY)

EFY is cultivated as a commercial crop in East and West Godavari districts of Andhra Pradesh (Fig. 56). Gajendra, an improved variety is dominating the EFY cultivation which was adopted by all the farmers. Like yams non monetary practices viz., land preparation, selection of seed materials, seed size, and depth of planting, method and time of fertilizer application, intercultural operations were correctly adopted by all the farmers. Regarding spacing, all the farmers tend to give lesser spacing of 60 - 75 cm. The reasons stated were more population and to get optimum size of tubers. The recommended dose of FYM was adopted by 35 % of farmers . Nitrogen and Phosphorus were applied in full doses by large majority of farmers (87 to 90 %). It was observed that potassium application was done correctly by only 14 % of farmers. Average quantity of NPK applied was 252, 152 and 130 kg ha^{-1}. All the Farmers were found practicing the pest and disease management measures. However it was noticed that pesticides and fungicides were used indiscriminately. All the farmers were producing their own seed materials in their farms and stored properly. The entire produce was marketed through traders and none found practicing processing techniques.

Fig. 56 Elephant foot yam in Andhra

An analysis was done to assess the status of dissemination efforts made by the tuber crops research system using a dissemination index. It was found that players of tuber crops research system, viz., CTCRI and the All India Tuber Crops Coordinating Centres were involved well in disseminating and transferring tuber crops technologies.

Strategic popularization of cassava technologies in potential and emerging industrial belts

During the period under report, the activities undertaken in this project included estimation of total starch content of the cassava clones raised in Beed district, Maharashtra, planting, harvesting and evaluation of selected clones in Maharashtra and planting, harvesti ng and evaluation of the promising short duration triploid cassava clone 3-4 under large scale demonstration in East Godavari district, Andhra Pradesh.

The total starch content on dry weight basis of the five promising clones of cassava harvested from the second stage of the trial in Beed district, Maharashtra

when analyzed at the Institute indicated no significant difference in starch content amongst them. The highest content of around 75% was recorded in the triploid clone 5-3 and it was on par with another triploid 4-2 (71.60%) and the released variety SreeRekha (69.89%). The other two varieties, H-226 and SreePadmanabha recorded around 67% starch. The performance of the accessions in terms of root yield and starch content during the last two years did not indicate any clear cut preference for the clones by the farmers. In the light of this, it was proposed to continue the trial with all the five clones during the ensuing year.

The trial during this year turned out to be a failure, as major portion of the stems dried up and the establishment of the stems planted was also very poor; hence no data could be collected from the trial. In view of this fact, it is required to continue the evaluation of promising clones with mosaic resistant high starch lines in more locations in Maharashtra.

The large scale demonstration of the short duration triploid cassava accession 3-4 identified as the most preferred one by the farmers from the trials undertaken during the past three years, was taken up in about 50 cents area in two villages in Peddapuram region of East Godavari district, Andhra Pradesh (Fig. 57). The farmers on their own interest have also planted other two clones 2-18 and CTCRI 3 along with the local check, PDP 5. The harvesting of the demonstration plot was taken up during last week of February with the promising accession 3-4 giving the highest amount (27%) of extractable starch and about 16 t ha^{-1} tuber yield. Though the other triploid 2-18 recorded the highest tuber yield of 18 t ha^{-1} , the extractable starch content of this clone was only 12.50%. It was observed from the past three years trial that unlike 3-4, the extractable starch content of the clone 2-18 was not stable and vary very much from year to year. In contrast, the short duration triploid 3-4 emerged as the most suitable clone for the rainfed tract of Andhra Pradesh with about 18-20 t ha^{-1} tuber yield and 27% extractable starch content.

It is expected that this clone can gradually replace the existing popular variety H-165 in due course of time. This clone was also included under All India Coordinated trial to facilitate its formal release.

Sustainable rural livelihood and food security to rainfed farmers of Odisha

The NAIP districts Dhenkanal, Kalahandi and Kandhamal of Odisha comprised of plain, hilly and backward areas. Though agriculture is the main occupation for livelihoods to the large population of this region, the farming has faced serious setbacks due to erratic monsoon, poor irrigation, inadequate supply of inputs and lack of awareness about improved technologies. Tuber crops technologies were introduced in these districts under NAIP project to improve livelihood of the farmers. A total of 218 demonstrations were conducted during the year 2012-13. Elephant foot yam var. Gajendra (21 demo), yam var. Orissa elite (80 demo), yam bean (44 demo), high yielding sweet potato varieties (49 demo), Orange flesh sweet potato varieties (10 demo) and cassava high yielding varieties (14 demo) were introduced in these districts. Disease-free quality planting materials

Fig. 57 Triploid cassava 3-4 in East Godavari, Andhra Pradesh

of tuber crops were given under demonstrations of our proven technologies. Elephant foot yam 840 kg, greater yam 2000 kg, yam bean 8.8 kg, sweet potato 1,47,500 vine cuttings and cassava 700 setts were given to the farmers. The yield of the crops was harvested and the yield of all the demonstrations were recorded. Elephant foot yam (Var. Gajendra) recorded 354 kg tuber per 100 m^2. Greater yam (var. Orissa elite) registered 451 kg tuber per 200 m^2. The sweet potato tuber yield was in the range of 391-421 kg tubers per 400 m^2. Yam bean recorded tuber yield of 533 kg/300 m^2 and cassava recorded 88 kg/50 m^2.

Four farmers' trainings on Tuber crops production and value addition were conducted at Kabara, for Khajuripada cluster, Mahanaju (Fig. 58), for G.Udayagiri cluster, at Mahadia, for Odapada cluster, Khamara, for Dhenkanal Sadar cluster. One exposure visit for Dhenkanal district farmers to the Regional Centre of CTCRI, Bhubaneswar was organized.

Fig. 58 Demonstration on cassava chakkuli/dosa preparation in Mahanaju village, Kandhamal district.

Impact Assessment of Research Investment

Sweet potato production technologies and supply chain analysis of sweet potato and cassava in India

Adoption survey of sweet potato production technologies was conducted in Bolangir and Ganjam districts of Odisha and estimated the adoption indices. For Bolangir district, adoption indices was worked out to be 57.56 indicating high adoption of the technologies while in Ganjam district, it was estimated as 43.69 and the state average adoption index with regard to the selected sweet potato production technologies was estimated as 55.61. About 71% and 11% of sweet potato farmers only adopted improved varieties of sweet potato in Bolangir and Ganjam districts respectively.

Surveyed Power loom service centre, Somanur, South Indian Textile Research Association (SITRA), Coimbatore and corrugation adhesive industry in Chennai and collected data to assess the cassava starch demand. Tapioca starch demand in textile sector for 2011 was estimated at 85 lakh tonnes and the projected demand for 2016, 2021 and 2026 is estimated at 90 lakh tonnes, 1.01 lakh tonnes and 1.15 lakh tonnes respectively.

Tapioca starch demand in corrugation adhesive sector for 2011 was estimated at 1.15lakh tonnes while the projected demand for 2016, 2021 and 2026 at current growth rate of 10% in the industry is 1.85; 2.98 and 4.36 lakh tonnes respectively. At 7% growth of the industry, it is projected as 1.61, 2.26 and 2.96 lakh tonnes respectively. It is projected at 2.31, 4.65 and 8.14 lakh tonnes respectively at an assumed growth rate of 15% in the corrugation box industry.

Studies and documentation of techno-economic feasibility of value added products from tropical tuber crops in india

Sweet potato pasta and gluten free pasta from cassava was the two value added products identified to prepare Techno-Economic Feasibility Report (TEFR). Data on latest costs of new machineries, raw materials, details of their suppliers for sweet potato and cassava pasta industries were collected from different sources. Latest statistics on prices, area, production and productivity details are collected and included while assessing the plant economics. Plant economics was worked out based on the information collected. Total capital investment for each unit with a working capacity of 38.4 tonnes sweet potato pasta and gluten free pasta from cassava was estimated at Rs. 44 and 45 lakh respectively. The TEFR were prepared on pasta from sweet potato and gluten free pasta from cassava.

Development of an interactive information management for tuber crops user system

Tuber information Cafe (TIC) was modified by including more user friendly features. Its design was also changed and made more attractive. The contents

also were refined. On line facility for early warning about mealy bug was developed and launched (Fig 59). This was developed using PHP/MySQL. Users can add data of different parameters in a location related to mealy bug and get an early warning about this pest. Different parameters include the weather data, parasite and predators found in the locality, pesticide use etc. A simulation model about the dynamics of mealy bug was developed and this is running at the back end to give predictions.

Fig. 59 On line facility for early warning about mealy bug

Participatory Development of a web based user friendly cassava expert system

To collect data for developing the expert system, the project team visited the panchayats , viz.,Chenkal (Thiruvananthapuram), Elammad (Kollam), Kadapra (Pathanamtitta), Manakadu (Idukki) and Perinthalmanna (Malappuram) and interacted with the cassava farmers (Fig. 60) and collected data regarding the problems faced by them and discussed with them about the solutions.The team visited the following cassava based industries also, viz., Tierra Foods, KINFRA, Punaloor, Asna Foods, Puthenathani, Malappuram district, Priya Foods, Alipparamb, Malappuram district. During the visits, interacted with the industrialists and discussed with them about various issues faced by them like non availability of raw material in required quantity and shape, marketing of their products, high price of tuber etc. The industrialists evinced great interest on the proposed online market for cassava. They offered all cooperation to make this venture a great success.

Fig. 60 Data collection through PRA techniques

Development of a disease diagnostic system of cassava

In the first year a disease diagnostic system of cassava, an online expert pathologist was developed on the web. This helps the users to clear their doubts regarding various cassava diseases.

Investigations on consumers' food choice, consumption patterns and acceptance of tuber crops based foods

Tuber crops consumption patterns of *Konyak* tribes, Nagaland

Among tuber crops, taro is widely consumed in both fresh and processed form. *Konyak* tribals consume the tender leaves, shoots, petioles, mother corms and cormels of taro and prepare a variety of dishes from them. However, *Konyaks* prefer only few landraces are preferred for consumption (Table 2). *Nalon* and *Toasa* varieties are widely preferred as all the parts can be utilized for consumption.

Table 2. Taro landraces preferred for consumption

Part of taro used	Preferred landraces
Young Unfolded leaf	Balsan, Balkedoh, Nalon, Kungnyak, Lama, Thungkho, Tunghcho, Tungphum, Tungtho, Toasa
Young leaf	Nalon, Tungcho, Toasa
Matured fresh leaf	Nalon, Lama, Thungkho, Tungphum, Tungtho, Toasa
Matured dry leaf	Balsan, Balkedoh, Nalon, Toasa
Young petiole	Balsan, Balkedoh, Nalon, Pungmathung, Tungcho, Tungtho
Matured petiole	Nalon, Tungcho, Toasa
Mother corm	All landraces
Cormels	All landraces

Processed taro leaf products like *Teangyakwan (Anishi), teangwan and teangkhoi* are prepared during harvest season and consumed throughout the year. Dried taro products are stored in bamboo baskets or cloth bags that are tied in a wooden structure placed above the earthen stove in the kitchen. The heat and smoke emerged during cooking prevent the spoilage of these products.

Traditional tuber crops recipes of Nagaland

About 20 tuber crops dishes from Nagaland (*Konyak* tribe – 17 and *Aao* tribe – 3) were documented. Semi-processed taro products like *Teangyakwan*(processed taro leaf), *Teangwan* (dried taro tubers), *Fluo* (dried taro leaves), *Shouhwan* (processed taro petioles) and *Tunggan* (Dried taro tubers) were documented. Several home-based recipes like *Teangyakhoi, Teanghoi, Teang, Fluo Curry*, *Tung Rahak Sui, Tungkungsui, Tungrhak* (Fig. 61), *Tunkhon,* and *Tung Pai* were also documented.

Teangyakwan | Shouhwan

Tungrhak | Fluo Curry

Fig. 61 Traditional tuber crops recipes of Nagaland

Tuber crops based food products under the study on optimum market positioning

Market analysis of tuber crops based pasta products

Pasta is still considered a luxury to most Indian households, but it is growing strongly in urban areas. Pasta types like penne, macaroni, fusilli and stuffed pasta like ravioli are commonly used. Pasta market is growing at 18% annually mostly due to rising disposable income, less time for cooking at home and exposure to western culture. In India, pasta sales are almost entirely made up of dried pasta and instant pasta is catching up. The size of pasta market in India is estimated around Rs. 216 million in 2012. Among health and wellness pasta, only whole wheat pasta is gaining market success.

Pasta in India was dominated by domestic manufacturers like Bambino Agro Industries Ltd, United Agro Industries, Savorit Ltd and Licia Macaroni Pvt Ltd. The only notable international brand was Nestle India's Buitoni. Other international brands like Barilla and Agnesi were mainly present in supermarkets and some still suffered from erratic supply and availability.

GENERATION AND APPLICATION OF COMPUTING TECHNOLOGIES FOR TUBER CROPS RESEARCH AND DEVELOPMENT

Development and validation of the EFY growth simulation model

A field trial to collect data regarding the physiology of elephant foot yam is being conducted and the observations are recorded at regular intervals. A growth simulation model of elephant foot yam was developed using this data. Growth of the crop was computed in terms of growing degree days with optimum temperature of 25^0C and base temperature of 15^0C.

Crop development was computed in iterms of Growing Degree Days(GDD) as:

$$GDD_i = \sum_{i=0}^{i} \left(T_{mean} - T_{base}\right)$$

where,

Tmean = Mean temperature in i days after planting

T_{opt}= Optimum temperature for growth= 25^0C

T_{base}= Base temperature= 15^0C

Growth was divided into different stages A,B,C,D,E and F and the dry matter in the mother corm at the end of each stage (DMM_i) is given by the equation:

$$DMM_i = DMM_{i-1}\prod_{k=1}^{n}\left(1-\frac{\left(\frac{dDMM_{k-1}}{dGDD_{k-1}}\right)}{100}\right)$$

where, i = growth stage,

The dry matter content in the mother corm becomes zero by the end of third month at the following rate:

$$\frac{dMM_{90}}{dGDD} = 0.525855$$

Dry matter in the shoot was accumulated at the following rate:

$$\frac{dHT}{dGDD} = 0.110709$$

Potential yield of cassava in all the 15 agro climatic zones of India was computed using the cassava simulation model SIMCAS. For this purpose weather of important locations within each agro climatic zone was simulated using the software NewLocClim and the model was run using this weather data. Overall average potential yield of cassava in India is computed to be 66.35 t.ha^{-1}. Eight zones (4,7,9,13,3,11,10 and 12) have average potential yield more than the national average of 66.35 t.ha^{-1}. Highest potential yield is in zone 12 (West Coast Plains and Hilly Regions consisting of Tamil Nadu, Kerala, Goa, Karnataka and Maharastra) with 106.91 t ha^{-1}. Lowest was found in zone 1 (Western Himalayan Region consisting of J&K, HP, UP and Uttaranchal) with 15.79 t ha^{-1}.

Development and application of statistical machine learning techniques for genomics and microarray data analysis in Tuber Crops

Distribution studies of SSR in EST data of cassava, sweet potato and yams

An EST analysis pipeline developed for the analysis of EST from tuber crops. EST sequence of sweet potato (10216), cassava (80631) and yam (44134) were downloaded from dbEST of NCBI. The schematic workflow is given in Fig. 62. Errors were removed using the tool "seqclean". The tools MISA and TRA helped in rapid discovery of Simple Sequence Repeats (SSRs) from bulk sequence data. 5489, 3373 and 2267 SSR containing sequences were identified for

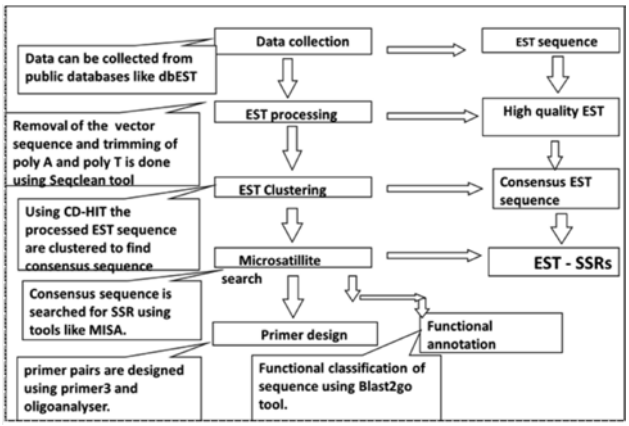


Fig. 62 Schematic representation of the EST analysis workflow

cassava, yams and sweet potato respectively. There were 789, 495 and 544 EST sequences containing more than one SSR in cassava, yams and sweet potato respectively. The *in silico* enrichment of discovered SSRs, for those likely to be polymorphic, would save considerable expense in laboratory assessment. An R function developed for SSR prediction, which identifies the location of the SSR in the sequence and the number of repeats.

Developing tools for miRNA analysis

MicroRNAs are RNAs of~24-nucleotide in length which serve as templates to drive post-transcriptional gene silencing. The mRNAs are involved in important cell functions like protein synthesis. So the identification of miRNA targets and the study of the relationship between miRNAs and their target mRNAs is now an attractive area in bioinformatics. An miRNA target prediction tool for the given mRNA sequence and miRNAsequence has been developed in R package incorporating sequence similarity score and energy prediction. The workplan represents the necessary steps involved in the development of algorithm to predict plant miRNAs targets (Fig. 63).

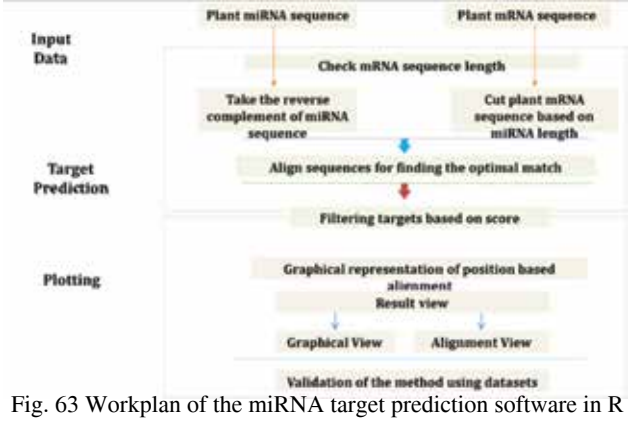


Fig. 63 Workplan of the miRNA target prediction software in R

The objective was to develop a miRNA target prediction program given the miRNA and mRNA sequences of the plant. It is established from the experimentally validated plant miRNAs targets that miRNA and their target have high complementarity between them. Hence the approach mostly concentrated on the sequence similarity scores. The method produces is a scatter plot which identifies all potential plant miRNA targets using dynamic programming with more accuracy. The main advantage of this program is that it gives a clear picture of the locations in mRNA sequence having high probability of target for miRNA, also it does not miss any short target of a plant mRNA having high probability of similarity. The algorithm is found equally effective in predicting plant miRNA targets in mRNA sequences compared with other existing tools like TAPIR, psRNAT has been verified with sequences from starBase database.

CTCRI-NEH PROGRAMME

Enhancing food security and sustainable livelihoods in the North-Eastern India through tuber crops technologies

Agro-eco system analysis and livelihood survey

A baseline survey was conducted in Manipur, Meghalaya, Nagaland and Tripura to identify the present livelihood status of the tuber crops farmers in the project villages. Besides the livelihood status, the major tuber crops production systems, the farmers' food insecurity status, proneness to shocks and disasters and their coping strategies were also studied. The project partners were equipped in the knowledge and skills necessary for conducting the livelihood survey in the training workshop on "Sustainable Livelihood Assessment and Value Chain Analysis" conducted at ICARRCNEH Nagaland Centre, Jharnapani, Nagalandduring 24-26, September 2012.

Front-line demonstrations of improved tuber crops technologies

Improved tuber crops production and protection technologies suitable for NEH region were identified and are being demonstrated through Front-Line Demonstrations (FLD) in the project villages. Quality planting materials were already distributed to the project areas to conduct FLDs. The details of front-line demonstrations conducted and planting materials distributed in project areas are given in Table 3.

Table 3. Details of Front-Line Demonstrations and planting materials distributed in project villages

State and Crop	No. ofFront-Line Demonstrations	Technologies demonstrated	Quantity of plantingmaterials distributed
Meghalaya			
Cassava	5	High yielding and high starch varieties	1500 stems
Greater yam	10	High yielding variety with good culinary quality	3600 kg
Taro	30	High yielding and disease resistant variety	3150 kg
Manipur			
Cassava	15	High yielding and high starch varieties	4500 stems
Taro	30	High yielding and disease resistant variety	3150 Kg
Nagaland			
Cassava	15	High yielding and high starch varieties	4500 stems
Taro	30	High yielding and disease resistant variety	3150Kg
Tripura			
Cassava	5	High yielding and high starch varieties	1500 stems
Taro	10	High yielding and disease resistant variety and management of taro corm borer	1050 Kg
Elephant foot yam	8	High yielding and non-acrid variety	4800 Kg

Conducting technology support programmes to facilitate adoption of improved tuber crops technologies

Various technology support activities like organizing subject matter specialist and farmers training programmes, printing and distribution of extension publications and field visits are regularly conducted to facilitate the farmers to adopt improved technologies. During 2012-2013, one subject matter specialist training was conducted at the CTCRI, Thiruvananthapuram during 3-7, December 2012 to equip the project partners on improved tuber crops production and processing technologies. Four farmers' training programmes were also conducted in Kolasib, Mizoram (1-2, June 2012), Jharnapani, Nagaland (21-9-2012), Mokokchung (21-3-2013) and Lembucherra, Tripura (16-10-2012) (Fig. 64). About 300 farmers were trained on tuber crops production and utilization technologies during these programmes.

Fig. 64 Farmers' seminar in Tripura

Popularizing tuber crops based products and tuber crops based enterprise development

Value addition of tuber crops and enterprise development is an important component of CTCRI-NEH programme. Initially surveys were conducted in Manipur (Ukhrul and Chandel districts) and Nagaland (Mon and Mokokchung districts) to identify indigenous tuber crops utilization patterns. Over 30 traditional food products prepared from tuber crops and three pig feed formulations were documented. A "Mini- Incubation Centre" for preparation of tuber crops products will be developed in Tura, Meghalaya, Ukhrul, Manipur and Mokochung, Nagaland for preparation of cassava flour, chips and starch. The progress of the project is monitored through six monthly monitoring & evaluation workshops conducted in the project states. Two workshops, one each in Mokokchung, Nagaland (20-3-2013)(Fig. 69) and Imphal (24-25, April 2013) were conducted and the progress of the programme at partner level is reviewed.

CTCRI TSP PROGRAMME

Livelihood improvement of tribal farmers through tuber crops technologies in tribal areas

Root and tuber crops find special niche in tribal food habits. They play crucial role in food and nutritional security of the tribals. Under Tribal Sub Plan (TSP), systematic effort was undertaken to improve the productivity of root and tuber crops by careful application of improved technologies. Thus the focus more on outreach programmes complemented with need based research modules which would be done through support of seed materials development and distribution, knowledge dissemination, production processing linkage, capacity building and entrepreneurship building.

During the year 2012-13, 465 tribal farmers were identified as beneficiaries from Chhatisgarh (Narayanpur district), Jharkhand (Deogarh) and Odisha (Kandhamal and Koraput districts) state and laidout 665 demonstrations on tuber crops technologies. Quality planting materials of yam 7400 kg, taro 1550 kg, yam bean 100 kg, sweet potato vine 110000 cuttings and cassava 40000 sett were distributed to the farmers (Table 4). The area covered under yam 3.7 ha, taro 1.24 ha, yam bean 8 ha, sweet potato vine 2.2 ha and cassava 4 ha in all the three states together (Table 5). The intervention yam (Odisha Elite variety) recorded tuber yield of 458 kg/200 m^2 area with the net return of Rs 4380/- . Yam bean (RM-1 variety) gave tuber yield of 498 kg/400 m^2 area with the net return of Rs 3180/- (Table 6).

Capacity building of farmers

Capacity building training programmes were organized for the tribal farmers one each in Narayanpur, Deogarh, Kandhamal and Koraput districts on root and tuber crops production and value addition. Two exposure visits for the tribal farmers to the regional Centre of Central Tuber Crops Research Institute, Bhubaneswar were organized to train the

Table 4. Quantity of planting materials distributed under TSP demonstrations

State	Yam (kg)	Sweet potato (vine cuttings)	Yam bean (kg)	Cassava (sett)	Taro (kg)
Chakapada	2000	35000	25	5000	-
Koraput	-	45000	25	12500	50
Narayanpur	3400	5000	25	12500	1300
Deogarh	2000	25000	25	10000	200
Total	7400	110000	100	40000	1550

Table 5. Area (ha) covered by the tuber crops

State	Yam (ha)	Sweet potato (ha)	Yam bean (ha)	Cassava (ha)	Taro (ha)
Chakapada	1.0	0.7	2.0	0.50	-
Koraput	-	0.9	2.0	1.25	0.04
Narayanpur	1.7	0.1	2.0	1.25	1.04
Deogarh	1.0	0.5	2.0	1.00	0.16
Total	3.7	2.2	8.0	4.00	1.24

Table 6. Yield and returns from tuber crops interventions

Crop	Number of demonstrations	Average demonstration area (m^2)	Average tuber yield (kg)	Gross return (Rs)	Net return (Rs)	Benefit cost ratio
Yam (Odisha Elite)	148	200	458	6870	4380	2.76
Sweet potato cuttings (ST14 and Kishan)	55	400	496	2480	1400	2.30
Taro (Muktakeshi)	62	200	262	3930	2320	2.44
Yam bean (RM-1)	200	400	498	4980	3180	2.76
Cassava (Sree Jaya, SreeVijaya and VellayaniHrushwa	200	200	366	1830	1080	2.44

Farm gate sale price: Yam Rs 15/kg; sweet potato Rs 5/kg; taro Rs 15/kg; yam bean Rs 10/kg; cassava Rs 5/kg

tribal farmers in root and tuber crops production and processing (Fig. 65).

Hilly plateau regions of Chhattisgarh, Jharkhand and Odisha states of India, the cultivation of high yielding varieties of tuber crops like yam, yam bean, sweet potato, cassava and taro hold promising. Root and tuber crops has played significant role in the improvement of livelihoods of tribal farmers.

Table 4. Quantity of planting materials distributed under TSP demonstrations

Fig. 65 Women farmers with the harvested tubers of yam (Orissa Elite)

TECHNOLOGIES ASSESSED AND TRANSFERRED

Technology transferred

1. Cassava triploids 4-2 and 5-3 with high tuber yield of 39 and 37.6 t $ha^{-1}$and high extractable starch of 30.2 and 29.9% respectively compared to the ruling variety H-226 were spread in the industrial belt of Tamil Nadu.
2. Value added fried products and fried chips from cassava with following parties on a consultancy mode through ITMU
   a. Dr. Meena Rani Suresh on 27th March, 2013
      Karayam Puthusseril, Ayiroor South P.O
      Pathanamthitta-689611
   b. VFPCK on 27th March, 2013
      Mythri Bhavan
      Kakkanad, Kochi
   c. M/s Palazhi Foods on 31st January, 2013
      Dwaraka, Kunnida
      Koliyakode P. O, Thiruvananthapuram
   d. Mr. Zainudheen, on 5th June, 2012
      M/s Asna Food Products
      Malappuram- 676551
   e. Mr. Arun. R.S on 17th May, 2012
      Kazhakuttam
      Thiruvananthapuram

M/s Palazhi Foods

Technologies assessed and ready for transfer

Elite Cassava clones

- The short duration triploid 3-4 cassava accession was identified as the most suitable clone for the rainfed tract of Andhra Pradesh with about 18 - 20 t ha^{-1} tuber yield and 27% extractable starch content. The high yielding clone Ce-185 of cassava was recommended in AICRP(TC), AGM XIIth (2012) for state release in Kerala. Aniyoor and 7 III E3-5 were identified as K efficient cassava genotypes. The CMD resistant hybrids,CMR239 and CMR27 with the highest yield and highest starch content (28%) identified through advanced yield trial, are ready for release.

Elite sweet potato clones

- The sweet potato genotypes ST-10 with high extractable starch (20.8 - 21.2%), ST-14 with high carotene (13.2 - 14.4 mg per 100 g) and ST-13 with high anthocyanin (85 - 90 mg per 100 g) are registered at NBPGR. Anthocyanin rich ST-13 and carotene rich line CIPSWA-2 are recommended for release.

Elite Yam clones

- High yielding greater yam Da-25 was recommended for release. Promising greater yam accession (Da-331) with purple flesh and higher yield (28.0 t ha^{-1}); tall white yam hybrids (Dr-657) with higher yield (35.0 t ha^{-1}), good tuber shape and better cooking quality; dwarf white yam hybrids (Drd-1068, Drd-1157) with higher yield (25 t ha^{-1}) and good culinary identified through on-farm trial are ready for release.

Production technologies

- Green manuring *in situ* with cowpea, vermi compost @ 3.91 tha^{-1}, coir pith compost @4.6 t ha^{-1} as alternate source to FYM @12.5 t ha^{-1} for cassava.
- Technology for organic production of taro: Organically produced seed material, FYM @ 15 t ha^{-1}, green manure to generate 15-20 t ha^{-1}, neem cake @ 1 t ha^{-1}, ash @ 2 t ha^{-1} and biofertilizers (Mycorrhiza @ 5 kg ha^{-1}, *Azospirillum* and phosphobacteria @ 3 kg ha^{-1} each).

Soil health and Nutrient management

- For obtaining better nutrient use efficiency, eighty percent of nitrogen and potassium fertilizers may be applied through fertigation in the first 80 days after planting and only 20 % thereafter.
- Integrated application of organic manures, secondary and micro nutrients along with half of the recommended doses of NPK, to enhance the cormel yield as well as quality of taro. Soil amendment with lime @ 0.5 t ha^{-1} not only enhanced productivity and quality of the produce but also improved soil fertility. Site specific nutrient management (SSNM) recommendations and current and future suitability maps of elephant foot yam cultivation in India.
- Soil application of agricultural grade zeolites for improving water and nutrient use efficiency in sweet potato.

Bio -intensive pest management

- Management of sucking pests in vegetable crops and pseudo stem weevil by using CTCRI developed bio formulation.
- Application of *Trichoderma* by tuber treatment (@5 g per kg of tuber in cowdung slurry) and biofertilizers, viz., Nitrogn fixer, P solubiliser and K solubiliser by soil application(10^7@10 g per plant) for collar rot management and sustainable production of Amorphophallus.
- Soil and tuber treatment with *Trichoderma* @ 50 g of 10^7 cfu g^{-1} and 5 g in fresh cow dung slurry per kg of tuber respectively along with foliar spraying of Carbendazim @0.05% three times at 15 days interval after initiation of the symptom was most effective for management of greater yam anthracnose caused by *Colletotrichum gloeosporioides*.

Disease diagnosis

- Serological and nucleic acid based diagnostic techniques for cassava mosaic virus (CMD), sweet potato leaf curl virus (SPLCV), sweet potato feathery mottle virus (SPFMV) and dasheen mosaic virus (DsMV) in *Amorphophallus* and yam mild mosaic virus (YMMV) infecting *Dioscorea* sp and early and accurate detection of *P. colocasiae* through PCR using species specific primers.

Healthy and fortified foods

- Low gluten-free and glycaemic pasta from cassava, low glycaemic spaghetti from sweet potato, protein and fibre fortified pasta from *Amorphophallus* and yam.
- Stable natural colour cum health protectant from *D. alata* and Sweet potato.

Starch based polymer materials

- Process for the production of debranched starch with high resistant starch content.
- Technology for the production of porous superabsorbent polymer with fast-swelling properties for use in personal care products and biomedical applications as occlusion devices.
- Technology for the production of slowly absorbing and desorbing superabsorbent polymers for agricultural use for water conservation.

User interface/ TEFRs

- A web based disease diagnostic system of cassava
- TEFRs on sweet potato pasta and Gluten free pasta from cassava to the interested entrepreneurs.
- An miRNA target prediction tool for mRNA and miRNA sequences.

EDUCATION AND TRAINING

Education

CTCRI is recognized as the research centre by University of Kerala, Kannur University and Manonmaniam Sundaranar University for carrying out Ph.D programmes on tuber crops. During the year 2012-13, CTCRI was involved in offering Ph.D programmes, exposure training to the students and project work to M.Sc and M.Tech students as shown below. The scientists of CTCRI have handled courses at college of Agriculture, Vellayani for the students of M.Sc in Integrated Biotechnology

Particulars of the Programme	Nature and Number of Participants
M.Sc / M.Tech Project work for students	Seventeen M.Sc / M.Tech students from different state university departments and colleges had undergone two months project work at CTCRI
B.Sc / B.Tech Project work for students	Nineteen B.Sc. / B.Tech students undergone two months project work at CTCRI
Ph.D Programme under the guidance of CTCRI Scientists	Forty two students are doing full time Ph.D programmes in the topic related to tuber crops

Trainings organised by CTCRI

Sl. No.	Particulars of Training	Nature of participants	
		Clientele	Sponsored by
1	Three days training program at the Regional centre of CTCRI during 19-21, April, 2012 and 3-5, 7-9, May, 2012.	ITDA farmers	OTELP-CTCRI collaborative RKVY project
2	"Diversification and value addition to agri-business in real areas" and demonstration of post harvest machineries in the training programme on "Promotion of rural agro processing centre" on 15th June, 2012.	Agricultural officers, Veterinary officers, Dairy extension officers and Technical officers of Fisheries Department, Kerala	SAMETI, Kerala
3	Three months Professional Attachment Training programme , during 16 May to 15th August, 2012 in "Advance Statistical methods in Biometrical analysis".	S.N. Rahana, Scientist, Sugarcane Breeding Institute, Coimbatore	CTCRI
4	"Seminar-cum-Training on Improved Tuber Crops Technologies" on 21st September 2012 at ICARRCNEH Nagaland Centre, Jharnapani, Nagaland.	Farmers from Mon, Wokha and Dimapur districts of Nagaland	CTCRI along with ICAR Research Complex, Barapani, Meghalaya
5	"Training workshop on Sustainable Livelihood Assessment and Value Chain Analysis" during 24 - 26 September, 2012 at ICARRCNEH Nagaland Centre, Jharnapani, Nagaland.	Farmers from Nagaland, Meghalaya, Tripura and Manipur	CTCRI along with ICAR Research Complex, Barapani, Meghalaya

6	Training on Agro Processing and value addition organized at SAMETI on 4th October, 2012.	Farmers of Kerala	SFAC, Kerala
7	Model Training Course on Sustainable management strategies of tuber crops based cropping systems organized at CTCRI during 5 - 12 October, 2012.	Extension personal in the rank of Assistant Directors and above working in the Departments of Agriculture / Horticulture from the states of Kerala, Meghalaya, Manipur and Nagaland	The Directorate of Extension, Ministry of Agriculture, Govt. of India
8	Three days training programme under Institute Tribal Sub Plan (TSP) at the Regional Centre of CTCRI during 10 - 12 October, 2012 and 22 - 24 November, 2012.	Tribal farmers from Chhattisgarh and Jharkhand Tribal farmers from Khandamal and Koraput districts of Odisha	CTCRI Tribal Sub Plan programme
9	"Seminar-cum-Training Programme on Tuber Crops Technologies" was organized on 16th October, 2012 at ICAR Research Complex for NEH Region , Tripura Centre, Lembucherra, Tripura as an activity under the CTCRI-ICAR NEH programme.	Farmers from various districts of Tripura	CTCRI NEH Programme
10	"Improved tuber crops production technologies for NEH Region under CTCRI North East programme" at CTCRI during 3-7 December, 2012.	Project partners of CTCRI-NEH programme	CTCRI NEH Programme
11	Farmers training on Tuber crops production and value addition on 7-8, 21-22, December, 2012.	Farmers from four different clusters of Odisha	ICAR-NAIP
12	Trainers training programme on managing pseudostem weevil of banana at CTCRI on 8th January, 2013.	Partners of the project	RKVY
13	One day training program in value addition of tuber crops on 8th, 10th January, 2013 and 6th February, 2013	Tribal farmers of Odisha, Jharkhand	CTCRI Tribal sub plan program
14	Training on value chain analysis of roots and tuber crops at Salem, Tamil Nadu, 10-13 March, 2013.	Technical staff of the project	IFAD and CIP
15	Training cum Awareness Programme on "Protection of Plant Varieties and Farmers Right Act" organized at CTCRI, Trivandrum on 26th March, 2013.	Farmers from Trivandrum District of Kerala	PPV&FR Authority, Ministry of Agriculture, GOI
16	One day training on production and processing of tuber crops at CTCRI – 15 batches.	Farmers of Kerala	VFPCK, Kerala
17	Exposure visits of students of colleges and schools – 35 batches..	Students of Kerala, Tamil Nadu,Uttar Pradesh and Maharashtra	Respective schools and colleges
18	One day training programme on production and organic farming of tuber crops – 12 batches.	Farmers of Kerala and Tamil Nadu	ATMA Kerala and Tamil Nadu

19	Training programme on value addition of Tropical tuber crops - 8 batches.	Farm women of Kerala, Self Help Group workers,	ATMA , Kerala, Kudumbasree Mission, District Industries Centre, Thiruvananthapuram SFAC at Muhamma
20	One day exposure training on "Tuber Crops technologies" to farmers at CTCRI- 20 batches	Farmers of Kerala, Karnataka, Tamil Nadu, Maharashtra and Uttar Pradesh	ATMA programme of Department of Agriculture of Kerala and tamil nadu

Trainings attended by CTCRI Staff

Name	Particulars of the training
Mr. Harish, E. R	21 days training programme on Agro Ecosystem Analysis (AESA) & Ecological Engineering for Pest Management at NIPHM, Hyderabad during 1 – 21 November, 2012.
Krishna Radhika, N	Training on 'Cloning and other Molecular biology Techniques' for a period of one month from 18 June - 17 July, 2012 at Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram.
	Training on "Advances in gene identification and marker development" an ICAR sponsored short course for a period of 10 days from October 1st 2012 at National Research Centre for Banana, Trichy.
Dr. C.A. Jayaprakas	Training programme on 'Role of Next generation sequencing and Bioinformatics' during 15 - 25 October, 2012 at the Animal Biotechnology Division, Anand Agricultural University, Gujarat.
Dr.V.Ramesh	DST sponsored training at IIFM, Bhopal on "Role of scientists in Natural Resources and Environment Management" during 28th , January- 1st February, 2013.

- Over 100 classes were taken by the scientists of all divisions under various programs within and outside institute, benefiting department officials, subject matter specialists, students and farmers from different parts of the country. The topics taught were improved cultivation, agro techniques, post harvest and value additions in tuber crops, INM strategies for tuber crops, vermicompost production technologies, IDM strategies, etc.

AWARDS/RECOGNITION

- Regional Centre was awarded as second best centre in Horticulture at exhibition of Global Conference on Horticulture for food, nutrition and livelihood options held during 28 - 31 May, 2012 at OUAT, Bhubaneswar.
- Dr. C. A. Jayaprakas received "Swadeshi Innovation award 2012". The award was presented by Sri Sri Ravishankar.
- Dr. G. Byju, Principal Scientist, Division of Crop Production was awarded Dhiru Morarji Memorial Award for the best research paper published in Indian Journal of Fertilizers during 2011. The award was presented by Sri Srikanth Jena, Union Minister of State for Fertilizers during FAI Annual Seminar 2012 in Agra on 10 December 2012.
- Dr. Rajasekhara Rao Korada, Senior Scientist was selected to conduct research on "Insect-plant chemical interactions in sweet potato" with Prof. Micheal Stout and Dr. Jeff Davis, Dept. of Entomology, Louisiana State University, Baton Rogue, USA for a period of 12 weeks from 24th September to 14th December, 2012 under Norman Borlaug Science and Technology Fellowship Programme 2012 sponsored by United States Department of Agriculture-Foreign Agricultural Service (USDA-FAS).
- The Sardar Patel Outstanding Agricultural Institute Award for 2005 was won by this Institute. The Award money was received in 2006. The money was utilized to award the following best administrative, technical/skilled and support staff of CTCRI for 2007 to 2012. The award winners from 2007 to 2012. The award was presented by Dr.APJ Abdul Kalam on 28th January 2013 during golden jubilee celebrations curtain raiser.
- Dr. Mohan, C. was selected for Flemish Interuniversity Council VLIR-UOS Fellowship for attending 'International Advanced Course on Modern Breeding Techniques for Improvement of Sweet potato' at Ghent University, Ghent, Belgium from 20 – 31 August, 2012.
- Dr. G. Suja received the Netherlands Fellowship for attending the International course on "Agriculture in transition: Innovative approaches for sustainable farming" to be held at Wageningen UR Centre for Development Innovation, Netherlands during 13-24 May, 2013.
- Dr. V. S. Santhosh Mithra was invited by Michigan State University, USA to provide consultancy regarding the Sweet potato growth simulation model SPOTCOMS on its use for studying the impact of climate change on sweet potato in Eastern Africa particularly Uganda.
- Dr. P. S. Sivakumar was awarded Fulbright – Nehru Post-Doctoral Research Fellowship 2013-2014 for carrying out post doctoral research in the USA.
- Dr. S. K. Chakrabarti and Dr. T. Makeshkumar were nominated as President and councilor of south zone, Indian Phytopathological society for the year 2013

Institute award winners (2007-2012)

Year	Administrative	Technical	Skilled Supporting Staff
2007	Smt. K.V. P. Sarada	Sri. M. Manikantan Nair	Sri. K. Saratchandra Kumar
2008	Smt. R. Bhagavathy	Sri. V.R. Sasankan	Sri. A. Chandran
2009	Sri. T. Vijayakumara Kurup	Sri. N.C. Jena	Smt. P. Sarojini
2010	Sri. T. Jayakumar	Sri. A. Madhu	Sri. S. Radhakrishnan Nair
2011	Smt. C.K. Syamalakumari Amma	Sri. C.S. Salimon	Sri. K.C. Jena
2012	Sri. S. Sasikumar	Sri. B. Renjith Kishore	Sri. Samsuddin Khan

- Dr. C. S. Ravindran was designated as Nodal officer of the 17th All India Combined Examination for ICAR's JRF and admission to Masters Degree Programme held on 15th April 2012 at CTCRI, Thiruvananthapuram.
- Dr. K. Susan John was recognized as a Member in the following committees:

– Technical Expert committee for revision of soil testing manual for the Department of Agriculture, Government of Kerala, revised the manual and prepared one with 2 volumes comprising the analysis of soil, plant, water and organic manures.

– Technical Expert committee for suggesting measures to strengthen the existing soil testing services of Kerala.

– Technical Committee & Monitoring committee of the Kerala State Planning Board Coordinated Project on 'Soil based Plant Nutrient Management Plan for Agro Ecosystems of Kerala'.

- Shirly Raichal Anil was recognized as a member in the Technical Expert Committee for finalizing purchase of chemicals for BMFC, Kazhakuttom, Department of Agriculture, Government of Kerala.
- Dr. T. Makeshkumar is an outside expert in Institute Biosafety Committee of Indian Institute of Spices Research, Calicut.
- Dr. K. Laxminarayana was recognized as
- Member, Source verification of turmeric seed materials for focus area development program, Govt of Odisha
- Technical expert, Potato seed source verification, Govt of Odisha
- Dr. J. Sreekumar has been nominated for the Editorial Board of Journal of Tropical Agriculture by Kerala Agricultural University

Dr. Rajasekhara Rao Korada during Norman Borlaug Fellowship Programme

Dr. G. Byju, receiving Dhiru Morarji Memorial Award

H H Sri Sri Ravishankar presenting Swadeshi Innovation Award-2012 to Dr. C.A. Jayaprakas

LINKAGES AND COLLABORATIONS

The Institute has International collaborations with International Potato Centre (CIP), Lima, Peru; International Centre for Tropical Agriculture (CIAT), Cali , Columbia; CIRAD, France and EMBRAPA, Brazil. CTCRI is also a partner to the CIP-IFAD project on Root and tubers, for food security.

Extra mural funding is provided through 30 external aided projects including one International Network project on Taro funded by European Commission, ICAR Network projects, NAIP projects, Revolving Fund projects, NAIP project, Outreach projects etc. and DST, DBT, MOEF, DIT, CSIR, NABARD, Kerala State Planning Board, RKVY and KSCSTE.

CTCRI, besides having linkages with various International and National Institutions, has very long association with Sagoserve, Tamil Nadu and many of the starch and sago factories located in Tamil Nadu and Andhra Pradesh, M/s. Tierra Foods, Kerala, KVKs in major tuber crops growing states and leading NGO's like Mithraniketan, CARDS, CISSA, Sri Ramakrishna Mission etc. for effective transfer of Tuber crops technologies.

The North East Hill Region programme and Tribal Sub Plan sanctioned during 12th Plan have been implemented by roping in KVKs and NGOs of the implementing States as functional partners.

The Regional Centre established active linkage with OTELP, Bhubaneswar, Directorate of Horticulture, Bhubaneswar, PRAVA and other development agencies for conducting front line demonstration, capacity building and information exchange.

CIP - IFAD Workshop in China

ALL INDIA COORDINATED RESEARCH PROJECT ON TUBER CROPS

Head Quarters

Central Tuber Crops Research Institute
Thiruvananthapuram – 695017, Kerala

All India Coordinated Research Project on Tuber Crops (AICRPTC), functioning since 1968 is the largest national network of tropical tuber and root crops covering sixteen states and one Union territory (Andaman and Nicobar Islands). The AICRPTC centres are located in 13 State Agricultural Universities and 3 ICAR Institutions. The details of the centres and their mandate crop details are mentioned below.

Sl. No.	Name of the coordinating centres	Year of start	Mandate Crops
1	*Central Tuber Crops Research Institute, Thiruvananthapuram 695017, Kerala	1968	Cassava, Sweet potato and Aroids
2	Rajendra Agricultural University, Dholi, Muzaffarpur (Dt.) 843 121, Bihar.	1968	Sweet potato, *Colocasia,* Yams, Elephant foot yam and Yam bean
3	Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu.	1968	Cassava at Yethapur (Salem) Sweet potato, *Colocasia*, Elephant foot yam and Yams at Coimbatore
4	Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh	1969	Cassava at Peddapuram, Sweet potato and Yams at Rajendranagar; *Colocasia*, Elephant foot yam and Yams at Kovvur
5	Assam Agricultural University, Jorhat 785 013, Assam.	1971	Cassava, Sweet potato, *Colocasia,* Elephant foot yam and Yams
6	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri (Dt) 415 712, Maharashtra.	1975	Cassava, Sweet potato, *Colocasia,* Elephant foot yam and Yams
7	*ICAR Research Complex for NEH Region, Barapani 793 103, Meghalaya.	1975	Cassava, Sweet potato and Aroids
8	Bidhan Chandra Krishi Viswavidyalaya,Nadia, Kalyani 741 235, West Bengal.	1976	Cassava, Sweet potato, *Colocasia*, Yam bean, Elephant foot yam and Yams
9	*Regional Centre of CTCRI, Bhubaneswar-751 019, Odisha	1983	Cassava, Sweet potato, Aroids and Yams.
10	Birsa Agricultural University, Kanke, Ranchi 834 006, Jharkand	987	Sweet potato, *Colocasia*, Elephant foot yam and Yam bean
11	Indira Gandhi Agricultural University, Kumharwand, Jagdalpur (Baster) 494 005, Chhattisgarh.	1987	Cassava and Yams at Jadgalpur Sweet potato, Elephant foot yam and *Colocasia* at Raipur
12	Narendra Dev University of Agriculture and Technology, Faizabad 224 229, U.P.	1987	Sweet potato, *Colocasia* and Elephant foot yam
13	Navsari Agricultural University, Navsari 396 450, Gujarat	1994	Cassava, Sweet potato, *Colocasia* and Yams
14	*Central Agricultural Research Institute, Port Blair 744 101, Andaman & Nicobar Islands.	2000	Cassava, Sweet potato and Yams.
15	*Central Agricultural University, Iroisemba, Imphal 795 004, Manipur	2006	Sweet potato, aroids and yams
16	**Maharana Pratap University of Agriculture and Technology, Udaipur 313 001, Rajasthan	2006	Aroids, Yams and Sweet potato
17	**University of Horticultural Sciences, Bagalkot, Karnataka	2007	Sweet potato and Aroids

*Voluntary Centres ** Cooperating Centres

ACHIEVEMENTS OF AICRP ON TUBER CROPS

The mandate of AICRPTC is to generate region-specific value added varieties, agronomic interventions and production system technologies including disease and pest management of tropical tuber crops along with creating awareness among the farming community, policy makers and researchers.

Collection and conservation of genetic resources

One of the major objectives of AICRP on tuber crops is the collection, conservation and evaluation of the genetic stocks of tuber crops from the various agro climatic zones for manifold purposes ranging from food production to climate change resilience. Constant efforts are therefore, being made to collect the indigenous germplasm of different tuber crops from different agro-climatic zones through coordinating centres. A total of 4666 accessions of different root and tuber crops are being maintained at different field gene banks in various AICRP Tuber Crops centres. Major share in gene bank is held by sweet potato (1957) followed by taro (776) and cassava (660). The centres are maintaining a total of 972 accessions of *Colocasia* spp, 228 collections of elephant foot yam and 167 accessions of yam bean. Evaluation and characterization are ongoing programme and passport data of those accessions whose IC numbers have not yet been obtained has since been filed. Molecular characterization of genotypes of taro (20), EFY (18), sweet potato (45), swamp taro (15) and yam bean (11) have been done using RAPD, SSR markers at BCKV, Kalyani.

Testing of genetic resources at various agro climatic environments

Under Uniform Regional Trial (URT) on cassava at Navasari, the maximum yield (40.42 t ha^{-1}) was obtained in entry CM-9966 which was at par with entry CE-142 (38.50 t ha^{-1}).Under Multi Location Trial (MLT) on cassava (2012-13), the entry *CM*-9966 was recorded maximum tuber yield (35.76 t ha^{-1}) at Dapoli. Under MLT on cassava (2007) at Venkatramannagudem, out of four entries evaluated in 5 locations during 2012-13 Kharif, the entries viz., Ci-800 and Ci- 823 recorded maximum tuber yield (32.14 and 29.22 t ha^{-1}) with starch content of 25.16% and 23.34 % respectively as against check Sree Athulya. Minimum amount of HCN was recorded in Ci-823 (36.06 ppm) followed by Ci-800 (48.67 ppm).

Among seven white fleshed sweet potato entries under poly cross breeding, the maximum number of seeds were obtained in DOP-92-48 (204 seeds) followed by DOP-92-1 (96 seeds) and RS-92 (54 seeds) at Dholi. Under MLT on sweet potato, entry Co-3-4 recorded the highest yield (42.32 t ha^{-1}) which was at par with entry C-71 with 32.68 t ha^{-1} production under south Gujarat conditions. Among the five entries, only one entry S-1-60 recorded highest marketable tuber yield (20.3 t ha^{-1}), harvest index (78.82), lowest dry matter (28.83%) and minimum sweet potato weevil infestation (6.8%) over four locations of Bihar. In the case of MLT in orange fleshed Sweet potato varieties at Imphal, maximum yield was recorded from 1GSP-15 (18.03t ha^{-1}).

Under MLT, highest mean tuber yield of 55.37 t ha^{-1} was recorded with the most promising cultivar "Gajendra" which was statistically on par with only one entry BCA-1 (Bidhan Kusum) with mean average yield of 52.38 t ha^{-1} at BAU, Ranchi. The MLT trial on EFY among five locations in West Bengal, the cultivar, BCA-3 gave highest corm yield 47.81 t ha^{-1} and 48.82 t ha^{-1} in both the years 2011-2012 and 2012-13 respectively. The stem rot incidence in all the locations was also found low. This is a non-acrid cultivar. Under MLT, the check variety Gajendra produced highest tuber yield (53.65 t ha^{-1}) which was on par values with the entries IGAm- 8 (52.89 t ha^{-1}) and IGAm-1(52.32 t ha^{-1}) at Raipur.

Among the three taro entries evaluated under MLT, along with local and White Gauriya as standard check at three locations, it was found that IGCOL.E - 9 gave higher tuber yield (23.49 t ha^{-1}) over the standard check White Gauriya (19.61 t ha^{-1}) at Raipur. Analysis of three years pooled data of MLT on *Colocasia* at Rajendranagar revealed that in all the years and locations, RNCA-1 has got the maximum yield of 20.12 t ha^{-1} than other accessions. Among the five entries, only one entry *viz.,* AAU Col-46 recorded the highest mean tuber yield (21.2 t ha^{-1}) with lower *Phytophthora* leaf blight incidence (15.3%) as against 17.0, 18.6 and 16.4 t ha^{-1} against national checks i.e. Sree Rashmi, Sree Kiran and RA-1, respectively at Dholi. Among the entries tested, KKVXa-4 recorded the maximum yield of 12.68 t ha^{-1} followed by KKV

–Xa-1 (12.61 t ha^{-1}) and as KKV-Xa-3 (11.86 t ha^{-1}) under MLT on *Xanthosoma* at Rajendranagar.

Among the 10 entries of *Dioscorea alata* evaluated, the entry IGDa-3 recorded the highest tuber yield (28.34 t ha^{-1}) followed by IGDa-2 (26.41 t ha^{-1}) under URT at Jagdalpur. The incidence of anthracnose disease was highest (66%) in entry IGDa-1 during 7 months stage of the crop. Under URT in greater yam, maximum yield (18.56 t ha^{-1}) was recorded in the entry IGDa-2 which was at par with entry Da-25 (17.28 t ha^{-1}) at Navasari. Under MLT in lesser yam, highest and significantly superior mean tuber yield of 11.79 t ha^{-1} was recorded in the entry DE-17 at BAU, Ranchi.

Under yam bean improvement programme, seed setting was observed only in 37 crosses (out of 55) and varied from 1 to 27 in number. Maximum seeds (27 seeds) were obtained from DPH-58/DPH-70 followed by BCYB-1/DPH-9 (26 seeds). Among the yam bean lines, DPH-5 was found best suitable for the West Bengal condition and performed well in terms of tuber yield (17.11 t ha^{-1}) and harvest index (76.42%) followed by RM-1 and BCYB-1. DPH-5 may be promoted in this state for variety release. The new cultivar (Farmers' variety) of yam bean has been collected from Murshidabad district, West Bengal and named as BCYB-2. Under MLT, yam bean entry W.F x deshi recorded an average tuber yield of 21.03 t ha^{-1} over check RM -1 (17.58 t ha^{-1}) at Raipur.

A committee was constituted by Hon'ble DDG (Hort) during the XIIth Annual Group meeting of AICRPTC for recommendation on variety release. The committee met on 10th August, 2012 at CTCRI, Thiruvananthapuram and recommended 5 varieties (one in cassava, two in sweet potato, one in taro, one in greater yam and one in yam bean) for state as well as central release. The elite germplasm accession (Me 833) has been released as TNAU Tapioca Yethapur-1 during 2012 – 2013.

Agro techniques

Under the low input technology experiment in cassava at Venkatramannagudem, pooled data of three years revealed that, T_6 (Sunhemp @ 50 kg ha^{-1} + RDK + 50% RDNP + *Azospirillum* + PSB @ 5kg ha^{-1} each) recorded significantly higher number of tubers per plant (12.7), yield (33.6 t ha^{-1}) and starch content (26.2%). The results of integrated weed management in cassava revealed that significantly highest tuber yield was recorded with four hand weeding (at 1, 2, 3 and 4 MAP) at Bhubaneswar followed by black polythene mulch. At Venkatramannagudem, black polythene mulch applied plots registered significantly higher weed control efficiency (98.2%) and yield (36.20 t ha^{-1}) followed by application of Oxyflourfen @ 0.06 kg ai ha^{-1} (Pre Emergence) + 2 hand weedings at 2 and 3 MAP to manage the weeds effectively to exploit higher tuber yield (33.94 t ha^{-1}) in cassava.

Elephant Foot Yam + Turmeric (1:2) was the most suited option (71.36 t ha^{-1}) followed by Elephant Foot Yam + Ginger (1:2) [68.57 t ha^{-1}] for obtaining maximum yield equivalents at BAU, Ranchi. At Kovvur also this combination proved to be the best with highest elephant foot yam equivalent yield (67.36 t ha^{-1}) and Land Equivalent Ratio (1.68) followed by EFY + Turmeric (1:1) with elephant foot yam equivalent yield (59.68 t ha^{-1}) and Land Equivalent Ratio (1.45) based on three years pooled data. On the basis of yield equivalent ratio (YER), EFY + ginger at 1:2 ratio was found most economical (74.35 t ha^{-1}) followed by same treatment at 1:1 ratio (66.21 t ha^{-1}) over sole crop of EFY at Dholi. Under intercropping system in elephant foot yam in mango orchards, the highest corm yield of 38.66 t ha^{-1} was recorded in the treatment where full dose of NPK was applied. In *Colocasia* yield reduction was observed under intercropping systems at Rajendranagar.

Under phenology studies in cassava at VR Gudem, tuber initiation in Sree Vijaya was observed 61 days after 50% sprouting and in H-226 at 67 days after 50% sprouting. The growth of Sree Vijaya at initial periods was rapid as compared to H-226. Amongst two varieties of sweet potato, Sree Bhadra performed better than local check RS-92 in respect of all phenological parameters at Dholi. Early sprouting at 4 days after planting and tuber initiation at 43 DAP were observed in Sree Bhadra than RS-92 (5 DAP and 45 DAP respectively). At Bhubaneswar and at Ranchi, Sree Bhadra performed better. At Kalyani, sprouting started at 7 DAP in Sree Bhadra and BCSP-10 and tuber initiation started at 46 DAP. The variety Gajendra recorded more shoot, root dry matter and tuber yield than local under phenology studies. The variety Gajendra also had more starch, sugar and dry

matter than local. Under the phenology of greater yam experiment at Jagdalpur, the local genotype recorded better morphological and yield characters. The maximum average tuber weight (1.80 kg per plant) was recorded in entry IGDa-11(Local) as compared to Sree Keerthi (1.65 kg per plant).

Under site specific nutrient management of elephant foot yam at Kovvur, significantly highest yield of 13.2 t ha^{-1} was recorded with the application of recommended dose of NPK which was on par with application of fertilizers based on soil test data (12.04 t ha^{-1}). For developing suitable farming systems involving tuber crops, chick, goat and fish components were introduced in the tuber crops in tribal areas of Bhubaneswar. After 3 months, chicks attained 850 g weight whereas fish gained 250 g weight. Goats gained 2 kg weight after 2 months.

Pests and disease management

The evaluation of cassava lines for mosaic tolerance/ resistance experiment with 42 genotypes conducted at Jagdalpur indicated that the entry CE-142 was more susceptible as compared to other entries. Entries found tolerant against CMD were IGT-11, CM-69-1, H-740/95, H-152/93, CM-9966, IKTAP-04-02, IKTAP-04-13 and IKTAP-04-18 and rest of the 28 entries recorded resistant against CMD. Among different intercrops for management of weevil, sweet potato + coriander (1:1) recorded lowest tuber infestation (9.8%) and gave highest marketable tuber yield at Dholi (16.6 t ha^{-1}). Promising cultivars of taro viz. BCC-2, BCC-5, BCC-9 had very low intensity blight disease under high natural disease pressure in West Bengal situation compared to the susceptible check Telia.

On the basis of pooled mean of three years data amongst 140 yambean genotypes only four genotypes viz; DL-1, DPH-11, DPH-33, DPH-82 and DPH-70 exhibited relatively high level of field tolerance and identified as moderately resistant to the pest pod borer as compared to local check Desi (12.4%) and national check RM-1 (28.3%) which showed tolerant and moderately susceptible reaction against pod borer. Application of 5% aqueous solution of yam been seed extract could reduce the population of leaf eating caterpillar in swamp taro and significantly reduced the leaf damage and improved the stolon yield. The rotenone content of yam bean seed has been estimated by HPLC method at Kalyani and it is presumed that rotenone of yam bean seed had the toxic effect to the larvae. Yam bean seed extract at 5% and 2% (aqueous) concentrations proved most effective for controlling the aphid population at Dapoli also. Pooled mean of three years data at Dholi revealed that among various treatments yam bean seed extract (5%), tobacco decoction (3%) and neem oil (3%) proved more efficient in minimizing borer population (2.7 to 3.8/flower shoot) which were at par to foliar spray of dimethoate (0.05%) at 3rd day after spraying.

Planting material production

During the period under report altogether 10325 kg planting materials (450 kg sweet potato vine, 8600 kg EFY, 250 kg yam bean seed, 800 kg taro tubers and 225 kg lesser yam tubers) were made available to 40 farmers besides one each ICAR Institute, SAU and Agril. Department, Govt. of Bihar. During the period, Dholi centre generated Rs. 2,02,880 (Rupees two lakh two thousand eight hundred eighty only) revenue through sale of planting materials/seeds of different tuber crops. Large scale planting material production programme of promising *Colocasia* variety "Ahina Kachu" in collaboration with KVKs of AAU is in process in farmers' participatory mode. About 25 quintals of *Amorphophallus* variety 'Gajendra' was distributed among farmers from AAU, Jorhat. Similarly 3.62 quintal of 'Gajendra' and 8200 vine cuttings of sweet potato were distributed from Raipur centre. One Hi-Tech poly house of 200 sq m has been installed at Imphal for planting material multiplication.

Research extension interface

Steamed/ boiled tubers of *Dioscorea alata*, cassava, *Dioscorea bulbifera* and prepared Tikhur Barfi (Sweets of *Curcuma angustifolia* starch) and Kewkand Pickle (Pickle of *Costus speciosus* rhizomes) were demonstrated at Jagdalpur during different meetings and programmes under popularization of tuber crops in Urban and peri-urban and non-traditional areas. "Tikhur and Kewkand processing unit" has been established and inaugurated on 02/02/2013 at SG CARS, Jagdalpur under the project "Promotion of Tikhur and Kewkand products in Bastar region of

Chhattisgarh" running at SG CARS, Jagdalpur with AICRP on Tuber Crops. A day long Tuber Crops Farmers' Day was organized by Jorhat Centre on 27th February, 2013. A two days State level trainers training programme on "Tuber crops based farming system for sustainable production and income generation" was organized at Imphal.

Training programme at CTCRI

Three days training programme on Germplasm conservation, climate change resilience and e-networking was held at CTCRI, Thiruvananthapuram from 24-27th September, 2012 to give exposure to all the AICRP scientific staff to the new projects undertaken in the concerned areas.

E-networking of AICRP on tuber crops became functional and all the centres started using the network effectively.

Dr. Sashi Tharoor, Hon'ble Member of Parliament (presently Minister of State for HRD) releasing the manual on E-networking of AICRPTC during the inaugural programme of Training organized by AICRPTC

Cultivation of swamp taro in low land fallows and its suckers .A view from BCKV, Kalyani

RAU, Dholi receiving best AICRPTC Centre Award in the 12th Annual Group Meeting (2011-2012)

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8. Ravi, V. and Saravanan, R. 2012. Crop Physiology of Sweet Potato. In: Nedunchezhiyan M., Byju, G. (Eds.) Sweet Potato. *Fruit, Vegetable and Cereal Science and Biotechnology* 6 (Special Issue 1), pp. 17-29.
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11. CTCRI Annual report 2011- 2012
12. CTCRI - AICRPTC Annual report 2011-12
13. CTCRI News Vol. 29 (2) 2012
14. CTCRI News Vol. 29 (3) 2012
15. CTCRI News Vol. 29 (4) 2012

ONGOING PROJECTS

INSTITUTE PROJECTS

Sl. No	Project / Sub project title	PI	Co-PIs
Mega Project I: Collection conservation and evaluation of germplasm of tropical root and tuber crops			
1	Collection, conservation, cataloging and evaluation of cassava germplasm	Dr. M. N. Sheela	Dr. K. Susan John, Dr. G. Padmaja, Dr. M. S. Sajeev, Dr. Bala Nambisan, Dr. C. A. Jayaprakas, Dr. V. Ravi, Dr. T. Makeshkumar
2	Collection, conservation, cataloguing and evaluation of sweet potato germplasm	Ms. Shirly Raichal Anil	Dr. C. Mohan, Dr. Bala Nambisan, Dr. Lila Babu, Dr. C.A. Jayaprakas, Dr. V. Ravi, Dr. G. Byju, Dr. M. S. Sajeev, Dr. A. N. Jyothi
3	Collection, conservation, cataloguing and evaluation of germplasm of yams	Dr. M. N. Sheela	Dr. James George, Dr. J. T. Sheriff, Dr. M.L. Jeeva
4	Collection, conservation, cataloguing and evaluation of aroids germplasm	Dr. A. Asha Devi	Dr. R. S. Misra, Dr. C. S. Ravindran, Dr. C.A. Jayaprakas, Dr. Archana Mukherjee, Dr. S.S. Veena, Dr. T. Makeshkumar, Dr. G. Suja, Dr. M.S. Sajeev, Dr. K. Rajasekhara Rao
5	Genetic diversity analysis of taro (*Colocasia esculenta* L. (Schott)) germplasm using molecular markers	Dr. A. Asha Devi	Ms. N. Krishna Radhika, Dr. J. Sreekumar
6	Collection, conservation, cataloguing and evaluation of minor tuber crops	Dr. C. Mohan	Dr. A. N. Jyothi
7	*In vitro* conservation of tuber crops germplasm	Ms. Shirly Raichal Anil	Ms. N. Krishna Radhika, Dr. A. Asha Devi, Dr. C. Mohan, Dr. M.N. Sheela
8	Collection, evaluation, cataloguing and conservation of tuber crops	Dr. Archana Mukherjee	Dr. K. Pati, Dr. R.S. Misra, Dr. R.C. Ray, Dr. M. Nedunchezhiyan, Dr. K. Laxminarayana,
Mega Project II: Varietal improvement in tropical tuber crops			
1	Genetic Improvement of cassava for CMD resistance, earliness, high starch and keeping quality through Polyploidy breeding	Dr. M. N. Sheela	Dr. S. Ramanathan, Dr. C. Mohan, Dr. A. Asha Devi, Dr. T. Makeshkumar, Dr. A. N. Jyothi, Dr. G. Suja,
2	Marker aided selection for CMD resistance using association mapping	Dr. C. Mohan	Dr. J. Sreekumar, Dr. T. Makeshkumar,
3	Modifying genes in starch metabolism- A means to enhance starch content and develop waxy cassava.	Ms. N. Krishna Radhika	Dr. M. N .Sheela, Dr. Shirly Raichal Anil, Dr. A. Asha Devi, Dr. T. Makeshkumar

4	Breeding high starch, high carotene orange-fleshed sweet potato (OFSP) lines for consumption and industrial application	Dr. C. Mohan	Dr. M. Nedunchezhiyan, Dr. P. S. Sivakumar,
5	Potentials of aeroponics in tropical tuber crops	Dr. Archana Mukherjee	Dr. S.K. Chakrabarti, Dr. K. Pati, Dr. M. Nedunchezhiyan, Dr. J. T. Sheriff
Mega Project III: Production and integrated nutrient and water management in tuber crops and related physiological studies for tuber crops			
1	Weed management in cassava	Dr. C. S. Ravindran	Dr. V. Ravi, Dr. J. T. Sheriff
2	Precision approach in tuber crops cultivation	Dr. James George	Dr. G. Byju, Dr. S. Sunitha, Dr. M. S. Sajeev, Dr. J. Sreekumar
3	Management of fertigation in elephant foot yam	Dr. M. Nedunchezhiyan	Dr. G. Byju
4	Cropping systems involving short-duration cassava and legumes	Dr. G. Suja	Dr. K. Susan John
5	Studies on water requirement and scheduling of irrigation in elephant foot yam	Dr. S. Sunitha	Dr. James George, Dr. V. Ravi, Dr. G. Suja
6	Fertilizer best management practices by SSNM for sustainable tuber crops production and soil health	Dr. G. Byju	Dr. M. Nedunchezhiyan, Dr. C. S. Ravindran, Dr. James George
7	Long term effect of manures and fertilizers in an acid Ultisol growing cassava	Dr. Susan John	Dr. C. S. Ravindran, Dr. James George
8	Organic Farming of Yams and Aroids	Dr. G. Suja	Dr. A. N. Jyothi Dr. R. S. Misra
9	Nutrient Management in Tuber Crops based Cropping Systems	Dr. G. Laxminarayana	Dr. Archana Mukherjee, Dr. C. S. Ravindran, Dr. K. Susan John
10	Screening potassium efficient cassava genotypes for industrial and domestic uses	Dr. K. Susan John	Dr. M. N. Sheela, Dr. G .Suja
11	Integrated soil and water conservation strategies for hill cassava production systems	Dr. V. Ramesh	Dr. C. S. Ravindran, Dr. G. Byju, Dr. J. Sreekumar
12	Studies on Production Physiology of Elephant Foot yam	Dr. V. Ravi	Dr. James George, Dr. G. Suja, Dr. M. Nedunchezhiyan
13	Analysis of gene expression during tuber formation and development in sweet potato	Dr. V. Ravi	Dr. S. K. Chakrabarti, Dr. T. Makeshkumar
14	Studies on salt tolerance in sweet potato	Dr. G. Laxminarayana	Dr. D. P. Singh, Dr. D. Burman
15	Rapid multiplication of disease-free planting materials in tuber crops	Dr. James George	Dr. S. Sunitha, Dr. M. Nedunchezhiyan, Dr. T. Makesh Kumar, Dr. M. N. Sheela, Dr. Archana Mukherjee, Dr. A. Asha Devi

Mega Project IV: Integrated pest and disease management			
1	Eco friendly techniques for the management of insect pests of tuber crops	Dr. C. A. Jayaprakas	Dr. Rajasekhara rao Koroda
2	Physical and chemical interactions between plant-insect interface in tuber crop ecosystem	Dr. Rajasekhara Rao Korada	Dr. C. A. Jayaprakas, Dr. Archana Mukherjee, Dr. J. T. Sheriff
3	Application of microbes for disease management and sustainable production of tropical tuber crops	Dr. R.S. Misra	Dr. R. C. Ray Dr. M. Nedunchezhiyan Dr. K. Laxminarayana
4	Exploitation of Toxic Metabolites of *Colletotrichum gloeosporioides* and Bio-intensive Methods in the Management of Greater Yam Anthracnose	Dr. M. L. Jeeva	Dr. S. S. Veena
5	Exploitation of vermicompost for eco-friendly management of taro leaf blight and collar rot of elephant foot yam	Dr. S. S. Veena	Dr. M. L. Jeeva, Dr. James George
6	Studies on characterization, diagnosis and management of viruses of tuber crops	Dr.T. Makeshkumar	Dr. S. K. Chakrabarti, Dr. M. L. Jeeva Dr. J. Sreekumar, Dr. Shirly Rachal Anil
Mega Project V: Post harvest technology and industrial biotechnology of tuber crops			
1	Production of food extrudates from tuber crop flour / starch	Dr. J. T. Sheriff	Dr. G. Padmaja, Dr. M. S. Sajeev, Dr. A. N. Jyothi
2	Technology upgradation for starch processing machineries	Dr. J. T. Sheriff	Dr, M. S. Sajeev, Dr. A. N. Jyothi
3	Development of biofilms from native and modified tuber starches	Dr. M. S. Sajeev	Dr. J.T.Sheriff, Dr. A. N. Jyothi
4	Developing technology for nutritionally fortified pasta and designer food products from tuber crops	Dr. G. Padmaja	Dr. J. T. Sheriff, Dr, M. S. Sajeev
5	Bioactive principles from tuber crops	Dr. Lila Babu	Dr. M. N. Sheela, Ms. Krishna Radhika
6	Development of bioprocess for the production of functional oligosaccharides from tuber starches	Dr. A. N. Jyothi	Dr. G. Padmaja, Dr. M. S. Sajeev, K. N. Anith, Assoc. Prof., KAU,Vellayani R. Ezekiel, Principal Scientist& Head, CPRI, Shimla
7	Bio-ethanol production from sweet potato by SSF using thermotolerant yeast (*Saccharomyces cerevisiae)*	Dr. R. C. Ray	Nil
8	Refinement of technologies for fermented food products and transfer of technology	Dr. R. C. Ray	Dr. R.S. Misra, Dr. G. Padmaja, Dr. M. Anantharaman, Dr. P. S. Sivakumar, Dr. M. Nedunchezhiyan

Mega Project VI: Transfer of technology, market and social sciences related studies in tuber crops			
1	Dissemination and adoption status of tuber crops technologies: a cross sectional analysis	Dr. M. Anantharaman	Dr. S. Ramanathan, Dr. J. Sreekumar, Dr. Sethuraman Sivakumar, Dr. M. Nedunchezhian
2	Strategic popularization of cassava technologies in potential and emerging industrial belts	Dr. S. Ramanathan	Dr. M. Anantharaman, Dr. C. S. Ravindran, Dr. K. Laxminarayana, Dr. P. Sethuraman Sivakumar, Dr. J. T. Sheriff
3	Impact Assessment of Research Investment on sweet potato production technologies and supply chain analysis of sweet potato and cassava in India.	Dr. T. Srinivas	Dr. M. Nedunchezhiyan
4	Studies and Documentation of Techno-Economic Feasibility of Value Added Products from Tropical Tuber Crops	Dr. T. Srinivas	Dr. M. S. Sajeev, Dr. G. Padmaja
5	Development of an interactive information management for tuber crops user system	Dr. V. S. Santhosh Mithra	Dr. T. Srinivas, Dr. T. Makeshkumar, Dr. V. Ravi, Dr. G.Byju
6	Development and application of statistical machine learning techniques for computational genomics and microarray data analysis in tuber crops	Dr. J. Sreekumar	Dr. V. S. Santhosh Mithra, Dr. C. Mohan
7	Investigations on consumers' food choice, consumption patterns and acceptance of tuber crops based foods	Dr. P. Sethuraman Sivakumar	Dr. M. Anantharaman, Dr. G. Padmaja, Dr. R. C. Ray, Dr. J.T. Sheriff, Dr. S. Seeralan, Scientist, ICARRC NEH, Barapani
8	Development of optimum market positioning models for tuber crops based food products	Dr. Sethuraman Sivakumar	Dr. M. Anantharaman, Dr. G. Padmaja, Dr. J.T. Sheriff, Dr. R. C. Ray, Dr. N. Sivaramane, Senior Scientist, NAARM, Hyderabad

Other Research programmes

I. Under NEH programme

1	Title of sub project	Enhancing food security and sustainable livelihoods in the North-Eastern India through tuber crops technologies
2	Team leader	Dr.S.K.Chakrabarti
3	Nodal officer and Core team members	Dr. M. Anantharaman, Head-Social Sciences Dr. M. Ramanathan, Principal Scientist (Agricultural Extension) Dr. R.S. Misra, Head, Regional Centre Dr. G. Padmaja, Head, Crop Utilisation Dr. C.S. Ravindran, Head, Crop Production Dr. C.A. Jayaprakas, Head, Crop Protection Dr. J.T. Sheriff, Principal Scientist (Crop Utilisation) Dr.M.S. Sajeev, Principal Scientist (Crop Utilisation) Dr. K. Laxminarayana, Senior Scientist, Regional Centre Dr. P. Sethuraman Sivakumar, Scientist (Agricultural Extension)
4	External Team members	Dr. S. V. Ngachan, Director, ICARRCNEH, Barapani Dr. A.K. Jha, Senior Scientist, ICAR NEH
5	Partners	1.ICAR NEH Research Complex, Badapani 2.Rural Resource and Training Centre (NGO),Umran, Meghalaya 3. Ramakrishna Math and Ramakrishna Mission, Tripura West 4.Volunteers for Village Development, Ukhrul, Manipur 5. Ukrul District Community Resource management Society 6.SHIBAWELFARE, Dimapur, Nagaland 7. Department of agriculture, Nagaland
6	Operational states	1. Nagaland: 2. , Manipur :3, Meghalaya : 4. Tripura

II. Under TSP programme

1	Title of the sub-project	Livelihood improvement of tribal farmers through tuber crops technologies
2	Team Leader	Dr. S.K. Chakrabarti, Director, CTCRI
3	Nodal officer and team members	Dr. R.S. Misra, Head, RC of CTCRI Dr. James George, PC, AICRPTC Dr.C.S.Ravindran, Head, Crop Production Dr.G.Padmaja, Crop Utilisation Dr.C.A.Jayaprakas Dr. M. Nedunchezhiyan, Senior Scientist (Agronomy) Dr. R.C. Ray, Principal Scientist (Microbiology) Dr. A. Mukherjee, Principal Scientist (Cytogenetics) Dr. K. Laxminarayana, Senior Scientist (Soil Science) Dr. K. RajasekharaRao, Senior Scientist (Entomology) Dr.Kalidas Pati, Scientist (Horticulture-Vegetable Science) Dr. M. Anantharaman, Head, Social Sciences Dr. S. Ramanathan, Principal Scientist Dr. J.T. Sheriff, Principal Scientist Dr. T. Srinivas, Senior Scientist
4	Partners	Shri. Biswamohan Mohanty (ORRISSA) (Kandhamal) Shri. Prabhakar (PRAGATI) (Koraput) Shri. Sevanand (RKM, Ranchi, Jharkhand), Shri. Manish Maharaj (RKM, Narainpur, Chattisgarh)
5	Operational states	Odisha, Chhatisgarh and Jharkhand

Externally aided projects

1	Isolation of differentially expressing genes in CMD resistant parent (MNga-1) by Suppression Subtractive Hybridization (SSH) using cDNA library	Dr. C. Mohan	Shri. M. Unnikrishnan, Dr. T. Makeshkumar	Department of Biotechnology, Government of India
2	Developing DUS testing criteria and varietal gene bank establishment for the tropical tuber crops: cassava and sweet potato	Dr. M. N. Sheela,	Dr. Archana Mukherjee	PPV& FRA
3	Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro.	Dr. Archana Mukherjee	Dr. Kalidas Pati	PPV& FRA
4	Soil- based plant nutrient management plan for agro eco-systems of Kerala	Dr. K. Susan John	Dr. G. Suja, Shri. M. Manikantan Nair	DoA, Govt. of Kerala
5	Development of eco-friendly technologies for quality cassava production and to safeguard soil health and environment	Dr. G. Suja	Dr. K. Susan John, Dr. J. Sreekumar, Dr. VinayakaHegde	MoEF
6	Evaluating fly ash zeolites for soil water and nutrient use efficiency of sweet potato	Dr. V. Ramesh	Dr. James George, Dr. S. M. A. Shibli	DST-FAU
7	Assessment of soil carbon sequestration potential of hill cassava production system: Relationship among soil properties and glomalin	Dr. V. Ramesh	Nil	DST-SERC-FTS
8	Sustainable rural livelihood and food security to rainfed farmers of Odisha	Dr. M. Nedunchezhiyan	Dr. K. Laxminarayana, Dr. K. Rajashekara Rao, Dr. P. S. Sivakumar	NAIP
9	Promotion of Sweet potato to increase cropping intensity,livelihood enhancement and nutritional security in coastal saline soils of Erasama block, Jagatsinghpur district of Orissa	Dr. K. Laxminarayana	-	NHM,Directorate of Horticulture, Govt of Odisha
10	Establishment of Leaf/Tissue Analysis Laboratory	Dr. K. Laxminarayana	-	NHM, Directorate of Horticulture, Govt of Odisha
11	Novel Molecules produced by unique bacteria and their bioactivity	Dr. C.A. Jayaprakas	Nil	DST-DPRP
12	Identification and formulation of insecticidal active principles of cassava seeds	Dr. C.A. Jayaprakas	Nil	KSCSTE

13	Popularisation of cassava biopesticide against borer pests of banana in three districts of Kerala.	Dr. C.A. Jayaprakas	Dr. S. Ramanathan, Dr. Santhosh Mithra, Dr. G. Byju Shri. E.R. Harish	RKVY
14	AMAAS(Application of Microorganisms Agriculture and Allied Sectors) project on "Isolation and Development of Plant Growth Promoting Organisms from High Biodiversity Region for Tropical Tuber Crops"	Dr. M. L. Jeeva	Dr. K. Susan John Dr. R. S. Misra Dr. Veena, S. S.	ICAR network project
15	*Phytophthora, Fusarium* and *Ralstonia* Diseases of Horticultural and Field Crops	Dr. M.L. Jeeva	Dr. S. S. Veena, Dr.Vinayaka Hegde Dr. R.S.Misra,	ICAR Network Project
16	Development of mosaic resistant transgenic cassava	Dr. T. Makeshkumar	Dr. S.K. Chakrabarti Dr. M.N. Sheela	ICAR Network Project
17	Development of low glycaemic noodles from sweet potato and low calorie sago from cassava as anti diabetic foods	Dr. G. Padmaja	K. Jeevaratnam, Dr. J. T. Sheriff, Dr. M. S. Sajeev, Dr. A. N. Jyothi	ICMR, Govt. of India
18	Development of functional pasta and spaghetti from yams and aroids based composite flours	Dr. M. S. Sajeev	Dr. G. Padmaja, Dr. J. T. Sheriff	AICRP on PHT
19	Synthesis, process optimization and characterization of Superabsorbent polymers from cassava starch	Dr. A. N. Jyothi	Dr. M. S. Sajeev	DST, Govt. of India
20	Participatory Development of a web based user friendly cassava expert system	Dr. V. S. Santhosh Mithra	Dr. M. Anatharaman, Dr. S. Ramanathan,Dr. G. Byju	KSCSTE, Govt. of Kerala
21	Development of Statistical Machine learning Tools and Methods for analysis of Microarray Gene expression data	Dr. J. Sreekumar,	Dr. V. S. Santhosh Mithra , C. Mohan	DIT, Govt. of India
22	Investigations on the consumers need, knowledge, attitude and purchase behavior of functional foods from starchy staples	Dr. P. Sethuraman Sivakumar	Dr. M. Anantharaman	Indian Council of Social Science Research, New Delhi

CONSULTANCY AND PATENTS

Value added fried products and fried chips from Tapioca with following parties on a consultancy mode

a. Dr. Meena Rani Suresh on 27th March 2013
Karayam Puthusseril, Ayiroor South P.O
Pathanamthitta-689611

b. VFPCK on 27th March 2013
Mythri Bhavan
Kakkanad, Kochi

c. M/s Palazhi Foods on 31st January, 2013
Dwaraka, Kunnida
Koliyakode P. O, Tvm

d. Mr. Zainudheen, on 5th June, 2012
M/s Asna Food Products
Malappuram- 676551

e. Mr. Arun. R.S on 17th May, 2012
Kazhakuttam
Thiruvananthapuram

Assignment Deed made with National Research Development Corporation (NRDC), New Delhi-110048 for the commercialization of following technologies;

a. Mobile Starch Extraction Plant

b. Cassava Harvester-second order lever type

c. Hand Operated Cassava Chipping Machine

d. Pedal Operated Cassava Chipping Machine

e. Motorized Cassava Chipping Machine

f. Apparatus and process for extraction of bio-pesticide from Cassava bio-wastes

MOU was signed on 30th November, 2012 with Small Farmers AgriBusiness Consortium, SFAC (Society under the Department of Agriculture, Govt. of Kerala),Thampanoor, Tvm- 695001 for setting Techno Incubation Centre (TIC) for Agro-processing of tuber crops and make value added products from tuber crops.

Agreement for licensing of knowhow of cassava chipping machine and mobile starch extraction unit to

M/s. Matha Engineering Works,
Thumba, Thiruvananthapuram

Patent Services

The unit has taken inititative in filing 2 complete applications as follows:

1. A Process for making high protein carotene rich pasta from orange fleshed sweet potato
2. Apparatus and process for extraction of biopesticide from Cassava bio wastes

INSTITUTE RESEARCH COUNCIL (IRC) / RESEARCH ADVISORY COMMITTEE (RAC) / INSTITUTE MANAGEMENT COMMITTEE (IMC)

Institute Research Council (IRC) meeting

The 38th Institute Research Council (IRC) meeting of Central Tuber Crops Research Institute was held during 24-26 April 2012. Dr. S.K. Chakrabarti, Director, CTCRI chaired all the sessions. Dr. Umesh Srivastava, Assistant Director General (ADG) (Hort. II), ICAR, special invitee for the meeting, chaired three sessions along with the Director on 26th April 2012. The Director in his initial remarks appreciated the quality of research being done at the Institute and stressed on carrying out research with multidisciplinary problem solving approach. He emphasized on the need for the popularization of tuber crops technologies in new potential areas and also mentioned the need for good agricultural practices, setting up of quality seed production block and identification of ideotypes for yield and other important characters. A total of 55 ongoing Institute sub-projects and 12 new sub-project proposals under six mega projects of the Institute were discussed during seven technical sessions. Fourteen sub-projects were concluded and recommendations emerged from these projects were discussed. During the plenary session, ADG appreciated the manner in which IRC is conducted at the Institute and suggested to incorporate the recommendations of Research Advisory Committee (RAC) while proposing new projects and to reduce the number of projects.

Research Advisory Committee (RAC)

The second meeting of Research Advisory Committee –VI of CTCRI was held on 14th and 15th February, 2013 in the Golden Jubilee Hall of the Institute Headquarters. Since Dr. S. P. Ghosh, Chairman, RAC, was on international assignment in Bangladesh, the meeting was held under the acting chairmanship of Dr. S. Pandey as per the advice from the Chairman.

Members Present

Dr. S.K. Pandey	Member
Dr. Narayan Rishi	Member
Dr.Ramesh Chandra	Member
Dr. R.H. Singh	Member
Dr. S.K. Chakrabarti	Member (Ex-Officio)
Dr. Umesh Srivastava	Member (SMD rep)
Dr. M.N. Sheela	Member Secretary

Director gave a brief presentation of the Institute profile, covering the major activities of the Institute during the last 5 years. Dr. Sheela, M.N., Member Secretary, presented the action taken report. The Heads of Divisions presented the salient achievements of their respective Divisions during 2012-13 which were discussed thoroughly and the following recommendations have come out.

Crop Improvement

- Fifty percent of the germplasm may be brought under *in vitro* during a period of three years.
- DNA fingerprinting of released varieties.
- Targeted explorations may be carried out in unexplored risk prone areas like Andamans & Nicobar islands.
- Development of core collection of germplasm. Duplicates to be identified and may be removed from the germplasm. Molecular characterization of core collection may be outsourced.
- Development of short duration varieties to fit into different cropping systems.

Crop Production

- Experiments on slow release fertilizers and fortified fertilizers need to be taken to improve the fertilizer use efficiency.

- Work to improve water productivity and precision farming in different tuber crops may be initiated/ strengthened.
- B:C analysis of all the major technologies developed in the Division over the years may be compiled .
- Organic farming practices for the major tuber crops may be brought out as a technical bulletin.
- Experiment on effect of mulching on weed control should be taken up with different grades of plastic mulch and B:C ratio may be worked out.

Crop Protection

- The spot / farmer friendly diagnostic kits may be developed for identification of different races/ strains/biotypes for important pathogens in priority tuber crops.
- Virus cleaning through a combination of meristem culture, thermotherapy and chemotherapy of the varieties released by CTCRI may be undertaken. Virus cleaning may be taken up for selected ruling / commercial varieties in which crop loss is very significant due to viral diseases. The Institute should develop foolproof virus cleaning technique (as done in bud wood certification programme in citrus, including shoot tip grafting, biological indexing and PCR based techniques for virus detection etc) for most important known viruses.
- Studies on effect of biopesticides on natural enemies, parasitoids and fungi may be conducted.
- Package of protection techniques may be developed for the major pests and diseases.

Crop Utilization

- Studies on pre harvest practices on post harvest performances.
- For all the products developed, nutritive value may be highlighted on the packets.
- A recipe book with good photographs may be prepared for all the food products developed.

Social Sciences

- Impact analysis of varieties / 2-3 technologies developed by CTCRI need to be done on regular interval in order to assess adaptability of varieties and technologies.
- Studies to identify reasons for non adoption of technologies and reduction in area under tuber crops in certain pockets.

Regional Centre

- Research programmes being undertaken in the Regional Centre should be effectively linked with the research activities of respective Divisions.
- Strategy may be evolved to avoid duplication in research and to prioritize the research programmes at CTCRI, Regional Centre.

Institute Management Committee

Third Meeting of the IX Institute Management Committee was held on 15th March, 2013 . Dr. S.K. Chakrabarti, Director, CTCRI and Chairman of the Institute Management Committee chaired the meeting. The Members, Dr. C. Ashwath, Principal Scientist & Head, Division of Biotechnology, Indian Institute of Horticultural Research, Dr. M. Anantharaman, Principal Scientist & Head, Section of Social Science, CTCRI and Sri. Salim P Mathew, New Delhi, Sri. P.J. Davis, the Member Secretary and Administrative Officer, CTCRI were present. All the Head of Divisions, CTCRI and Finance & Accounts Officer attended the meeting. The committee has reviewed and approved the fresh proposal of purchase of equipments for 2012-2013 and works under plan and non-plan.

RAC Meeting

PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA ETC. IN INDIA

Dr. M. Anantharaman

- Annual Workshop Zone VIII, Zonal Project Directorate at TANUVAS, Chennai on 7th June, 2012
- Indian Agricultural Science Congress at Bhubaneswar, 7 - 9 February, 2013.
- CIP-IFAD Workshop on "Value chain analysis on Tuber crops in India" at Salem , 10 -13 March, 2013.

Dr. Archana Mukherjee

- PPV & FRA sponsored meeting at New Delhi in connection with plant variety protection and community based germplasm conservation, 21 - 22 May, 2012.
- 'Showcasing Tuber Crops Technologies' in Global Conference on Horticulture for Food, Nutrition and Livelihood Option, 28 - 31 May 2012 at Orissa University of Agriculture and Technology, Bhubaneswar, Odisha.
- Horticulture divisional meeting for monitoring foreign aided projects at Pusa, KAB-II on 7th June, 2012 and presented the progress of EU funded INEA project of CTCRI.
- Annual AICRP (TC) meeting at Udaipur, 18 - 20 June, 2012 and presented the compiled report on germplasm and varietal improvement in tuber crops.
- AICRP programme on 'Climate Change and Tuber Crops' at Thiruvananthapuram, 24 - 27 September, 2012.
- PPV & FRA Programme on IPR & Plant variety protection issues, policy advocacy etc. at New Delhi, 22 - 24 November, 2012.
- CIP & Odisha Govt. project launching workshop at XIMB on 18th January, 2013.
- Horticulture divisional meeting for monitoring foreign aided projects at Pusa, KAB-II on 7th February, 2013 and presented the progress of EU funded INEA project of CTCRI.
- XI Agricultural Science Congress at Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, 7 - 9 February, 2013.

Dr. G. Byju

- Third National Conference on Agroinformatics and Precision Agriculture 2012 at Hyderabad, India, organised by Indian Society of Agricultural Information Technology and Indian Institute of information Technology, Hyderabad, India, 1 - 3 August, 2012.
- Second National Symposium on 'Innovative Approaches and Modern Technologies for Crop Productivity, Food Safety and Environmental Sustainability', 19 - 20 November, 2012 at Thrissur, Kerala organised by Society for Applied Biotechnology

Mr. Harish E.R

- Celebrations meet on "Control of papaya mealy bug: A success story" at NBAII, Bangalore on 20th October, 2012.

Dr. James George

- National Seminar on "Innovative Technologies for conservation and sustainable utilization of Island biodiversity" , 21 - 22 December, 2012 at CARI, Port Blair.

Dr. C.A. Jayaprakas

- XII Annual Group Meeting of AICRP on tuber crops' organized at MPUAT, Udaipur, 17 - 22 June, 2012
- National Workshop on "Strategies and Action Plan for Plant Health Management in 12th Five Year Plan" at Thiruvananthapuram, 7 - 8

February, 2013

- National Science day at Mar Ivanios college on the topic Green pesticide for Green Technology

Dr. M.L. Jeeva

- National Symposium on "Heading Towards Molecular Horizons in Plant pathology: Host Resistance, Pathogen Dynamics, Diagnostics and Management" at Sugarcane Breeding Institute, Coimbatore,16 - 17 November, 2012
- Quinquennial Review Team's assessment meeting of ICAR Net Work Project on AMAAS at CIBA, Chennai on 15th December, 2012
- Meeting on the revision of Schedule V of Plant Quarantine Order (PQ order), 2003 at NCPIM, IARI, New Delhi on 10th December, 2012

Dr. A.N. Jyothi

- National Seminar on 'Frontiers in Chemistry (NSFC-2012)', 25 - 27 April, 2012 at Department of Chemistry, University of Kerala, Thiruvananthapuram.
- DST-Project advisory committee meeting at University of Pune on 8th November 2012.
- National Carbohydrate Conference (CARBO 27) held at CFTRI, Mysore during 13 -1 5 December, 2012.
- "Chemists' Conclave"- Brain Storming Session, organized by the Division of Agricultural Chemicals, IARI, New Delhi during 15 - 16 January, 2013.
- National Workshop on "Foresight and Future Pathways of Agricultural Research through Youth in India" at NASC Complex, New Delhi during 1 - 2 March, 2013 and acted as a resource person for the session on Value addition and Post Harvest Technology.

Dr. Kalidas Pati

- Global Conference on "Horticulture for Food, Nutrition and Livelihood Option" from 28 - 31 May, 2012 at Orissa University of Agriculture and Technology, Bhubaneswar, Odisha.
- CIP & Odisha govt. project launching workshop at XIMB on 18th January, 2013.
- Expert consultation Meeting of the Odisha Biodiversity Board on 5th Febuary, 2013 at Regional Plant Resourse Centre (RPRC), Bhubaneswar, Odisha.
- XI Agricultural Science Congress from 7 - 9 February 2013 at Orissa University of Agriculture and Technology, Bhubaneswar, Odisha.
- State Govt. Agricultural Exhibition (Krushi Mohosav) at Janata Maidan, Bhubaneswar during 19 - 22 March, 2013.

Dr. K. Laxminarayana

- XIX Zonal Workshop of KVKs held at Jagdalpur, Bastar, Chattisgarh and presented transferable technologies with respect to tropical root and tuber crops through KVKs in Odisha, Chattisgarh and Madhya Pradesh states, 4 -6 May, 2012.
- Global Conference on Horticulture for Food, Nutrition and Livelihood Options' at Orissa University of Agriculture & Technology, Bhubaneswar from 28 - 31 May, 2012.
- Technical Support Group Meet at Directorate of Horticulture, Govt of Odisha on 2nd June, 2012
- Rural Advisory Committee Meeting on 14th June at Doordarshan Kendra, Bhubaneswar and Industry Institute Interaction Meet on 19th June,2012
- Tender Finalization Meet of Vegetable Seeds at Odisha on 18th and 22nd August, 2012
- CTCRI-ICAR NEH Project Planning and Inception Workshop on 24-25 July, 2012 at ICARRCNEH, Barapani, Meghalaya and Technical support group meet under NHM at Bhubaneswar on 31st August, 2012
- Central Government Employee Welfare Committee Meet at Bhubaneswar on 9th October, 2012
- Attended the State level Workshop on "Productivity Improvement of Horticultural Crops " held at OUAT organized by Directorate of Horticulture and Odisha Horticulture Development Society, Bhubaneswar , 29 - 30 November, 2012.

- National Seminar on "Developments in Soil Science – 2012" held at Punjab Agricultural University, Ludhiana, Punjab , 3 - 6 December, 2012.
- XIth Agricultural Science Congress held at Orissa University of Agriculture & Technology, Bhubaneswar , 7 - 9 February, 2013.

Dr. Lila Babu

- HRMS school for three days conducted by Waters India private Ltd at Peenya Industrial Estate, Bangalore during May 2012 and gained basic expertise in operating the system.

Dr. T. Makeshkumar

- National Symposium on "Heading Towards Molecular Horizons in Plant pathology: Host Resistance, Pathogen Dynamics, Diagnostics and Management" at Sugarcane Breeding Institute, Coimbatore, 16 - 17 November, 2012.
- National symposium on Blending conventional and modern plant pathology for sustainable agriculture held at IIHR, Bengaluru, 4 - 6 December, 2012.
- 'Brainstorming session of Phytoplasma problems in palms' organized by CPCRI at Kayankulam on 8th December, 2012.
- Review meeting of ICAR network project on Transgenics in crops, at NRCPB (IARI), New Delhi, 15 - 16 January 2013.
- National conference on "Innovative approaches in Bioscience, Chemical and Physical science for sustainable growth" held at Maharaja co-education arts & science college, Tamil Nadu held during 31st January and 1st February, 2013.

Dr. C. Mohan

- "CTCRI-NEH Project Planning and Inception Workshop" at ICAR-RC NEH, Barapani, Meghalaya, 24 - 25 July, 2012.
- International workshop on "Molecular Markers and Genome Analysis in Plants" held at Department of Botany, University of Kerala, Thiruvananthapuram, 12 - 16 March, 2013.

Dr. M. Nedunchezhiyan

- Conference on "Livelihood and Environment Security through Resource Conservation in Eastern Region of India (LESRC)", OUAT, Bhubaneswar, Odisha , 5 - 7 April, 2012.
- Global conference on "Horticulture for Food, Nutrition and Livelihood Options", OUAT, Bhubaneswar, Odisha, 28 - 31 May, 2012.
- International Workshop on "Understanding water-energy-GHG nexus for future water and food security" at New Delhi, India, 27 - 28 September, 2012.
- Third International Agronomy Congress: Agriculture diversification, climate change management and livelihoods at New Delhi, India, 26 - 30 November, 2012.
- State level workshop on productivity improvement of Horticultural crops at Directorate of Horticulture, Bhubaneswar, Odisha on 29th November 2012.
- Launching workshop on tuber crops based farming systems under AICRPTC tribal sub plan on 1st February, 2013 at Kandhamal district of Odisha.
- Regional Workshop on Geo-information system (GIS) mapping for food security through Root and Tuber Crops (RTCs) at Nanning, China under IFAD-funded CIP- Food start Project , 26th February to 2nd March 2013.

Dr. G. Padmaja

- Meeting of the Honorable Minister, Govt. of Kerala organized to seek areas of co-operation between state Govt. and CTCRI on 27th June 2012 in the Legislative Complex, Thiruvananthapuram.
- Meeting organized by Additional Chief Secretary (Industries & Commerce), Govt of Kerala on 31st October 2012 at KSIDC, Thiruvananthapuram.

Dr.Rajasekhara Rao Korada

- Global Conference on " Horticulture for Food, Nutrition and Livelihood Options" organized by ASM Foundation and OUAT at

Bhubaneswar from 28 - 31 May, 2012

- Workshop on "Perspectives of Termite Management", organized by Society for Plant Protection and Environment at OUAT, Bhubaneswar on 10th July 2012.
- 4th International Conference on "Insect Science 2013" at Bangalore , 14 - 17 February, 2013.

Dr. S. Ramanathan

- XIIAnnual Group Meeting of AICRP on Tuber Crops at MPUAT, Udaipur during 18 - 20 June, 2012.
- Farmers' Meet for data collection in Alapuzha, Malappuram and Idukki districts and visit to cassava based industries under KSCSTE project Participatory Development of a web based user friendly cassava expert system during 16 - 21 July, 2012.
- Farmers' Meet and field visit under Tribal Sub Plan at Narainpur, Chattisgargh during 8 - 9 August, 2012
- Attended the Stakeholders Workshop on preparation of Training Manual for Kerala state at SAMETI, Thiruvananthapuram on 20th October, 2012
- XXXII Zonal Research and Extension Advisory Council & Kuttanad Package Review Workshop at RARS (KAU), Kumarakom on 6th November, 2012
- Inter Departmental Working Group (IDWG) Meeting of ATMA at SAMETI, Thiruvananthapuram on 17th November, 2012
- Multi stakeholder Interactive Meeting on "Land Use Planning" at Thiruvananthapuram , 17 - 18 January, 2013
- Inter Media Publicity Coordination Committee Meetings at Thiruvananthapuram on 06.07.2012, 10.08.1012, 10.09.2012, 04.10.2012, 02.11.2012, 07.12.2012, 06.02.2012 and 01.03.2012

Dr. V. Ramesh

- Group Monitoring Workshop of DST-Fast track scheme on 19th October, 2012 at UAS, Bangalore

Dr. C. S. Ravindran

- Group Monitoring Workshop of KSCSTE at Thiruvananthapuram as an expert to review the six monthly progress of the projects under the scheme.
- Visited the factory of M/s.Tierra Foods at Elamannoor on 1st May, 2012 and took part in the inauguration function of launching of the new product "Kappo" made from cassava.
- Annual Group Meeting of All India Coordinated Research Project on Tuber Crops held at MPUAT, Udaipur, 18 - 20 June, 2012
- Meeting on climate change held at Directorate of Agriculture, Thiruvananthapuram on 7th January, 2013.

Dr. V. Santhosh Mithra

- Workshop for sensitization of PME CELL in-charges of ICAR institutes which was held at NDRI Karnal on 8th December, 2012

Dr. M.S. Sajeev

- Group meeting of AICRP on PHT, at CTPHET, Ludhiana during 30 May - 1 June, 2012.
- State level work shop on "Agro Processing: Strategies and Action Plan for 12th Five Years Plan" organized by Small Farmers Agribusiness Consortium at KAU, Vellanikara, Trichur, 29 - 30 June, 2012.
- National workshop on "Value Addition- Tool for Food Security" at Tavanur on 6th October, 2012.
- Special Group meeting of AICRP on PHT to discuss about the post harvest losses survey work at CIPHET, Ludhiana, 15 - 16, November, 2012.
- International conference on food technology: "Food Processing Technologies- Challenges and Solution for Sustainable Food Security" at IICPT, Thanjavur, Tamil Nadu, 4 - 5 January, 2013.
- "Value chain analysis of root and tuber crops" organized by CIP, New Delhi at Salem, Tamil Nadu from10-13 March, 2013.

Dr. M. N. Sheela

- National Consultation Meeting on Horticultural PGR , NBPGR, New Delhi from 18-19, December, 2012.
- International Biodiversity Congress at Indian Institute of Science, Bengaluru from 21-30 December 2012.
- 7th Review Meeting of DUS test centres organized by PPV & FRA at Indian Institute of Vegetable Research, Varanasi from 28 February to 1 March, 2013.

Dr. J.T. Sheriff

- 3rd INCOFTECH 2013 International conference on food technology: "Food Processing Technologies- Challenges and Solution for Sustainable Food Security" at IICPT, Thanjavur, 4 - 5 January, 2013.
- 21st National Scientific Tamil Conference organised by All India Scientific Council and CIAE Coimbatore on 9 - 10 February, 2013.
- National seminar on "Value Addition and Product Diversification in Agriculture and Food Processing-Status and Strategies", Kerala Agri Food Products Meet organized by Department of Industries and Commerce, Government of Kerala at Kochi on 18th February, 2013.
- "Latest Trends in SAGO industry" organised by CII at IICPT Thanjavur, Salem on 4th March, 2013.
- Value addition machineries: Case of starch extraction from cassava. Training on value chain analysis of roots and tuber crops organised by IFAD and CIP during 10 - 13 March, 2013.
- Value chain analysis of root and tuber crops organized by CIP, New Delhi at Salem, Tamil Nadu, 10 - 13, March 2013.

Mrs. Shirly Raichal Anil

- XII Group meeting of AICRP on Tuber Crops at MPUAT, Udaipur, Rajasthan, 18 - 20 June, 2012.
- International Symposium and XXII Annual Conference of Indian Association for Angiosperm Taxonomy of " Innovative Prospects in Angiosperm Taxonomy" (ISIPAT-2012) held at Sant Gadge Baba Amravati University, Amravati, Maharashtra, 28 - 30 October, 2012.

Dr. J. Sreekumar

- Swadeshi Science Congress at Central Plantation Crops Research Institute, Kasaragod, Kerala , 6 - 8 November, 2012.
- International Conference on "Statistics and Informatics in Agriculture" at IASRI, New Delhi, 18 - 20 December, 2012.

Dr. T. Srinivas

- Workshop on "Biofuels and Poor" at NCAP, New Delhi on 18th April, 2012 and presented the economics of ethanol production using cassava starch.
- Annual meeting of ZTM-BPD Unit, South Zone at Directorate of Oilseeds Research (DOR), Hyderabad on 7th March, 2013 and presented the progress of ITMU of the Institute.

Dr. G. Suja

- Workshop on "Soil Fertility Management-Project Outputs and Way Forward" organized by Kerala State Planning Board at Thiruvananthapuram, 24 - 25 May, 2012.
- QRT Meeting of PDFSR on the Net Work Project on Organic Farming at Thiruvananthapuram, and presented a new project proposal on organic farming of minor tuber crops on 3rd July, 2012.
- Public Consultation Workshop on "State Action Plan on Climate Change" held at Thiruvananthapuram on 6th September, 2012.
- Third International Agronomy Congress: Agricultural Diversification, Climate Change Management and Livelihoods at Indian Agricultural Research Institute, New Delhi , 26-30 November, 2012.
- The Review Meeting of Ministry of Environment and Forests (MOEF) at Paryawaran Bhavan, New Delhi and presented the progress report

of the external project funded by MOEF on 17th December, 2012.

- One day State Level Seminar of Organic Farmers at Priyadarshini Planetarium and Science and Technology Museum, Thiruvananthapuram on 25th March, 2013.

Dr. K. Susan John

- State level workshop on 'Soil Fertility Management- Project Outputs and Way Forward' organized by the Kerala State Planning Board at Thiruvananthapuram, Kerala during 24 - 25 May, 2012.
- Eighth International Symposium on Plant- Soil Interactions at low pH" at Bengaluru, India, 18 - 22 October, 2012.

Dr. S. S.Veena

- National Symposium on "Heading Towards Molecular Horizons in Plant pathology: Host Resistance, Pathogen Dynamics, Diagnostics and Management" at Sugarcane Breeding Institute, Coimbatore, 16-17, November, 2012.
- Quinquennial Review Team's assessment meeting of ICAR Net Work Project on AMAAS at CIBA Chennai on 15th December, 2012.

The Director and all Heads of Divisions attended the meeting held at NASC complex, New Delhi on 12th and 13th March 2013 called by DG, ICAR. One day state level awareness programme on 'Protection of Plant Varieties and Farmers Rights Act' jointly organised by Protection of Plant Varieties and Farmers Rights Authority, Ministry of Agriculture, Govt. of India and Agriculture (WTO cell) Department, Govt. Of Kerala on 20th November 2012 was attended by the scientists of Division of Crop Improvement at CTCRI.

The following programmes conducted at CTCRI were attended by the scientists, technical and all other staffs of CTCRI

- Sree Vishakham Thirunal Endowment lecture, 18th May, 2012 at CTCRI.
- Foundation Day and the Cassava Bio - fumigant Pilot Plant Inauguration, CTCRI, Sreekariyam on 10th July, 2012.
- Tuber Fest 2012- CTCRI, Sreekariyam on 29th November, 2012.
- CeRA sensitization workshop at CTCRI, Sreekariyam on 17th December, 2012.
- Curtain raiser ceremony of Golden Jubilee celebrations of CTCRI on 28th January, 2013.
- National Science Day , 2013 on GM crops- a way forward to address the future of Indian agriculture, CTCRI on 28th February, 2013
- One day workshop on PPVFRA awareness at CTCRI on 26th March, 2013.

VISITS ABROAD

Name of the scientists	Period	Place	Purpose
Dr. G. Padmaja and Dr. M.S. Sajeev	30 April to 7 May, 2012	Bangladesh	Imparting training on value addition and post harvest machineries in sweet potato under the USAID project on Improving income, nutrition and health through potato and sweet potato and vegetables. Implemented by International Potato Centre (CIP) and The World Vegetable Centre (AVRDC).
Dr. M.N.Sheela Dr. G. Byju Dr. T. Makeshkumar Dr. M. Nedunchezhiyan	18 - 22 , June, 2012	Kampala, Uganda	Participated in the second Global Cassava Partnership Initiative meeting - 21st century (GCP21-II)
Dr. M.N. Sheela Dr. G. Byju Dr. T. Makeshkumar	23 - 24 June, 2012	Kampala, Uganda	Training program on "Integrated breeding procedure software for cassava" organized under Generation Challenge program.
Dr. J.T. Sheriff	17 -19 July, 2012	Chatham, UK	Kick-off meeting of EU funded project on "Improving the livelihood of smallholder farmers through better access to growth markets." at Natural Resources Institute, University of Greenwich.
Dr. R.S.Misra Dr. M. Anantharaman	27 August to 1 September, 2012	Chengdu, China	Regional Workshop on Food Security through Asian Roots and Tuber Crops (FoodSTART)
Dr. J.T. Sheriff Mrs. Shirly Raichal Anil	23 - 28 September, 2012	Abeokuta, Nigeria	16th ISTRC Symposium held at Federal University of Agriculture
Dr . T. Srinivas	15 - 27 September, 2012	Egypt	Training program on Seed Enterprise Management and Seed Marketing as a consultant
Dr. C. Mohan	20 - 31 August, 2012	Belgium	International Advanced Course on Modern Breeding Techniques for Improvement of Sweet potato held at Ghent University
Dr. James George	21 to 23 January, 2013	Ho Chi Minh City,	2nd Starch World Conference 2013 (Invited Speaker).
Dr. M. Nedunchezhiyan Dr. V.S. Santhosh Mithra	26 February to 2 March, 2013	Nanning, China	Regional Workshop on Geo-information system (GIS) mapping for food security through Root and Tuber Crops (RTCs).

DISTINGUISHED VISITORS

- Dr. A. P. J. Abdul Kalam, Ex-President of India visited CTCRI on 28th January, 2013 and inaugurated the Golden Jubilee Celebrations of CTCRI. He addressed the staffs and presented the Institute's best technical, administrative and supporting staff awards . He commented CTCRI for the achievements it had made during the past fifty year period especially for the success in science and technological mission towards the development of tuber crops.

- Shri Tariq Anwar, Union Minister of State for Agriculture and Food Processing Industries, Govt. of India visited CTCRI on 15 December 2012. He visited the museum and labs and addressed all the staffs.

- Dr. Shashi Taroor, M.P. visited CTCRI on 24th September, 2012 and inaugurated "A National Training Programme on "Germplasm conservation, climate change mitigation & e-networking". Dr. Tharoor in his speech highlighted the importance of technologies generated at CTCRI to be transferred to the farmers for their benefit

- Shri. K.P. Mohanan, Hon'ble Minister for Agriculture, Govt. of Kerala. launched the Cassava Biofumigant Pilot Plant, on 10th July, 2012 during foundation day 2012.

- Dr. N.K. Krishna Kumar, DDG (Hort.), ICAR, New Delhi visited HQ and the Regional Centre in Bhubaneswar on 3rd October and 24th December, 2012 respectively. He visited the fields and had interaction with the scientists and other staffs of CTCRI. While interacting with scientists, he suggested that the research programmes of the Institute have to be planned, keeping in view the global scenario, especially on the development of tuber crops in Sub-Saharan Africa. He suggested

to give greater thrust on aspects of basic research in the coming years. He also emphasized on commercialization as well as marketing of the technologies and machineries developed at the Institute. While addressing the staff of the Institute, he mentioned that scientists and staff have the responsibility of making the country stronger in all fields, especially the agricultural scenario.

- Dr. Umesh Srivastava, Assistant Director General (Hort. II), ICAR.
- Dr. Kirti Singh, Ex- Chairman, ASRB.
- Dr. V.L. Chopra, Former DG, ICAR, Dr. N.K. Krishnakumar, DDG (Hort.).
- Dr. Gordon Prain, CIP, Lima, Peru.
- Dr. R.P. Raja, Deputy Director (Rtd.), Kerala, Health Service and Member of Mavelikkara Royal Family.
- Prof. V.N. Rajasekharan Pillai, Executive Vice-President, Kerala State Council for Science, Technology and Environment (KSCSTE) and Ex-officio Principal Secretary, Department of Science and Technology, Government of Kerala.
- Dr. N.K. Dwivedi, Head, NBPGR Regional Station, Thrissur.
- Dr. S.V. Ngachan, Director, ICAR Research Complex for NEH, Umiam, Meghalaya.
- Dr. N.P. Kurian, Director, Centre for Earth Science Studies, Thiruvananthapuram.
- Shri. K.A. Muraleedharan, Deputy Director General, All India Radio, Thiruvananthapuram.
- Dr. P. Rajasekharan, Chief (Agri), Kerala State Planning Board.
- Dr. V. Rajmohan of Govt. Ayurveda College, Thiruvananthapuram.
- Dr. N. Ajithkumar of MG College, Thiruvananthapuram.
- Dr. Byju Jacob, Accountant General (Economics and Revenue Sector Audit), Office of the Accountant General, Thiruvananthapuram.
- Shri. Susanta Nanda IFS, Programme Director, Odisha Tribal Empowerment and Livelihood Programme (OTELP).
- Shri. K. Chadda IFS, Director, Directorate of Horticulture, Odisha.
- Dr. Basudev Behera, Prof. & Head, Department of Agronomy, Orissa University of Agriculture and Technology.
- Smt. Arunima, Joint Secretary, ORRISSA (NGO).
- Shri. K.R. Jyothilal IAS, Agricultural Secretary.
- Dr. S. Aravamuthan, Dy. Director, VSSC (ISRO).

Dr. Kirti Singh, Ex-Chairman, ASRB at CTCRI

MANAGERIAL PERSONNEL

Director	:	Dr. S.K. Chakrabarti
Project Co-ordinator	:	Dr. James George
Head, Regional Centre, Bhubaneswar	:	Dr. R.S. Misra
Administrative Officer	:	Shri. P.J. Davis
Finance and Accounts Officer	:	Smt. R. Sari Bai
Central Public Information Officer	:	Dr. C.S. Ravindran
Vigilance officer	:	Dr. V. Ravi
Head of Divisions		
Crop Improvement	:	Dr. M.N. Sheela
Crop Production	:	Dr. C. S. Ravindran
Crop Protection	:	Dr. C.A. Jayaprakas
Crop Utilisation	:	Dr. G. Padmaja
Extension and Social Sciences	:	Dr. M. Anantharaman

Regional Centre, CTCRI, Bhubaneswar

PERSONNEL

Headquarters, Thiruvananthapuram, Kerala

Director		Dr. S.K. Chakrabarti
Project coordinator (AICRP on Tuber Crops)		Dr. James George
Dr. Sunitha S.		Scientist

Head of Divisions/Section

Crop Improvement		Dr. (Mrs) M.N. Sheela
Crop Production		Dr.C.S.Ravindran
Crop Protection		Dr.C.A. Jayaprakas
Crop Utilization		Dr.G.Padmaja
Social Sciences		Dr.M.Anantharaman

Division of Crop Improvement

Dr. Asha K.I.	Joined on 11.3.2013	Principal Scientist
Dr.C.Mohan		Senior Scientist
Dr (Mrs). Asha Devi		Senior Scientist
Smt. Shirly Raichal Anil		Scientist (SG)
Ms. N. Krishna Radhika		Scientist

Division of Crop Production

Dr.V.Ravi		Principal Scientist
Dr.G.Byju		Principal Scientist
Dr.G.Suja		Principal Scientist
Dr.K.Susan John		Principal Scientist
Dr.V.Ramesh		Senior Scientist
Shri.Saravanan Raju		Scientist (SG)

Division of Crop Protection

Dr.M.L Jeeva		Principal Scientist
Dr.T. Makeshkumar		Principal Scientist
Dr.S.S.Veena		Principal Scientist
Shri. Harish E.R.		Scientist

Division of Crop Utilization

Dr.Bala Nambisan	Rtd on 31.12.2012	Principal Scientist
Dr.Lila Babu		Principal Scientist
Dr.J.T .Sheriff		Principal Scientist
Dr.M.S.Sajeev		Principal Scientist
Dr.A.N.Jyothi		Senior Scientist

Section of Social Sciences

Dr.S.Ramanathan		Principal Scientist
Dr.T.Srinivas		Senior Scientist
Dr.V.S.Santhosh Mithra		Senior Scientist
Dr.J.Sreekumar		Senior Scientist
Dr. P.S. Sivakumar		Senior Scientist

Technical

Library/RCM Unit/Photography

Smt K.S.Sudha Devi		Technical Officer (T7-8)
Smt.P.K.Rajamma (Library)	Rtd on 13.5.2012	Librarian (T9)
Smt. T.K. Sudhalatha		Technical Officer (T6)
Shrit.V.S.Sreekumar		Technical Officer (T5)

Field / Farm/Lab.Technians

Shri. A.S.Sabu		Farm Supt. (T9)
Dr.S.Chandra Babu		Technical Officer (T9)
Shri.M.Manikantan Nair		Technical Officer (T7-8)
Smt. L.Rajalekshmi		Technical Officer (T7-8)
Shri.R. Bharathan		Technical Officer (T7-8)
Dr. L.S.Rajeswari		Technical Officer (T7-8)
Shri.M.Easwaran		Technical Officer (T6)
Shri.A.Madhu		Technical Officer (T6)
Shri.I.Puviyarasan		Technical Officer (T6)
Shri.C.S.Salimon		Technical Officer (T6)
Shri.M.Kuraikose		Technical Officer (T6)
Shri.G.Venukumaran		Technical Officer (T5)
Shri.L.V.AjithKumar		Technical Officer (T5)
Shri.V.L.Mathew		Technical Officer (T5)
Shri.R.Sukumaran Nair	Retired on 30.11.2012	Technical Officer (T5)
Shri.S.Divakaran		Technical Officer (T5)
Shri.V.R.Sasankan		Technical Officer (T5)
Shri.V.Ganesh		Technical Officer (T5)
Shri.B.Renjith Kishore		Technical Officer (T5)
Shri.S.Natarajan		Technical Assist (T4)
Shri.G.Suresh		Jr.Tech Assit.(T3)
Shri.N.P.Ramadasan		Jr.Tech Assit.(T3)
Shri.Patric M.Mascrene		Craftman Fitter (T5)
Shri. A.S.Manikuttan Nair		Jr.Tech Assit. (T4)
Shri. L.Luke Armstrong		Jr.Tech Assit.(T2)
Shri.T.Raghavan		Jr.Tech Assit.(T2)
Shri.G. Shaji Kumar		Driver (T3)
Shri.T.R.Unnikrishnan	Rtd on 31.1.2013	Diver(T2)
Shri.B.Satheesan		Jr.Tech Assit. (T1)
Shri. D.T. Rejin		Jr.Tech Assit. (T1)
Shri. T.M. Shinil		Jr.Tech Assit. (T1)
Dr. S.Shanavas		Lab Tech. (T3)
Shri B.S.Prakash Krishnan		Lab Tech.(T3)

Administration and Accounts

Shri.P.J.Davis		Administrative Officer
Smt.C.K.Syamalakumari Amma	Rtd.31.1.2013	Asst.Admn. Officer
Smt.R.Sari Bai		Finance and Accounts Officer
Shri.T.Jayakumar	Promoted to AAO wef 1.2.2013	Assistant
Smt. Jessymol Antony		Asst. Finance Accounts Officer
Smt.K.Padmini Nair		Personal Asst
Shri.S.Sasikumar		Personal Asst.
Shri.M.Padmakumar		Personal Asst.
Smt.S.Sunitha		Stenographer Grade-III
Smt .K.Prasanna		Assistant

Smt.R.Bhagavathy	Rtd. 31.1.2013	Assistant
Smt. K.V.P. Sarada		Assistant
Shri.P.C.Noble		Assistant
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		U.D.C
Shri .S.Harendra Kumar		U.D.C
Smt . Sathyabhama		U.D.C
Shri.O.C.Ayyappan		U.D.C
Shri. S. Sreekumar		U.D.C
Shri.C.Chandru		L.D.C
Shri.Adarsh.R.S		L.D.C
Canteen Staff		
Shri S.Radhakrishnan Nair		Wash boy
Supporting staff		
Shri.A.R.Bhaskaran		Skilled Support staff
Smt .S.Thankamani Amma		Skilled Support staff
Shri.G.Ravindran		Skilled Support staff
Smt.S.Ushakumari		Skilled Support staff
Shri.V.G.Sankaran		Skilled Support staff
Shri K.Manikantan	Expired on 7.7.2012	Skilled Support staff
Shri.K.Mani	Rtd. 31.05.2012	Skilled Support staff
Shri.K.P.Somasekaran		Skilled Support staff
Shri.C.K.Bhaskaran	VRS on 1.1.2013	Skilled Support staff
Shri.M.Krishnan		Skilled Support staff
Smt.P.Sarojini		Skilled Support staff
Shri.P.Udayakumar		Skilled Support staff
Shri.K. Saratchandra Kumar		Skilled Support staff
Shri.G.Madhu		Skilled Support staff
Shri.A.Chandran		Skilled Support staff
Smt.C.T.Chellamma		Skilled Support staff
Smt.M.Syamala		Skilled Support staff
Shri.K.Velayudhan		Skilled Support staff
Shri P.Ramankutty		Skilled Support staff
Shri.T.Lawrence		Skilled Support staff
Shri. N. Appu		Skilled Support staff
Shri. K. Sivadas		Skilled Support staff
Smt .J.Thenmozhi		Skilled Support staff
Shri.M.Sam		Skilled Support staff
Shri.L.Samynathan		Skilled Support staff
Shri.C.Krishnamoorthy		Skilled Support staff
Shri.S.Sreekumaran		Skilled Support staff
Shri.T.Manikandan Nair		Skilled Support staff
Shri.K.Chandran		Skilled Support staff
Regional Centre, Bhuvaneswar		
Dr.R.S.Mishra		Head, Regional Station
Dr.R.C.Ray		Principal Scientist
Dr.Archana Mukherjee		Principal Scientist
Dr. M.Nedunchezhiyan		Principal Scientist
Dr.K.Rajasekhara Rao		Senior Scientist
Dr.K.Lakshminarayana		Senior Scientist
Dr. Kalidas Pati		Scientist
Technical		
Shri.B.C.Patnaik	Rtd. 31.1.2013	Technical Officer (T5)
Shri. Yudhistra Sahoo		Technical Officer (T5)
Shri. Sushanta Kumar Jata		Jr. Farm Supt. (T3)
Shri. N.C.Jena		Technical Asst (T5)
Shri. Niranjan Patnaik		Tech. Assit (T4)
Shri. Bharat Kumar Sahoo		Jr.Tech.Asst. (T3)
Shri .Pramod Kumar Mati		Fitter (T4)
Shri .Bibhudi Bhusan Das		Jr.Tech.Asst (T4)
Shri .Kesha Paikray		Jr.Tech Asst (T1)
Administration & Accounts		
Shri . Kalakar Malik		Asst. Admn.Officer
Shri .P.K.Acharya		Private Secretary
Shri .K.Lakshmana Rao		U.D.C
Supporting Staff		
Shri .Ramachandra Das		Skilled Support staff
Shri .Bijoykumar Nayak		Skilled Support staff
Shri.Akshayakumar Naik		Skilled Support staff
Shri .Purna Samal		Skilled Support staff
Shri Bhajaman Malik		Skilled Support staff
Shri Sauri Pardhan		Skilled Support staff
Shri K.C.Jena		Skilled Support staff
Shri Ramesh Nayak		Skilled Support staff
Shri Babuli Sethi		Skilled Support staff
Shri Fakircharan Bhoi		Skilled Support staff
Shri Samsuddin Khan		Skilled Support staff
Shri Sanatan Senapati		Skilled Support staff

OTHER INFORMATION

TRAINING AND OTHER RELATED PROGRAMME

CTCRI Training organized in Kolasib, Mizorum

Two training programmes one on value addition of tuber crops and use of bio-pesticides from cassava were organized for the officials of Krishi Vigyan Kendras (KVKs) in Mizoram state on 1st July 2012 and the second one for farmers on 2nd July 2012 at ICARRCNEH Mizoram centre, Kolasib.

CTCRI-NEH Planning and inception workshop

After a series of interactions and deliberations with ICARRCNEH and KVK and NGO partners, the CTCRI has launched its technology intervention programme on "Enhancing food security and sustainable livelihoods in the North-Eastern India through tuber crops technologies" in the form of a planning and inception workshop conducted at ICARRCNEH, Meghalaya during 24 - 25 July, 2012. This workshop was inaugurated by Shri. BO Wajri, IAS, Additional Chief Secretary, Govt. of Meghalaya who during his inaugural speech termed tuber crops as "basic necessity" of the NEH region which can also transform the rural livelihoods through an array of marketable products.

Seminar-cum-Training on Improved Tuber Crops Technologies in Nagaland

The Central Tuber Crops Research Institute, Thiruvananthapuram along with ICAR Research Complex, Barapani, Meghalaya has organized a "Seminar-cum-Training on Improved Tuber Crops Technologies" on 21st September 2012 at ICARRCNEH Nagaland Centre, Jharnapani, Nagaland as a part of week-long "Technology Week" celebrations. About 100 participants from Mon, Wokha and Dimapur districts of Nagaland have benefitted from this programme. During the seminar, the farmers were exposed to improved varieties, profitable cropping systems and agro-techniques, pest and disease management strategies and value added products from tuber crops. Scientists from CTCRI and ICAR Research Complex for NEH acted as resource persons for this programme. Quality planting materials of improved cassava and sweet potato varieties were distributed to the farmers.

National Training Programme by AICRP on Tuber Crops

A National Training Programme on "Germplasm conservation, climate change mitigation & e-networking"was inaugurated by Dr. Shashi Tharoor, M.P. at CTCRI on 24th September, 2012. The inaugural function was presided over by Dr. S.K. Chakrabarti, Director, CTCRI in which the Project Coordinator of AICRP on Tuber Crops, Dr. James George spoke about the relevance of the training programme especially in view of the climate change resilience potential of tuber crops like tapioca and yams. Dr. Tharoor in his speech highlighted the importance of technologies generated at CTCRI to be

transferred to the farmers for their benefit. He also informed the house about the discussion with Dr. Sam Pitroda for transformation of Thiruvananthapuram as "Knowledge City" by the initiation and consolidation of internationally acclaimed Scientific Institutions like CTCRI in the city.

Training workshop on Sustainable Livelihood and Value Chain held at Nagaland

The Central Tuber Crops Research Institute, Thiruvananthapuram along with ICAR Research Complex, Barapani, Meghalaya has organized a "Training workshop on Sustainable Livelihood Assessment and Value Chain Analysis" during 24 - 26 September, 2012 at ICARRCNEH Nagaland Centre, Jharnapani, Nagaland. This training was conducted as a part of CTCRI NEH programme on "Enhancing Food Security and Sustainable Livelihoods in the North Eastern India through Improved Tuber Crops Technologies" being implemented in NEH states in collaboration with ICAR Research Complex for NEH, Barapani and NGOs. About 20 trainees from Nagaland, Meghalaya, Tripura and Manipur states participated in the programme. During the training, they were equipped with various tools and techniques of livelihood assessment and value chain analysis.

Model Training Course on Tuber Crops

The All India level Model Training Course on Sustainable management strategies of tuber crops based cropping systems sponsored by the Directorate of Extension, Ministry of Agriculture, Govt. of India was organized at CTCRI from 5 - 12 October, 2012. Ten extension personnel in the rank of Assistant Directors and above, working in the Departments of Agriculture/Horticulture from Kerala, Meghalaya, Manipur and Nagaland participated in this week long programme. Latest production and processing techniques of tuber crops perfected at this Institute were imparted to the trainees through interactive sessions and visits to experimental and farmers' fields.

CTCRI Training organized in Tripura

A "Seminar-cum-Training Programme on Tuber Crops Technologies" was organized on 16th October, 2012, at ICAR Tripura Centre, Lembucherra, Tripura as an activity under the CTCRI-ICAR NEH programme. About 100 farmers from various districts of Tripura participated in the programme. During the training, the farmers were exposed to scientific tuber crops cultivation.

Training programme for NEH Region

A training programme on "Improved tuber crops production technologies for NEH Region" under CTCRINEH programme was organized at CTCRI during 3-7 December, 2012 to equip the CTCRI-NEH programme partners to conduct Frontline Demonstrations on tuber crops technologies in the project sites in NEH region. Inaugurating this programme on 3rd December 2012, Dr. S.V. Ngachan, Director, ICAR Research Complex for NEH, Umiam, Meghalaya said that tuber crops play a crucial role in the food and nutritional security of the NEH people and occupy a prominent role in their food culture.

- Around 40 batches of farmers were given training on tuber crops production and processing technologies and on various activities of CTCRI wherein >1000 farmers and >70 officials from Kerala, Tamil Nadu, Karnataka and Uttar Pradesh participated. Around 25 batches of around 1100 students and sixty two teachers from Karnataka Kerala, Maharashtra and Nagaland also attended awareness programmes on tropical tuber crops and training programmes conducted at CTCRI, Thiruvananthapuram. Regional Centre of CTCRI imparted training on 'Agrotechniques and value addition in Tuber Crops' to three batches of farmers and Officials of Odisha Tribal Empowerment and Livelihood Programme (OTELP), wherein 60 farmers from Odisha participated. Thirteen batches of 421 farmers and farm women from Andhra Pradesh, Bihar, Jharkhand and Odisha were trained on various tuber crops technologies at the Regional Centre. Management of Pseudostem weevil in banana was demonstrated at farmers' fields at ATMA, Udupockiri, Trivandrum on 17th July, 2012 and Frontline demonstration of cassava biopesticide against pests on vegetables and banana was organised by KVK, Mitranikethan under the Core Support Project b (DST) on 16th August, 2012.

Gender sensitizing awareness training

One day training cum awareness programme was conducted for stakeholders on "**awareness programme on community based conservation and preservation of genetic resources of tuber crops and protection of plant varieties for livelihood security**". This was jointly organised by Regional Centre of Central Tuber Crops Research Institute (RCCTCRI), Bhubaneswar and Protection of Plant Varieties and Farmers Right Authority (PPV&FRA), New Delhi on 15th March 2013, at RCCTCRI Bhubaneswar. The objective of the training was to create awareness among the stakeholders comprising of farmers, breeders, researchers and especially farmwomen about conservation and preservation of plant genetic resources of tuber crops, their protection as well as to realise their importance in improving socio-economic-cultural standards of stakeholders. A total of 102 participants actively participated in the programme from different parts of Odisha. Of which 79 participants were women.

IMPORTANT EVENTS

XII Annual Group Meeting of AICRP on Tuber Crops

The XII Annual Group Meeting of All India Coordinated Research Project on Tuber Crops (AICRPTC) was held at Maharana Pratap University of Agriculture & Technology (MPUA & T), Udaipur from 18 to 20 June, 2012. The inaugural function was presided over by Prof. O. P. Gill, the Hon'ble Vice Chancellor of MPUA&T, Udaipur. Dr. H.P. Singh, Hon'ble Deputy Director General (Hort.), ICAR inaugurating the meeting highlighted the importance of tropical tuber crops especially in the context of their potential resilience to climate change and gave a broad outline of areas to be focused while envisaging new technical programme. Dr. S.K. Chakrabarti, Director, CTCRI and Shri. K.K. Kaushal, IFS, MD, SAGOSERVE felicitated on the occasion. Dr. James George, Project Coordinator, AICRPTC presented the progress report of the project during the year 2011-12.

HH Sree Visakham Tirunal Endowment Lecture

The third HH Sree Visakham Thirunal Endowment Lecture, 2012 organized jointly by the Central Tuber Crops Research Institute (CTCRI) and the Indian Society for Root Crops (ISRC) was inaugurated on 18 May, 2012 at CTCRI and Dr.S.Ramanathan, President, ISRC, welcomed the gathering. Dr. R.P. Raja, Deputy Director (Rtd.), Kerala Health Service and Member of Mavelikkara Royal Family was the chief guest of the occasion. Dr. S.K. Chakrabarti, Director, CTCRI gave the Presidential address. Prof. V.N. Rajasekharan Pillai, Executive Vice-President, Kerala State Council for Science, Technology and Environment (KSCSTE) and Ex-officio Principal Secretary, Department of Science and Technology, Government of Kerala who delivered the endowment lecture on "Promotion of Traditional Crops of Kerala – Science & Technology Interventions", said that obsolete farming practices and lack of scientific interventions and modern marketing strategies were the major impediments to agricultural development in Kerala.

TUBER FEST 2012

Commemorating the Thrikarthika Day, the Indian Society for Root Crops joining hands with CTCRI organized TUBER FEST 2012 at the Institute during 29 - 30 November, 2012. Best tuber crops farmers nominated by the Department of Agriculture, Govt. of Kerala from different districts and the winners of the Agricultural quiz conducted in connection with the Fest were recognized and suitably rewarded during the celebration. As a part of the Fest, an agricultural exhibition involving various organizations such as CPCRI, NRC Banana, FIB, NIDS, VFPCK, Kudumbasree Mission and progressive farmers was also organized and it was open to school and college students on the second day.

Foundation day and launching of cassava biofumigant pilot plant

CTCRI Celebrated Foundation Day and launched the Cassava Biofumigant Pilot Plant, which was inaugurated by Shri. K.P. Mohanan, Hon'ble Minister for Agriculture, Govt. of Kerala on 10 July, 2012. The biopesticides christened Nanma (against mealy bugs), Menma (against borer pests) and the Biofumigant (against borer pests) were released on the foundation Day. A technical bulletin prepared on Modified Tuber Starches and the web based mealy bug warning system were released. About 700 "Foundation day Kit" which contains planting materials of tuber crops and cassava tubers, were distributed to all those who attended the function.

Curtain raiser ceremony for the Golden Jubilee celebrations of CTCRI

Curtain raiser of the golden jubilee celebrations of CTCRI was held on 28th January, 2013 in the Millennium Hall, CTCRI. Honourable Dr. A.P.J. Abdul Kalam, Former President of India inaugurated the celebrations. Dr. S. K. Chakrabarti, Director, CTCRI presided over the function. During the inaugural address, Dr. Kalam commented CTCRI for the achievements it had made during the past fifty year period especially for the success in science and technological mission towards the development of tuber crops and its related products for sustainable development of the nation. He presented awards for the best technical, supporting and administrative staff members of CTCRI.

Vigilance Awareness Week

CTCRI observed the Vigilance Awareness Week during 29 October to 3 November 2012. Dr. Byju Jacob, Accountant General (Economics and Revenue Sector Audit), Office of the Accountant General, Thiruvananthapuram delivered a talk on "Transparency in Public Procurement" on this occasion on 31 October 2012.

National Science Day

National Science day 2013 was celebrated at CTCRI on February 28, 2013 with a focal theme of "GM crops- a way forward to address the future concerns of Indian agriculture". This program was inaugurated by Dr. P.R. Sudhakaran, Director, Kerala Biotechnology Commission and in his address mentioned that every technology has pros and cons and we need to cautiously utilize it for the betterment of mankind and also environmentally safe. Eventhough currently lot of debate is going on GM crops, we need to carry forward research on this area where ever it is essential. During this event four guest lectures and competitions on poster painting and quiz were organised on the focal theme. Guest lectures were delivered by

1. Dr. Srinivas Parimi & Dr.Pankaj Bihani (Mahyco, Aurangabad) – Challenges in Agriculture & Potentials of agricultural biotechnology
2. Dr. P. Balasubramanian (TNAU, Coimbatore) – Transgenic crops & Human welfare
3. Dr. K. Rajmohan (CoA, KAU, Trivandrum)- GM technology Vs Food / Environmental safety
4. Mr. R. Sridhar (Thanal, Trivandrum) – GM Crops- Unnecessary risk

The participants include the students from S.N. College, Chempazhunthi, Government womens college, Trivandrum, University of Kerala, Kariavattom, College of Agriculture, Trivandrum and many others. Dr.S.K.Chakrabarti, Director, CTCRI distributed the prizes to the winners

PARTICIPATION IN EXHIBITIONS

- Santhigiri Expo 2012 at Pothencode, Thiruvananthapuram from 18 - 25 April, 2013.
- 7th Organic Fair 2012 at Kochi during 29 April – 1 May, 2012.
- Planning work shop of CTCRI – ICAR NEH Collaborative programme, ICAR NEH, Badapani on 24 - 25, July, 2013.
- Farmers Seminar at ICARRCNEH Nagaland Centre, Jharnapani, Nagaland on 21st ,September, 2013.
- Bharat Nirman Public Information Campaign 2012 at Pathanamthitta during 10 - 12 October, 2012.
- Farmers Seminar-cum-training on tuber crops technologies" at ICAR NEH – Tripura Centre on 16th October, 2012
- TUBER FEST 2012 at CTCRI, Thiruvananthapuram from 29 - 30 November, 2012.
- Chaithanya Karshika Mela 2012 at Thellakom, Kottayam from 29 November to 2 December, 2012.
- Indian Biodiversity Expo 2012 at Bengaluru during 9 - 12 December, 2012.
- National Biodiversity Conference Expo at Thiruvananthapuram from 21 - 30 December, 2012.

7th Organic Fair 2012 at Kochi

- Karshika Mela 2013 at Thodupuzha from 26 December, 2012 to 5 January, 2013.
- Gramolstavam 2013 at Mitraniketan, Thiruvananthapuram during 21 - 23 January, 2013.
- Sasthra Jalakam National Science Expo at Thiruvananthapuram during 28 January to 3 February, 2013.

Indian Biodiversity Expo 2012 at Bengaluru

CTCRI LIBRARY

CTCRI Library continued its information support activities for research and training programmes of the Institute.

Collection Development

During the period, 73 books, 20 journals, and current protocols in Molecular Biology (six volumes) and RHS Colour Chart were added to the stock.

Library Services

Library has also provided the following services

1. **CD-Searches:** Facilities were provided to the users to search the CD Databases available in the library.
2. **Ready-reference service**: Provided ready assistance and solutions to the queries of users on matters related to information sources, URLS of websites related to tuber crops research, downloading of files, common plant names, phone numbers, geographical information etc.
3. **AGRINEWS:** Monthly service on circulation and issue of compiled newspaper clippings related to agriculture was continued.
4. **Circulation of books:** 426 books were issued to the users on loan. Several documents were also provided to the users for reading inside the library.
5. **Photocopying:** Library continued to provide photocopying service to the institute staff and other library users on official/payment basis. During the period 61, 332 exposures were provided against work indents and requests.
6. **CeRA:** Efforts were made to maximize the use of CeRA platform and 372 copies of the library materials were send against the request from outside users of CeRA.
7. **CeRA Sensitization Workshop at CTCRI**

   In order to discuss facilities currently available in CeRA for better usage and to interact with scientists / faculty / librarians / other researchers, NAIP has organized a one day regional CeRA Sensitization Workshop at CTCRI on 17th December 2012 with the participation of 88 delegated from various agricultural institutes
8. **Software developed to assist library functions**

   Developed two softwares to help the users and to assist the routine library activities in asp.net application

Photocopying : Online facility installed for utilizing the photocopying facility of the library by keeping its account as per request from staff and outside users.

Book loan register to keep account of books issued to the library users.

NEW JOINING

Dr. S. K. Chakrabarti, Principal Scientist, CPRI, Shimla joined as the Director of CTCRI on 2nd April 2012.

Dr. M. N. Sheela, Principal Scientist, Division of Crop Improvement, CTCRI joined as Head of that Division on 6th September 2012.

Dr. Kalidas Pati, joined as at Regional centre of CTCRI, Bhubaneswar on 16th May 2012.

Shri. Harish, E.R. joined as scientist in the Division of Crop Protection on transfer from Sunnhemp Research Station, Pratapgarh, Uttar Pradesh, Regional Station of Central Research Institute for Jute and Allied Fibres on 4th June 2012.

Dr. Asha, K. I. joined as Principal Scientist in the Division of Crop Improvement on transfer from NBPGR Regional station, Thrissur on 11th March 2013.

वर्ष 2012 -13 के दौरान इस संस्थान में की गयी राजभाषा कार्यान्वयन से सम्बन्धित कार्यक्रम

राजभाषा कार्यान्वयन समिति की बैठक का आयोजन

इस संसथान की निदेशक महोदय, डॉ. एस.के. चक्रवर्ती की अध्यक्षता में, ता. 23.03.2012, 30.06. 2012, 29.09. 2012, 22.12.2012 और 27.03.2013 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 गया।

हिन्दी कार्यशाला का आयोजन

क) संघ सरकार की राजभाषा नीति के अनुपालन में इस संस्थान के सभी कर्मचारियों के लिए 29.06.2012 को हिन्दी टिप्पण और आलेखन पर एक दिन की हिन्दी कार्यशाला आयोजित किया गया। डॉ. एस.के. चक्रवर्ती, निदेशक और अध्यक्ष(राजभाषा), हिन्दी के महत्व पर प्रकाश डालते हुए समारोह का उद्घाटन किया। डॉ. वी.एस संतोष मित्र, वरिष्ठ वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभा का स्वागत किया, विशेष रूप से श्री.आर.जयपाल, हिंदी अधिकारी, भारतीय अंतरिक्ष विज्ञान प्रौद्योगिकी संस्थान, तिरुवनंतपुरम का स्वागत किया और कार्यशाला में अचछी उपस्थिति पर संतोष प्रकट किया। श्री.आर. जयपाल ने 'हिन्दी टिप्पण और आलेखन' पर क्लास लिया। कुल 47 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.आर.जयपाल की क्लास की सराहना की।

ख) ता. 27.03.2013 को हिन्दी जागरूकता कार्यक्रम/ टिप्पण और आलेखनन पर एक दिन की हिन्दी कार्यशाला आयोजित किया गया। डॉ. एस.के. चक्रवर्ती ,निदेशक और अध्यक्ष(राजभाषा), कार्यशाला का उद्घाटन किया। डॉ. वी.एस संतोष मित्र, वरिष्ठ वैज्ञानिक और संपर्क अधिकारी (राजभाषा) ने सभा का स्वागत किया, विशेष रूप से श्री. ए. सोमदत्तन, सेवानिवृत सहायक निदेशक (राजभाषा), तिरुवनंतपुरम का स्वागत किया। श्री. ए. सोमदत्तन ने 'हिन्दी जागरूकता कार्यक्रम/टिप्पण और आलेखन' पर क्लास लिया। कुल 49 प्रतिभागियों ने कार्यशाला में उत्साहपूर्व भाग लिया। श्रीमती. टी. के सुधालता, तकनीकी अधिकारी (हिंदी) ने धन्यवाद प्रस्ताव पेश किया और श्री. ए. सोमदत्तन 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 2012 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 आदि प्रतियोगिताएं आयोजित की गई.)। ता. 10.10.2012 को हिन्दी पखवाड़ा का समापन समारोह आयोजित किया गया। निदेशक महोदय, डॉ. एस.के. चक्रवर्ती ने समारोह की अध्यक्षता की और श्री. ए. सोमदत्तन, सेवानिवृत सहायक निदेशक(राजभाषा) द्वारा सभी विजेताओं / प्रतिभागियों को पुरस्कार वितरित किया।

- इसके अलावा तिरुवनंतपुरम नगर राजभाषा कार्यान्वयन समिति के तत्वावधान में आयोजित हिंदी प्रतियोगिताओं में और केरल हिंदी प्रचार सभा में, राज्यस्तरीय हिंदी पखवाडा के अवसर पर आयोजित हिंदी प्रतियोगिताओं में इस संस्थान के प्रतिभागियों ने भाग ले करके पुरस्कार प्राप्त हुआ।
- तिरुवनंतपुरम नगर राजभाषा कार्यान्वयन समिति की बैठकों में, इस संस्थान के निदेशक महोदय और अध्यक्ष(राजभाषा), डॉ. एस. के. चक्रवर्ती, डॉ. वी.एस संतोष मित्र, वरिष्ठ वैज्ञानिक और संपर्क अधिकारी (राजभाषा) और श्रीमती. टी. के सुधालता, तकनीकी अधिकारी (हिंदी) ने भाग लिया।
- इस संस्थान का वार्षिक रिपोर्ट / सी टी सी आर आई समाचार आदि अनुवाद करके मुद्रित किया गया और सभी संस्थानों को भेजा गया।

हिंदी प्रशिक्षण कार्यक्रम

भारत सरकार की राजभाषा नीति के अनुसार इस संस्थान की 19 कुशल समर्थन स्टाफ 2 प्रधान वैज्ञानिक और 1 वरिष्ठ वैज्ञानिक को हिंदी प्रबोध प्रशिक्षण कार्यक्रम दिया गया। ता. 05 फरवरी 2013 से 16 मई 2013 तक श्रीमती श्रीलता, वी एस एस सी की हिंदी प्रद्यापक ने उनको क्लास लिया। प्रतिभागियों को यह बहुत लाभान्वित किया।

प्रोत्साहन योजना

हिन्दी में काम करनेवालों को प्रोत्साहन योजना शुरू किया गया। प्रोत्साहन योजना में भाग लिए/ प्रोत्साहन के पात्र कर्मचारियों को नकद पुरस्कार दिया गया। वर्ष 2012 को, 4 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 कागजात द्विभाषी रूप में किया था।
- हिंदी में प्राप्त पत्रों के उत्तर हिंदी में दिए गए।
- वार्षिक कार्यक्रम के निर्धारित लक्ष्यानुसार अधिक से अधिक पत्राचार हिंदी में किया था।