CTCRI/QSF/RP/400

वार्षिक प्रतिवेदन
Annual Report
2021

भा कृ अनु प - केन्द्रीय कंद फसल अनुसंधान संस्थान

भारतीय कृषि अनुसंधान परिषद्

श्रीकार्यम, तिरुवनन्तपुरम - 695 017, केरल, भारत

ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE

(Indian Council of Agricultural Research)

Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

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Cover Illustrations

Theme: Biofortified tuber crops for nutritional security

Front : Orange and purple fleshed sweet potato tubers and light green leaved sweet potato plants

Back : Greater yam (*Dioscorea alata*) plants with male and female infloresences and purple fleshed greater yam tubers

Citation
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Preface

The ICAR-Central Tuber Crops Research Institute has endeavoured for the past 58 years to make a perceptible impact on various stakeholders involved in the cultivation and use of tropical tuber crops. The Institute has released 68 high yielding varieties, 83 production practices including organic farming and good agricultural practices, nine protocols for quality planting material production, 11 pest and disease management packages, 25 value added food products, 15 industrial products, seven computer simulation models | information systems for tuber crops management. I consider it as a privilege to present the research accomplishments, technological advancements and development activities of this premier Institute dedicated especially to the welfare of the weaker sections of the society which is documented as the Annual Report of ICAR-CTCRI, for the year 2021.

Inspite of the covid-19 pandemic situation, we could meticulously conserve germplasm wealth of 5685 accessions belonging to 50 species of tropical tuber crops mostly propagated vegetatively. In 2021, a cassava variety 8S501 (Sree Kaveri) with resistance to cassava mosaic disease (CMD) and drought tolerance was identified for central release. Efforts were made to develop seed chain for the popularization of released varieties through decentralized seed multiplier scheme. The impact of climate change on crop, water and irrigation requirement of major tuber crops were analysed over the major tuber crops growing areas in India for 2030 and 2050 using the FAO-CROPWAT and LARS-weather generator. Large scale demonstrations of new high yielding varieties, bioformulations, profitable cropping system models, integrated pest and disease management strategies were undertaken across different states of India under the centrally sponsored and development schemes like NEH, TSP, RKVY and SCSP. Under the SCSP programme, 185 demonstrations on improved varieties and production technologies were conducted for enhancing the productivity and profitability of tuber crops. In the NEH programme, quality planting materials of improved varieties of tuber crops were distributed to the farers for establishing seed villages. 'Rainbow Diet Campaign' was conducted among children and youth in Arunachal Pradesh and Tripura for creating awareness about biofortified varieties of tuber crops. During this year, 523 tribal households were adopted under TSP in Odisha. The e Crop based smart farming technology was developed and demonstrated in sweet potato farmer's fields. The Institute has developed many value added products and trained farmers for doubling their income. The techno incubation centre and agri business incubator at headquarters and regional station are involved in promoting enterpreneurship among the stakeholders. The Institute has developed Chinese potato grader for promotion of mechanisation in grading of tubers.

The biopesticides developed from cassava leaves received great acceptability within the farming community for the control of some important pests of vegetables. Patent was obtained in 2021 for the design of the apparatus and for the process for extraction of biopesticides from cassava leaves.

The Institute gives emphasis in carrying out basic and strategic research in a multi-disciplinary approach for sustaining the productivity and profitability of tropical tuber crops. Our research focuses on developing stress tolerant varieties, profitable cropping system models, organic and natural farming practices, integrated management of pests like cassava mealybug and major diseases in different crops. Cassava is a popular first generation biofuel crop. The Institute has developed technology for cassava bioethanol production and efforts are underway for scaling up to make it 'market-ready' for commercial utilization.

The Headquarters (HQ) of the All India Co-ordinated Research Project (AICRP) on tuber crops is functioning at ICAR-CTCRI, HQ with 21 centres situated all over India for location specific testing of the varieties and technologies developed at the Institute.

I am thankful for the trust, confidence and guidance received from Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR in all the endeavours of the Institute. I also thank Dr. A K Singh, Deputy Director General (Horticultural Science) and Dr. Vikramaditya Pandey, Assistant Director General (HS-I) for their continuous support and motivation. The conscientious efforts of the editorial board in the preparation of this annual report are gratefully acknowledged.

Sreekariyam
23.05.2022

Dr. M.N. Sheela
Director (A)

Contents

1.0 About the Institute

The ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) was established during the Third Five Year Plan for intensification of research on tuber crops (other than potato). The Institute started functioning in July 1963 with its Head Quarters (HQ) at Sreekariyam, Thiruvananthapuram, Kerala. It has one Regional Station (RS) at Bhubaneswar, Odisha. The ICAR-CTCRI is conducting basic, strategic and applied research on various edible tropical tuber crops. The Institute has a broad objective of generating information through research of tropical tuber crops which can help to enhance crop productivity and improve the utilization potential of tropical tuber crops.

Mandate

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

Vision

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

Mission

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

Mandate 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: *Solenostemon rotundifolius* (Poir.) J.K. Morton, Lamiaceae
12.	Yam bean: *Pachyrhizus erosus* (L.) Urban, Fabaceae
13.	Arrowroot: *Maranta arundinacea* (L.), Marantaceae
14.	Queensland arrowroot: *Canna edulis* (Ker-Gawler), Cannaceae

Overview

The ICAR- Central Tuber Crops Research Institute (ICAR-CTCRI) under the Indian Council of Agricultural Research (ICAR) is a premier research organization in the world dedicated exclusively for the research and development of tropical tuber crops *viz.,* cassava, sweet potato, yams, aroids (elephant foot yam, taro, tannia), arrowroot and minor tuber crops like Chinese potato, yam bean, tikhur and winged bean. The Institute has a Regional Station (RS) at Bhubaneswar, Odisha.

The focus of ICAR-CTCRI is farmers' welfare through co-ordinated research, development and extension activities through improved varieties, cost effective agro techniques, eco-friendly pest and disease management, value addition, outreach programmes and policy recommendations. During the last 58 years, the major outcome of the Institute includes 68 high yielding, good quality, trait specific varieties, 83 production practices with emphasis on Good Agricultural Practices (GAP) of tuber crops, nine protocols for quality planting material production, 11 pest and disease management packages, 25 value added food products and 15 industrial products including biodegradable plastic and ethanol, seven computer simulation models and information systems for crop management.

The Institute HQ has a germplasm wealth of 4437 accessions belonging to 50 species of tuber crops *viz.,* cassava (1216), sweet potato (1110), yams (1121), aroids (683) and minor tuber crops (307) and RS having a total collection of 1248 accessions of different tuber crops. The pioneering role of ICAR-CTCRI in conventional and molecular breeding of tropical tuber crops led to international collaborations in the breeding and genetic improvement of these crops. The 68 improved varieties released from ICAR-CTCRI included, cassava (19), sweet potato (21), yams (17), taro (8), elephant foot yam (2) and Chinese potato (1). The cassava varieties *viz.,* H-165, H-226, Sree Athulya, Sree Apoorva and the triploid variety Sree Harsha released for industrial belts of India played a pivotal role in the growth and development of starch and sago industries. The three cassava mosaic disease (CMD) resistant varieties *viz.,* Sree Reksha, Sree Sakthi and Sree Suvarna released during 2017-18 with high yield and farmers' acceptability was a breakthrough in cassava research. Development of the potassium (K) efficient cassava variety Sree Pavithra in 2015 having only 50% requirement of K under low K soil was also a land mark in the crop improvement programme. The short duration cassava varieties *viz*. Sree Jaya and Sree Vijaya released in 1998 is still grown in the sequential cropping system in the rice fallows of Kerala. The β-carotene rich sweet potato varieties *viz.,* Sree Kanaka, Bhu Sona, Bhu Kanti and Bhu Ja and anthocyanin rich Bhu Krishna and midseason drought tolerant Bhu Swami have gained wider popularity among the rural and tribal people of the country. The Institute released the first hybrid in EFY, Sree Athira in 2006 and the first hybrid in yam, Sree Shilpa in 1998. The dwarf white yam varieties namely, Sree Dhanya and Sree Swetha were released during 1993 and 2017 respectively. The biofortified yam varieties *viz.,* Sree Neelima and Da-40 were dedicated to the nation by the Hon'ble Prime Minister of India in 2020 and the biofortified orange and purple fleshed sweet potato and purple fleshed yam varieties were included in the National Nutrition Strategy of NITI Aayog in 2017. The biotechnological research included, development of diagnostic tools for viral and fungal diseases and evolution of transgenic plants for conferring resistance to CMD and strategies to enhance the starch content of cassava tubers and to develop waxy cassava varieties.

Agrotechniques of all tropical tuber crops suited to different production systems of the country both under sole cropping and under cropping systems were developed. The major technologies in the sustainable production of these crops included, use of minisetts for quality planting material production, integrated nutrient management (INM) involving major, secondary and micronutrients, site specific nutrient management (SSNM), crop specific liquid micronutrient formulations, organic farming packages of tuber crops for both sole cropping and for major cropping systems and use of nutrient use efficient cassava genotypes to reduce chemical fertilizer usage. The 'waste to wealth' technology developed were cassava starch factory solid waste (*thippi*) composting and biochar preparation. Technology of surface coating of cassava tubers with paraffin wax extended the shelf life. Precision approaches in water management through micro irrigation and drip fertigation were standardised. Soil, water, nutrient conservation for rainfed cassava under hill production system was evolved. The Institute has initiated decentralized seed multiplier system for the vast spread of the released varieties. Natural farming experiments, development of Integrated Farming System (IFS) models, vertical farming and climate smart production practices are in progress.

Integrated crop protection technologies were developed for the management of major pests and diseases like cassava mosaic disease (CMD), cassava tuber rot, taro leaf blight, elephant foot yam collar rot, greater yam anthracnose and sweet potato weevil. Diagnostic kit was developed for Dasheen Mosaic Virus (DsMV) detection. Research is in progress to diagnose and manage new emerging pests, diseases and nematode infestation through integrated approaches as well as by evolving resistant genotypes. The biopesticides developed from cassava leaves *viz., Nanma, Menma* and *Shreya* were effective in the control of some important pests of vegetables like mealy bug as well as pseudostem weevil in banana.

Post harvest utilization is mainly on diversified technologies for value addition both for edible and industrial uses apart from the development of pre and post harvest machineries. The important technologies included preparation of value added food products like pasta, noodles, extruded products and fried snack foods. Significant technologies developed for the industrial sectors were preparation of products like biodegradable plastics (patented), bioethanol, modified starches, super absorbent polymers, adhesives, thermoplastic starch and particle boards. Recent developments included, preparation of functional foods and technology for the preparation of encapsulated anthocyanin from sweet potato leaves and tubers and fabrication of Chinese potato grader. These technologies and products are providing greater opportunities for the entrepreneurs. The HQ and RS have well established Techno Incubation Centres (TIC) especially for promoting entrepreneurship in value added food and industrial products.

Most of the technologies developed at the Institute were tested and validated under on farm trials of KVK's and included in the Package of Practices (PoP) recommendation of Agricultural Universities especially Kerala Agricultural University (KAU). These validated technologies as well as released varieties are popularised among the farming community across the country through different centrally sponsored programmes and RKVY projects.

Innovative extension programmes and methodologies have been developed for enhancing technology utilization and income of farmers and stakeholders. Empowerment index of women in tuber crops were documented. Impact analysis of technologies transferred were also assessed. Information technology (IT) tools such as e Crop and growth simulation and self learning growth models for different crops were developed and validated. Online marketing platforms *viz.,* Tuber Crops Online Marketing System (TOMS) and Horticultural Crops Online Marketing System (HOMS) were developed. Intelligent bioinformatics tools were developed to predict plant-pathogen interaction, biological network construction, omics data integration and visualization. Molecular markers, miRNAs, lncRNAs and differentially expressed genes associated with biotic/abiotic stress and quality parameters of tuber crops were identified.

In the past years, more than thousand front line demonstrations and training programmes were conducted as a part of technology transfer. Two international training programmes under 'Feed the Future India Triangular programme' was organized exclusively for the African officials. The developmental programmes were undertaken by the Institute successfully during the past years namely North Eastern Hill (NEH) programme, Tribal Sub Plan (TSP) and Scheduled Castes Sub Plan (SCSP) have greatly helped to increase the spread of varieties and technologies which in turn secured the livelihood of farmers and other stakeholders across the country.

The ICAR-CTCRI bagged the ICAR instituted Sardar Patel Outstanding Institution Award in 2005 for its contributions to research, development and extension activities in tuber crops and inclusive growth and well being of its stakeholders. The International awards bagged by the Institute in the past included, D. L. Plucknett Award for Tropical Root Crops (2000) and Pat Coursey Award (2006). The Institute was recognized for its outstanding research in cassava at the First International Meeting on Cassava Plant Breeding, Biotechnology and Ecology organized at Brasilia, Brazil in 2006.

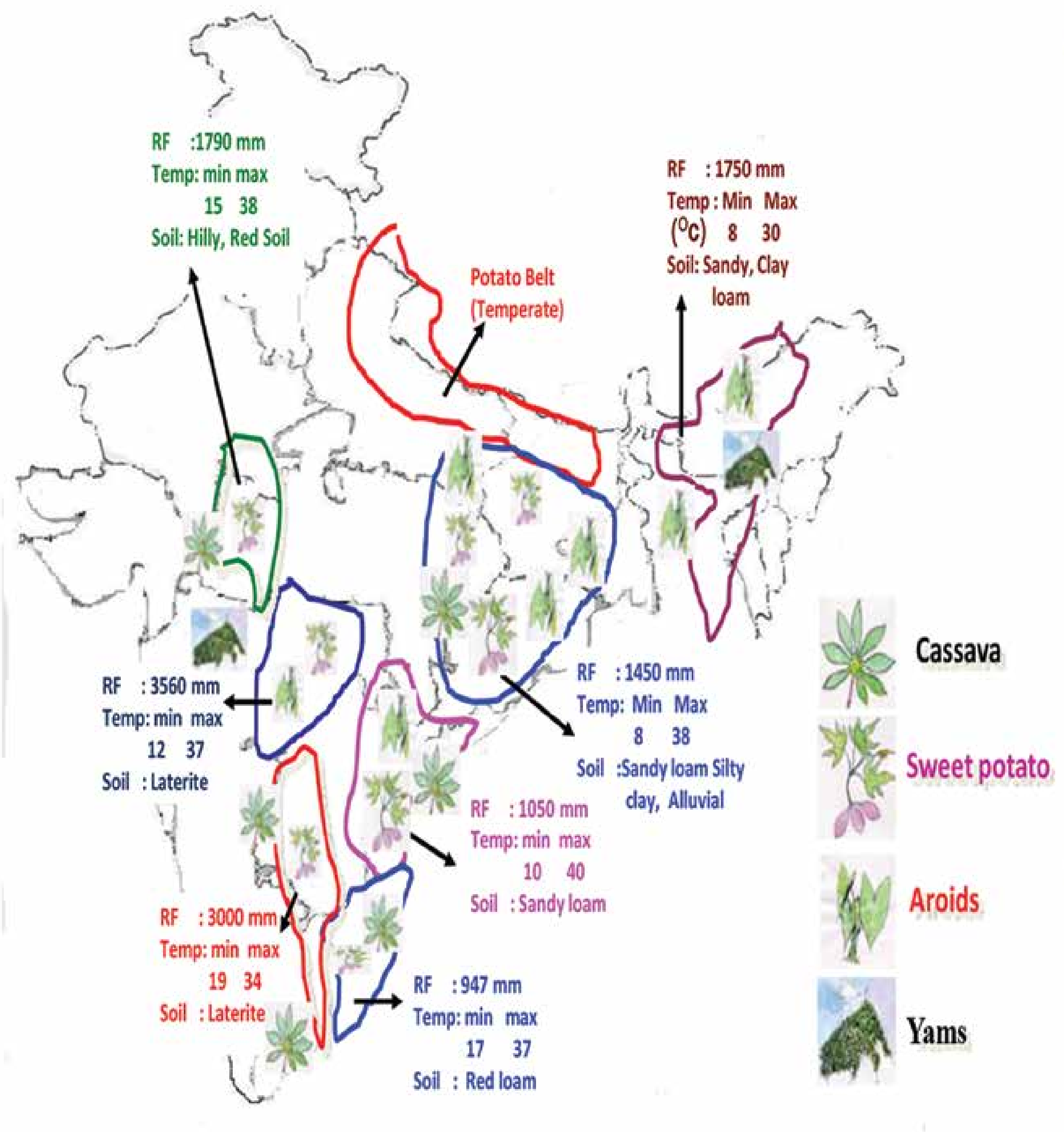
The national awards included, J. Chinoy Gold Medal (1970), ICAR Team Research Award (1985, 1996, 1998, 2014), Hari Om Ashram Trust Award (1993), Jawaharlal Nehru Award (1975, 1995, 1998, 2000, 2003), Young Scientist Award instituted by Deseeya Sasthra Vedi (1996), NRDC cash reward for biodegradable plastics (2000), Vasantharao Naik Memorial Gold Medal (2002), Samantha Chandrasekhar Award (2013), International Potash Institute (IPI)-Fertilizer Association of India (FAI) Award (2014), Shri. L.C. Sikka Endowment Award (2014), International Zinc Association (IZA)-FAI Award (2017) and Panjabrao Deshmukh Woman Scientist Award (2017). In addition, the Institute bagged several awards in national and international agricultural exhibitions in recognition of its contribution to tuber crops growers and consumers worldwide. The Best Annual Report Award was received by the Institute among the category of small Institutes during 1997-98 and 2017-18. The Institute obtained patent in 2021 for the design of the apparatus and the process of extraction of biopesticides from cassava leaves.

The Institute has conducted more than 30 national and international symposia / seminars / workshops since its inception. The Institute was supported by international funding agencies like CIRAD, European Union, IFAD and ISCB and being supported by CIAT, CIP and national funding agencies like DBT, DIT, DST, DRDO, DSIR, ICAR, LSRB, MOEF, NABARD, PRII, PPV& FRA, CDB, UGC and state funding agencies like KSCSTE, DoAD & FW, Govt. of Kerala, Odisha KSPB and SHM.

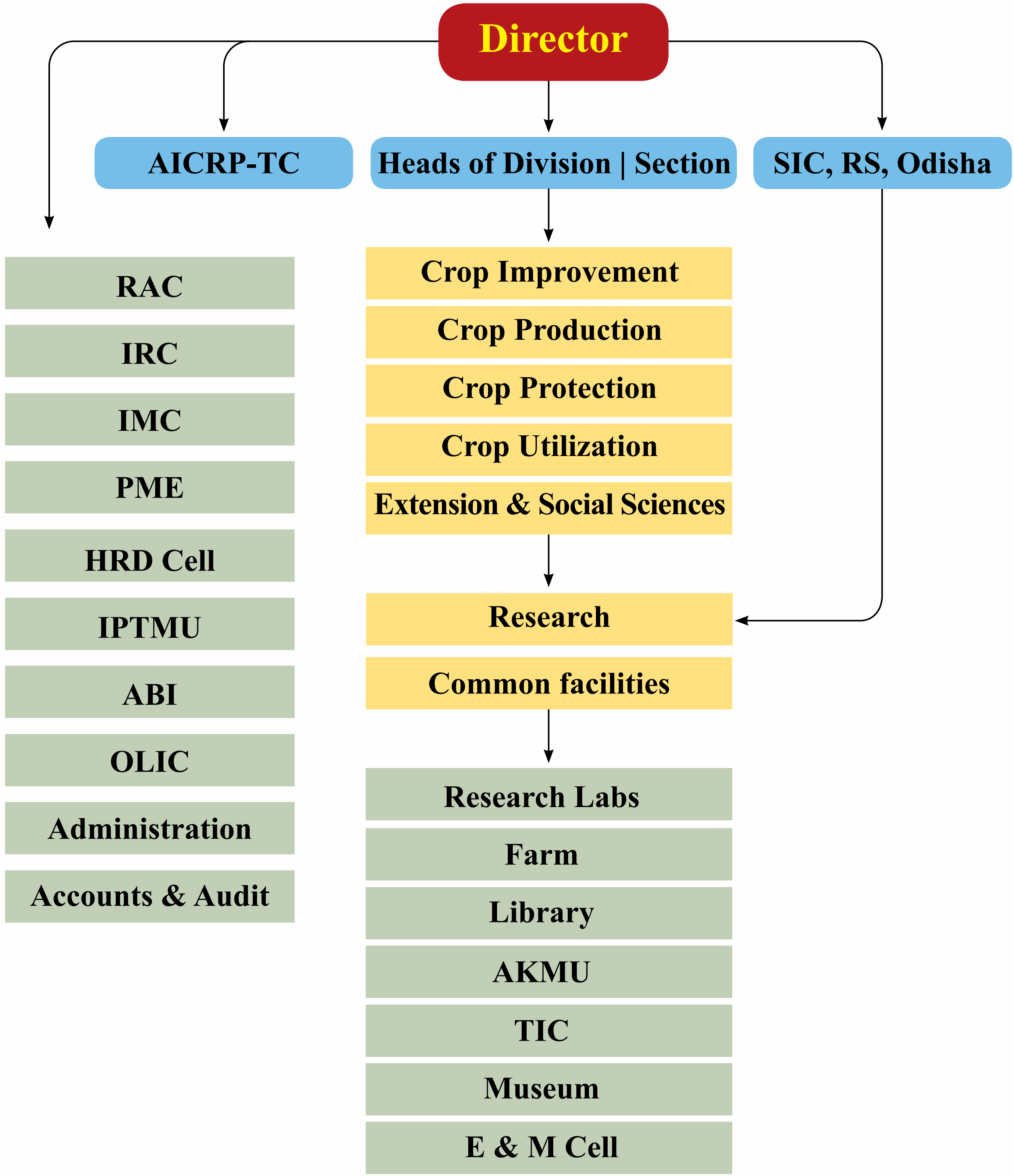
The IP related activities are executed by the Intellectual Property and Technology Management Unit (IPTMU) and various production, protection and processing technologies developed at the Institute are being commercialized through IPTMU under consultancy, licensing and contract research. The Agri Business Incubator (ABI) was established in 2019 both at HQ and RS under the National Agricultural Innovation Fund (NAIF - II). The Institute has installed Local Area Network (LAN) through a strong fibre optic backbone and the entire campus is wi-fi enabled. The VPN connectivity is established for global access to the servers.

The All India Co-ordinated Research Project on Tuber Crops (AICRP-TC) is functioning at ICAR-CTCRI HQ with 21 centres situated all over India for location specific testing of the varieties and technologies developed by the Institute. In addition, ICAR-CTCRI is a centre under the AICRP on Post Harvest Technology (PHT) and All India Network Programme on Organic Farming (AINP-OF).

2.0 Distribution of Tropical Tuber Crops in India



3.0 Organizational Structure



4.0 Staff Position

Category	Sanctioned	In position	Vacant
Research Management Post	1	0	1
Scientific	44	44	0
Technical	47	31	16
Administrative	30	22	8
Skilled Support Staff	38	25	13

5.0 Progressive Expenditure (2021-22)

Budget Head	Allocation (₹ lakhs)	Expenditure (₹ lakhs)
Establishment charges	1874.73	1872.70
Pension & retirement benefits	286.20	280.84
Grants for creation of capital assets	140.00	140.00
TA	13.73	13.73
Research & operational expenses	144.05	144.05
Administrative expenses	189.94	189.86
Miscellaneous expenses	2.28	2.28
SCSP	71.20	71.20
TSP	66.50	66.50
NEH	10.00	10.00
Internal research council share	25.00	25.00
Loans & advances	3.00	3.00
Total	**2823.63**	**2816.16**

6.0 Executive Summary

The gist of the research findings, development programmes and general activities carried out at the Institute during 2021 is presented below:

Crop Improvement

- The field gene bank (FGB) maintains 1216, 1110, 1121, 683 and 307 accessions of cassava, sweet potato, yams, edible aroids and minor tuber crops respectively at HQ and 1248 accessions of the above crops at RS.
- Of the total cassava accessions, 552 accessions maintained in the FGB were characterized for 29 vegetative, flower and fruit characters and incidence of CMD.
- The characters of 375 indigenous cassava accessions pertaining to 51 traits were published as 'Catalogue of Cassava Genetic Resources Revised (Part-1)'.
- The cassava variety, 8S501 (Sree Kaveri) with CMD resistance, drought tolerance and high yield (61.30 t ha^{-1}) was recommended by AICRP (TC) for central release for Kerala, Tamil Nadu and Andhra Pradesh for industrial use.
- Studies on carbohydrate dynamics under drought conditions with two highly tolerant (8S501, CR43-7) and two highly susceptible (H97, M4) cassava genotypes indicated the distribution of non uniform spongy parenchyma tissue in the pith region of the stem in the susceptible genotypes.
- Transcriptome sequencing of cassava accessions, 8S501 and H97 revealed that, 126 genes were upregulated and 129 genes were downregulated in both the genotypes and 2916 genes were upregulated in the genotype 8S501 and 1038 genes were downregulated in susceptible genotype (H97) under drought stress conditions.
- Identified the mutant cassava clones flowered in M_1V_2 generation of Sree Jaya with more female flowers and high fruit and seed set contrasting to their original parent cultivar (Sree Jaya).
- Hybridization between few mutant flowering clones in M_1V_2 and disease resistant clones of South American origin (3737 crosses) resulted in 1061 hybrid seeds, of which, 67 were susceptible and 480 were resistant to CMD.
- In the genetic analysis and QTL mapping for post harvest physiological deterioration tolerance and enhanced shelf life in cassava, the evaluation of the mapping population at different stages indicated significant variation for all the traits.
- Genome wide analysis led to identification of 73 glutathione s-transferase (*gst*) genes in cassava.

- The genes responsible for waxiness, *gbss* gene was elucidated from two cassava accessions 9S127 and 8S501 and the *gbss* gene sequence was used for designing guide RNAs for gene silencing construct.
- Preliminary evaluation of 366 orange fleshed sweet potato hybrids in the kharif season resulted in identifying the promising genotypes *viz.* 465/4, 517/2, 59/4, 473/8, 448/1 and 562/32 with yield ranging from 732-905 g plant^{-1}. Rabi season evaluation of the same genotypes identified the hybrids *viz.* 50/71, 352/14, 95/1, 364/6 and 50/63 as promising with total carotenoids to the tune of 2-20 mg 100 g^{-1} on fresh weight basis (FWB).
- The promising purple fleshed sweet potato hybrids performed well during kharif and rabi seasons were H-38/46, H-110/28 and H-38/15.
- Three orange fleshed sweet potato hybrids *viz.,* H-473/8, H-562/32 and H-43/83 were submitted for AICRP trials.
- Sweet potato genotypes *viz*., DB/21/57 (17.00 t ha^{-1}), RS-III-3 (16.60 t ha^{-1}), B × 7 (15.44 t ha^{-1}), SP-123 (13.37 t ha^{-1}) and S-162 (12.88 t ha^{-1}) were identified as drought tolerant lines.
- Sweet potato hybrids, four white fleshed (SPH 65, SPH 19, SPH 61, SPH 60) four orange fleshed (SPH 44, SPH 21, SPH 52, SPH 40) and five purple fleshed (SPH 31, SPH 30, SPH 29, SPH 15, SPH 14) are under evaluation at RS, Odisha.
- A total of 1121 accessions of yams comprising greater yam (600), white yam (158), lesser yam (222), potato yam (6) and wild yams (135) are maintained in the FGB.
- Among the 370 greater yam genotypes screened for anthracnose under field condition, Sree Karthika, SHY-132, S-53 and Da-11 were resistant, 138 were tolerant, 70 were susceptible and 158 were highly susceptible.
- In the Advanced Yield Trial (AYT) of greater yam, DaS-43 recorded the highest tuber yield (89.1 t ha^{-1}) and in the AYT of white yam, DRS-1047 recorded the highest tuber yield (88.5 t ha^{-1}).
- Among the non trailing white yam clones, DrD-1112 recorded the highest dry matter (44.2%) and SD-15 recorded the highest tuber yield (44.72 t ha^{-1}).
- Optimized the *in vitro* pollen germination medium for greater yam to test the pollen viability of male parents.
- The edible aroid germplasm was augmented with 20 new accessions.
- The aroid germplasm (FGB) consisted of 683 accessions comprising taro (429), elephant foot yam (203), tannia (48) and *Alocasia* (3).
- The lines having traits of interest identified from the edible aroid germplasm were seven early maturing taro accessions (CA61, CA62, CA63, CA64, CA65, CA67, CA68) which matured within five months, three flowering taro accessions (TCR947A, IC420620, TTr17-1) and two flowering tannia accessions (TTn14-6, Miz/20-8) and four high yielding taro lines (CE-558, CE-334357, CE-416937, CE-807949).
- In elephant foot yam, two high yielding hybrids were identified *viz.*, H-102-2015 and H-6-7-2017.
- Thirty accessions of Chinese potato evaluated showed that, the tuber yield ranged from 5.25 (TCR-144) to 34.90 t ha^{-1} (SAASV-15) and 16 accessions recorded higher tuber yield (15.95-34.90 t ha^{-1}) than the check variety, Sree Dhara (15.65 t ha^{-1}).
- Five starchy *Curcuma* accessions (IC 641835 to IC 641839) and seven Chinese potato accessions (IC 641828 to IC 641834) were allotted IC numbers.
- Pre selected four starchy *Curcuma* accessions were characterized for variability and compared with tikhur-1 (*Curcuma angustifolia)* and observed higher starch percentage, essential oil and antimicrobial compounds in *C. zedoaria* than tikhur-1.
- Methanolic extract of *C. angustifolia* showed antibacterial effects against *Staphylococcus aureus, Klebsiella pneumoniae, Mycobacterium smegmatis, Vibrio cholerae, Salmonella typhi* and also antifungal effects against *Candida albicans*
- Genetic variations were studied in 30 yam bean cultivars using molecular markers and based on biochemical characteristics.
- Proton-induced X-ray emission (PIXE) technique was employed for the first time to determine the nutrients present in 30 yam bean genotypes.

- Five best yam bean hybrid lines (3×5, 3×8, 3×9, 3×10 and 9×10) along with check variety (RM-1) were evaluated for yield and other biochemical traits at RS, Odisha.
- Seed quality evaluated for the RM1 variety of yam bean indicated light brown colour of seed coat is a good seed quality parameter.
- Poor seed quality in dark black seed coat is due to infection with *Penicillium* sp. and *Macrophomina phaseolina* in the seed health test.
- Among the 30 arrowroot accessions, the dry matter content was highest in TCR-110 (33.46%) and lowest in TCR-141 (22.32%).
- Six arrowroot accessions *viz.,* ASAKI-1 (29.92%), ASAKI-3 (31.56%), ASAKI-4 (30.97%), ASAKI-5 (29.87%), ASAKI-8 (29.67%) and SAASV-6 (30.12%) were identified as promising with higher dry matter than the check variety Sree Dhara (29.54%).
- In arrowroot, the fourth year AYT of seven genotypes showed a tuber yield of 23.69 (M-5) to 28.35 t ha^{-1} (M-7) with total tuber starch content of 18.20% (M-5) to 20.37% (M-3), crude fiber content of 0.83% (M-5), 0.84% (M-3) and 1.09% (M-1, M-7) and tuber dry matter content of 33.22% (M-6) to 38.93% (M-5).
- Developed *in vitro* plant regeneration protocol of taro high yielding early line (Telia) and Chinese potato variety (Sree Dhara).
- DUS testing guidelines were developed for taro, elephant foot yam, greater yam and yam bean.

Crop Production

- Rice-short duration cassava (var. Vellayani Hraswa) + cluster bean (var. Gloria) cropping system was the most productive (tuber equivalent yield: 35 t ha^{-1}, production efficiency : 97.11 kg ha^{-1} day^{-1}), profitable (net return: ₹ 2,86,147 ha^{-1}, added profit: ₹ 97,740 ha^{-1}) and energy efficient (230.03×10^3 MJ ha^{-1}), besides nutrient saving to the extent of half FYM , half N and full P to cassava.
- Intercropping of taro with vegetable cowpea (1:1) resulted in significantly greater cormel equivalent yield (23.54 t ha^{-1}) with a land equivalent ratio (LER) of >1, indicating its biological efficiency.
- In taro, use of weed control ground cover perforated mat (120 gsm) resulted in higher plant height (53.33, 62.33 cm), more number of leaves per hill (6.28, 10.93) and LAI at 2 and 4 MAP respectively with least weed density and weed dry weight.
- Paddy straw mulch in taro resulted in the highest tuber yield (25.8 t ha^{-1}) and lower weed dry weight (10.9 g m^{-2}).
- Planting taro at 74000 plants ha^{-1} resulted in higher tuber yield (17.4 t ha^{-1}) with better net returns.
- Supplementing sweet potato plants with furrow irrigation produced the highest tuber yield (16.25 t ha^{-1}).
- In taro, plastic ground cover mulching with drip irrigation at 50% CPE resulted in the highest cormel yield (27.94 t ha^{-1}).
- Supplementing greater yam plants with 60% CPE through drip irrigation along with N:P:K @ 100:60:100 kg ha^{-1} resulted in higher tuber yield and water use efficiency.
- Fertilizer Best Management Practices (FBMP) by SSNM significantly enhanced the tuber/corm yield of cassava (+16.30%), elephant foot yam (+14.5%), greater yam (+18.85%) and white yam (+17.70%) compared to present recommendation.
- Balanced application of N:P:K @ 80:60:100 kg ha^{-1} resulted in higher yield response (94%) over NK (52%) > NP (46%) > PK (43%) with the highest dehydrogenase and urease activities under N:P:K @ 80:60:80 kg ha^{-1}
- Out of 90 elite genotypes of sweet potato screened, Sree Bhadra produced significantly the highest tuber yield (46.8 t ha^{-1}) and Sankar, Kalinga, Kishan, Bhu Sona, Bhu Krishna, Sree Bhadra, Pusa Safed, Kanjangad and Kamala Sundari and genotypes *viz.,* SB 573/3 contained higher macro and micronutrients in tubers and leaves.
- Among the different INM approaches, the soil and plant test based customized fertilizers resulted in the highest tuber yield (32.0 t ha^{-1}) on par with low input management strategy (27.7 t ha^{-1}) in cassava.

- Soil application of borax @ 25 kg ha^{-1} (half each at basal and 3-4 MAP), foliar application of solubor @ 0.1% and calcium nitrate @ 1% (during 3-4, 5-6 and 7-8 MAP), soil application of lime @ 2 t ha^{-1} emerged as a corrective measure for the suspected B deficiency in yams.
- Soil B critical level for tuber cracking in sweet potato was found as below 0.5 ppm.
- Application of nutrients *viz.*, P, K, Ca, Zn and Si resulted in the reduction of mean percentage disease incidence (PDI) to 16.4 and 51.2% over initial (70.19%) at 6 and 8 MAP respectively.
- Study on soil carbon pools indicated that, the soil organic carbon was maximum (7.8 g kg^{-1}) in laterite soils, lowest in red soils (5.8 g kg^{-1}), labile carbon was maximum in clay loam (546.0 mg kg^{-1}) and lowest under laterites (263.5 mg kg^{-1}).
- Tuber yield of cassava was significantly higher in climate smart agriculture (CSA) practice (29.50 t ha^{-1}) than conventional practice (25.40 t ha^{-1}).
- Global warming potential (GWP) of CSA is 194 kg carbon equivalent (CE) ha^{-1}, and 272 kg CE ha^{-1} for conventional practice, showing the superiority of CSA in reducing GHG emission compared to the conventional practice.
- Foliar application of 1% KNO_3 during water stress period (3-5 MAP) enhanced the above and below ground biomass accumulation capacity and partitioning index by virtue of maintenance of higher photosynthetic efficiency, LAI and incidentally higher tuber yield (2.87 kg $plant^{-1}$).
- Application of GA_3 @ 100 ppm resulted in higher plant height (85 cm), stem girth (12 cm) and canopy spread (45 cm) with significantly higher tuber yield (38.75 t ha^{-1}) followed by IAA @ 200 ppm in cassava (var. Sree Reksha).
- In elephant foot yam, GA_3 @ 200 ppm resulted in highest corm yield (38.65 t ha^{-1}).
- A sett size of 50 g along with application of SAAF @ 1% enhanced the tuber yield in greater yam.
- The impact of climate change on crop water requirement as well as irrigation requirement of cassava, sweet potato, greater yam, elephant foot yam and taro were analyzed over the major growing areas in India using the FAO-CROPWAT and LARS-weather generator for 2030 and 2050. The increase/decrease in magnitudes of gross irrigation requirements for cassava, sweet potato, greater yam, elephant foot yam and taro to the current irrigation requirement was -2.6 to 291.1 mm, -0.3 to 18.4 mm, 5.3 to 392.1 mm, -33.6 to 311.2 mm and 100.8 to 263.8 mm respectively during 2030 and 2050. The optimum irrigation schedules were also developed for the selected crops over the major growing areas.
- On farm validation of SSNM based customized fertilizers and organic farming conducted in 10 coconut gardens of Pathanamthitta district, Kerala indicated that, cassava, SSNM resulted in higher yield over farmers' practices (FP) by 19.54% and PoP by 6.65%. In greater yam, SSNM performed better than FP by 16.82% higher yield and PoP by 12.26%. In cassava, organic farming yielded higher over FP by 18.20% and PoP by 3.26%. In greater yam, organic farming yielded higher over FP by 13.89 % and PoP by 11.99 %.
- Sree Suvarna variety of cassava had higher crop yield at controlled light treatment (4.31±0.32 kg $plant^{-1}$) compared to intermittent high light conditions (4.11±0.44 kg $plant^{-1}$) and was found to be tolerant to light fluctuations.
- A total of 115000 cassava stems, 37.5 MT of elephant foot yam, 32.5 MT of greater yam, 3 MT of white yam, 3.50 MT of lesser yam, 1410000 vine cuttings of sweet potato, 30000 vine cuttings of Chinese potato and 200 kg of yam bean were produced as quality planting material.
- Seed villages (13) were established for the production of quality planting materials of cassava, sweet potato, elephant foot yam and Chinese potato in Tamil Nadu and Kerala.
- Nineteen farmers were registered as Decentralized Seed Multipliers (DSM) for quality planting material production.
- Under RKVY Kerala, quality planting materials of elephant foot yam, cassava and sweet potato were produced in 5.5, 2 and 0.5 acres respectively.
- Under RKVY, Odisha, FLDs were conducted on sweet potato (118.3 ha), cassava (23.6 ha), yams (34.7 ha), yam bean (50.2 ha), elephant foot yam

(19.1 ha) and C*olocasia* (13.2 ha) with a total area of 259.10 ha involving 1360 beneficiary farmers.

- Seventeen off-campus trainings on value addition of tuber crops were organized benefitting 850 farmers in 10 districts of Odisha.

Crop Protection

- Screening of biopesticides *viz., Nanma* along with five other biopesticides *viz.,* Nimbecidine, Abtech, Guard, Agro bioplus and neem oil at three concentrations (1, 3 and 5%) against sweet potato weevil (SPW) by filter paper assay method showed highest mortality in agro bioplus (92%) at 24 HAT (hours after treatment) followed by neem oil (56.0%).
- Evaluation of six synthetic insecticides *viz.,* chlorpyrifos 20 EC, fenvalerate 20 EC, dimethoate 30 EC, dichlorvos 76 EC, quinalphos 25 EC and imidacloprid 17.8 SL in three concentrations (0.001, 0.01 and 0.05%) against SPW showed highest mortality at 168 HAT under 0.001% concentration of fenvalerate (74%) followed by imidacloprid (58.0%).
- Bioassay of various promising insecticides and their combinations against cassava mealybug gave best result with 80-85% mortality under the combination of *Nanma* and imidacloprid at 1:1 and 1:3 at 3DAT, followed by combination of spirotetramat 11.01% and imidacloprid 11.01% (Movento Energy 240 SC®) (80%) and flonicamid 50% WG (Ulala®) with 60-65% mortality.
- Survey of tuber crops pests in Thrissur and Malappuram districts of Kerala, indicated the presence of a new emerging pest in elephant foot yam, *Sphenoraia hopei* (Alticinae, Chrysomelidae) causing more than 40% foliage damage.
- Morphological screening of different *Ipomoea* sp. (*I. mauritiana, I. palmata, I. obscura* and *I.triloba*) against SPW using choice assay method revealed significantly less infestation in *I. mauritiana* tubers, which were selected for molecular screening studies.
- PCR amplification of protease inhibitor, cysteine protease inhibitor and kunitz trypsin inhibitor genes with specific primers were established in four *Ipomoea* sp.
- Fluopyram (0.5, 0.75 ppm) was the most effective among the tested chemicals causing cent percent mortality and hatching inhibition of *Meloidogyne incognita* in *in vitro*.
- Fungal bioagent *Trichoderma asperellum* (isolate Tr-9) was highly compatible with the nematicide carbofuran, while the biopesticide, *Nanma* was highly incompatible with *Trichoderma* in *in vitro*
- In cassava, the pathogen associated with stem and root rot belongs to FSSC (*Fusarium solani* species complex) Clade 3. In farmer's field, carbendazim and propineb showed highest reduction (100%) of the disease followed by *Nanma* (88%), *Trichoderma asperellum* (75%) and copper oxychloride (60%) after six months of its application.
- Sree Reksha did not exhibit any stem and root rot symptom while local varieties showed 20-50% root and stem rot incidence.
- Spraying of *Bacillus cereus*, an endophyte showed highest reduction in anthracnose intensity (63%) in greater yam compared to control, which was on par with growing Sree Keerthi in the border (60%); tuber treatment with *Nanma* and spraying the combination of 0.025% carbendazim and 0.7% *Nanma* seven times (53%); spraying 0.025% carbendazim (53%) and the present package of soil and tuber treatment with *Trichoderma asperellum* along with seven sprays of 0.05% carbendazim (49%).
- Among the 12 fungicides tested for taro leaf blight, collar rot and leaf rot in EFY, cymoxanil+ famoxadone was the most effective against *P. colocasiae*, with 100% mycelial inhibition at 6.25 $\mu g\ ml^{-1}$, difenconazole and carbendazim + mancozeb were highly effective against *C. gloeosporioides*, with 100% mycelial inhibition at 18.75 $\mu g\ ml^{-1}$, whereas hexaconazole and difenconazole were highly inhibitory to *S. rolfsii*, with 100% mycelial inhibition at 3.125 $\mu g\ ml^{-1}$.
- XG boost model for predicting PDI of taro leaf blight was developed based on factors *viz.,* crop age (MAP), minimum and mean temperature (°C), minimum relative humidity (%) and wind speed ($m\ s^{-1}$).

- Compatibility studies of *Trichoderma asperellum* with twelve fungicides at concentrations ranging from 3.125 µg ml^{-1} to 3200 µg ml^{-1} indicated least sensitivity to the fungicides *viz.,* propineb, copper oxychloride, cymoxanil + mancozeb and cymoxanil + famoxadone and highest sensitivity to the fungicides *viz.,* carbendazim, carbendazim + mancozeb and hexaconazole where concentration as low as 5µg ml^{-1} inhibited more than 50% mycelial growth.
- Analysis of cassava leaf samples collected from Thiruvananthapuram, Kozhikode and Kottayam districts showed mixed infection with *Sri Lankan Cassava Mosaic Virus* (SLCMV) and *Indian Cassava Mosaic Virus* (ICMV). Kollam and Wayanad districts had only SLCMV infection and Thrissur district had only ICMV infection.
- DsMV infection caused significant reduction in the corm yield of elephant foot yam (25-83.5%).
- Primers were designed for molecular variability analysis of the sequences of the P1, P3, CI, NIa, NIb, CP region of DsMV from the whole genome sequence data available in the NCBI database.
- ELISA performed using the DsMV-IgG in the field infected elephant foot yam and taro proved the efficiency of the antibody in detecting DsMV infection.
- Recombinase Polymerase Amplification (RPA) (TwistDx) diagnostic test was developed for detection of SLCMV, sweet potato feathery mottle virus (SPFMV) and DsMV.
- LAMP assay was standardized for the detection of SPFMV and a set of six primers were used based on the coat protein gene sequence of the virus.
- DsMV-IgG and SPFMV-IgG were used to develop lateral flow devices to detect DsMV and SPFMV from field infected elephant foot yam and sweet potato samples respectively.

Crop Utilization

- The biomass distribution of leaf, stem, peel and tuber of different varieties of cassava indicated the stem fresh weight ranged from 27.45 (H-226) to 42.23% (Sree Vijaya), tuber mass fraction ranged betwen 43.38 (Sree Vijaya) to 61.97% (H-226, Sree Suvarna). Vellayani Hraswa had the maximum leaf mass fraction (19.05%) while Sree Pavithra had the minimum (2.44%).
- Drying characteristics of cassava stem under sun and mechanical tray drying indicated the average drying rate as 0.358 g water min^{-1} 100 g^{-1} bone dry material under sun drying and 0.739 g^{-1} water min^{-1} 100 g^{-1} bone dry material for mechanical drying.
- Standardization of method for extraction of starch from cassava stem by varying the size of the stem (fine, medium, large) and soaking time (8, 16, 24 h) indicated the starch recovery ranged from 10.1-13.9% by conventional settling. Stem particle of larger size (2-2.5 cm) was suitable for getting maximum recovery with moderately high starch purity and colour. Viscosity of the starch extracted from stem is lesser than that of tuber starch due to the presence of fibrous material.
- The optimized conditions for the prepation of thermoplastic sheet from cassava starch-rice husk composite as per the response surface analysis was husk @ 25%, glycerol @ 50%, temperature @ 150ºC and pressure @ 140 bar.
- The optimized conditions for the preparation of thermoplastic sheet from cassava starch-rice straw composite as per the response surface analysis was straw @ 13 %, glycerol @ 25 %, temperature @ 125ºC and pressure @ 130 bar.
- Rheological properties of cement mortar mixed with native and modified starch were tested to explore the possibilities of using cassava starch for non-traditional applications in construction and building materials.
- Biodegradable film prepared from cassava starch-graft and soybean oil maleate (CS-SOMA) exhibited significantly lower moisture absorbability (<10% after 72 h of exposure at 78% relative humidity) than native cassava starch films. The aqueous solubility varied from 4.4-26.3% for different films.
- The reaction conditions were standardized for synthesizing different levels of cross-linked cassava starch by using sodium tripolyphosphate (STPP)

and sodium trimetaphosphate (STMP) reagents in different molar ratios and some of which could withstand high temperatures and were non-gelatinizable.

- Wet milling of *Alocasia* tubers after pretreatment with sodium metabisulphite could reduce the calcium oxalate content to 0.01-0.02 % in the tuber starch with the starch yield of 24% compared to 0.03% in the non-treated tubers.
- Important engineering properties such as moisture, length, width, thickness, arithmetic mean diameter, geometric mean diameter, roundness and sphericity were studied to design and develop a size based grader for Chinese potato tubers.
- Chinese potato grader was designed and developed with one tonne capacity per hour which can separate tubers based on size as small, medium and large.
- Nutrient rich breakfast pancake mix was developed using sweet potato - finger millet based composite flours which showed significantly higher fiber (1.31%), ash (8.54%), protein (15.37%) and starch (59.61%) on dry weight basis (DWB).

Extension & Social Sciences

- Fifteen FLDs on improved varieties of Chinese potato (Sree Dhara) conducted in Tirunelveli and Tenkasi districts of Tamil Nadu showed the yield of Sree Dhara (24.43 and 24.87 t ha^{-1}) was higher than that of local varieties (21.17 and 21.93 t ha^{-1}). Net income realized from Sree Dhara was ₹ 2.79 lakhs and ₹ 3.22 lakhs ha^{-1} (B:C ratio: 3.51 and 3.84) in comparison to local varieties, which was ₹ 2.31 lakhs and ₹ 2.74 lakhs ha^{-1} (B:C ratio: 3.15 and 3.49). Technology gap, extension gap and technology index of Sree Dhara was estimated as 3.57 and 3.13, 3.26 and 2.94, 12.75 and 11.18 respectively for Tirunelveli and Tenkasi districts.
- Farmers' innovations and ITKs pertaining to varieties, agronomic practices, nutrient management, pest and disease management, mechanization, pre and post harvest processing, value addition, storage of planting materials and tubers were documented from tuber crops growers of Wayanad, Malappuram, Ernakulam and Thiruvananthapuram districts of Kerala.
- Sensory evaluation and consumer assessment of biofortified sweet potato pasta conducted among school children in Arunachal Pradesh and college students in Tripura indicated orange fleshed sweet potato (OFSP) pasta had better preference than purple fleshed and white fleshed pasta. Over 80% of the children indicated, OFSP was preferred due to its health benefits and taste. The per capita monthly consumption of sweet potato is 0.23 kg.
- Mapping of women empowerment in Tirunelveli and Tenkasi districts in Tamil Nadu revealed that, majority of the women respondents (83.33%) and men respondents (71.21%) had medium level of participation in Chinese potato cultivation. The empowerment index was 0.55 for women and 0.80 for men.
- Price forecasting of sweet potato was carried out for six selected states in India using time series monthly market price. The time delay neural network model predicted accurate future prices of sweet potato in selected states of India. The forecasted average market price of sweet potato in selected states of India *viz*., Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana, would be in the range of ₹ 684 to ₹ 2757 per quintal during January 2022 to December 2022.
- The impact of FLDs conducted for Chinese potato (var. Sree Dhara) in Tamil Nadu revealed the average demonstration yield as 24.89 t ha^{-1} whereas the average farmers existing yield was 21.79 t ha^{-1} with a decline in extension gap from 3.8 - 3.1 t ha^{-1} with slight improvement in technology gap and technology index values.
- e Crop based smart farming technology was developed and demonstrated in sweet potato field by setting up a smart fertigation facility on station and the field trial is in progress.
- Phyre 2, a web based tool for predicting and analysing protein structure and function using advanced remote homology detection methods was used for 3D modelling of the identified genes.
- *In silico* methods were applied effectively for identifying the protein-protein interactions (PPI).

- Application of SVM (Support Vector Machine) classification in R resulted in about 71% accuracy prediction.
- Random Forest Model was developed for cassava intra species PPI.
- D-Script deep learning technique was performed in python environment.
- Under SCSP programme, 185 demonstrations on improved varieties and production technologies of tuber crops were conducted in Kerala, Tamil Nadu and Andra Pradhesh. Planting materials of improved varieties of tuber crops, inputs, farm implements and tools were distributed. Twenty nine outreach programmes were conducted for the benefit of 2097 farmers and other stakeholders.
- Under the NEH programme, quality planting materials of improved varieties of tuber crops *viz*., cassava, sweet potato, yams, elephant foot yam and taro were distributed to the farmers for seed villages. Six outreach programmes *viz*., training, group discussions and farm advisory visits were conducted in Arunachal Pradesh and Tripura for the benefit of 420 farmers and other stakeholders. Under 'Rainbow Diet Campaign', two nutritional awareness programmes were conducted among school children in Arunachal Pradesh and adolescents in Tripura. Ten frontline demonstrations of improved variety of taro were conducted in five villages in Anjaw district of Arunachal Pradesh.
- Under TSP, 523 tribal households were adopted from 9 blocks of Odisha and planting materials of sweet potato, greater yam, elephant foot yam, *Colocasia*, yam bean, cassava, maize seed, red gram and vegetable seed kits were distributed.

General Information

- One international workshop and one international training programme were organized, besides 29 webinars under Azadi Ka Amrit Mahotsav which was attended by more than 2000 stakeholders. A total of six iconic events and all important national and international days|week celebrations were conducted.
- Most of the scientists attended online training programmes|seminars|symposia|webinars and four technical and four administrative staff also attended different trainings.
- Five technologies were commercialized with a revenue generation of ₹ 3.25 lakhs, one technology received patent, one contract research was undertaken, nine technologies were developed, six technologies were transferred and seven technologies were recommended for addition in the existing PoP of tuber crops of Kerala Agricultural University (KAU).
- Under the education programme, there are 20 Ph.D, 60 M.Sc. and 99 internship students.
- A total of 575 farmers, 96 students and 23 officials visited the Institute HQ and RS.
- The Institute held 17 exhibitions mainly in Kerala, Tamil Nadu, Andhra Pradesh and Odisha.
- The Institute conducted all national and international days|week celebrations and live streamed all significant programmes and arranged awareness classes for the stakeholders during the occasion.
- The Institute was visited by dignitaries including the Hon'ble Minister for Agriculture Development and Farmers' Welfare, Govt. of Kerala; the Hon'ble MLA, Kazhakuttam; Respected Mayor, Thiruvananthapuram Corporation; Director, Department of Agriculture Development & Farmers Welfare (DoAD & FW), Govt. of Kerala (GoK).
- Out of the total 58 research papers in peer reviewed journals, more than 75% are in high rated journals with NAAS score above 6 with a total impact factor of 88.12 during this year. There were 53 popular articles, two books, 26 book chapters, 57 paper presentations, seven technical bulletins, seven chapters in course|training manuals, 76 pamphlets|leaflets| folders in different languages, one compendium paper, four Institute publications, one e-publication, four TV programmes, eight radio talks, one YouTube and six facebook live programmes.

7.0 Research Achievements

7.1 Crop Improvement

Theme Areas

- Germplasm conservation
- Trait specific breeding
- Marker assisted breeding
- Gene editing
- Allele mining
- Genomics

Achievements

- Developed a CMD resistant & drought tolerant cassava variety 'Sree Kaveri'
- Elucidated *gbss* gene from cassava accessions 9S127 and 8S501 for silencing and development of waxy cassava
- Identified drought tolerant sweet potato genotypes (DB/21/57, RS-III-3, B × 7, SP-123, S-162)
- Identified the first pre release arrowroot variety with high yield and starch
- Identified nutrient rich lines in yam bean using Proton-Induced X-ray Emission (PIXE) technique

Institute Projects

Sl. No.	Project code | Project title | PI	Co-PIs
I.	HORTCTCRISIL 202000901465 | **Conservation and utilization of germplasm of tuber crops for sustaining production** | **K. I. Asha**	M. N. Sheela, P. Murugesan, A. Asha Devi, Shirly Raichal Anil, Kalidas Pati, V.B.S. Chauhan, N. Krishna Radhika, Vivek Hegde, A.V.V. Koundinya, K.M. Senthilkumar, C. Visalakshi Chandra, T. Makeshkumar, M. L. Jeeva, S. S. Veena, E. R. Harish, H. Kesava Kumar, A. N. Jyothi, J. Sreekumar, T. Krishnakumar, M. Nedunchezhiyan, R. Arutselvan
II.	HORTCTCRISIL 202001001466 | **Genetic improvement of tuber crops through conventional breeding and molecular approaches** | **M. N. Sheela**	K.I. Asha, P. Murugesan, A. Asha Devi, C. Mohan, Shirly Raichal Anil, Kalidas Pati, V. B. S. Chauhan, N. Krishna Radhika, Vivek Hegde, A.V.V. Koundinya, K.M. Senthilkumar, C. Visalakshi Chandra, T. Makesh Kumar, M.L. Jeeva, S.S. Veena, E.R. Harish, A.N. Jyothi, J. Sreekumar, T. Krishnakumar, M. Nedunchezhiyan, K. Laxminararyana, S. Sunitha, Saravanan Raju, P. Prakash, P. Sethuraman Sivakumar, R. Arutselvan, R. Muthuraj, D. Jaganathan, K. Susan John, G. Byju, G. Suja

External Funded Projects

Sl. No.	Title | PI | Co-PIs	Funding agency
1	**Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro** | **Kalidas Pati** | J. Sreekumar	Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA), New Delhi
2	**Establishment of varietal gene bank and development of standards of DUS testing in yam bean (*Pachyrhizus erosus*) and greater yam (*Dioscorea alata*)** | **M. N. Sheela (Lead Centre)** **Kalidas Pati (Collaborating Centre)** | J. Sreekumar, Vivek Hedge, M. Nedunchezhian	Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA), New Delhi
3	**Establishment of varietal gene bank and development of standards of DUS testing in cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*)** | **M. N. Sheela** | K. I. Asha, A. Asha Devi Shirly Raichal Anil, Kalidas Pati N. Krishna Radhika	Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA), New Delhi

4	***In vitro* quality planting material production of tuber crops to meet the demand of Odisha** | **V. B. S. Chauhan** | Kalidas Pati, K. Hanume Gowda, M. Nedunchezhiyan	Rashtriya Krishi Vikas Yojana (RKVY), Dept. of Agriculture Development & Farmers Welfare, Government of Odisha (GoO)
5	**ICAR-CTCRI-CIP Collaborative work plan activity on crop improvement and varietal selection of sweet potato** | **Shirly Raichal Anil** | C. Visalakshi Chandra, A.N. Jyothi, V.S. Santhosh Mithra, P. Sethuraman Sivakumar, Saravanan Raju	International Potato Centre (CIP), New Delhi
6	**Applied mutagenesis in cassava for improved agronomic, disease resistance and post harvest traits** | **A.V.V. Koundinya**	Board of Research in Nuclear Sciences, Department of Atomic Energy, Government of India

Institute Project I

Conservation and utilization of germplasm of tuber crops for sustaining production

The project comprises Field Gene Bank (FGB) and *in vitro* conservation of germplasm of tropical tuber crops *viz.,* cassava, sweet potato, yams, elephant foot yam, taro, tannia, arrowroot, yam bean and minor tuber crops and the new collections made during this year for exploring their utilization in evolving new varieties with desired specific traits.

At ICAR-CTCRI-HQ, the germplasm collection comprises cassava(1216), sweet potato (1110), yams (1121), edible aroids (683) [taro (429), elephant foot yam (203), tannia (48), *Alocasia* (3)] and minor tuber crop (307) accessions. At RS, Odisha, a total of 1248 accessions of these crops are maintained.

Cassava

A total of 28 accessions comprising 26 voucher samples received from HRS, Peddapuram, Andhra Pradesh and two others, one each from Thenmala, Kollam district and Ranni, Pathanamthitta district were added to the existing germplasm. The existing 1216 accessions of cassava comprising indigenous, exotic, landraces and breeding lines were replanted in the field during 2020-21 for maintenance, characterization and preliminary evaluation (Fig.1). Of these, 552 accessions were subjected to preliminary characterization for 29 vegetative, flower and fruit characters (22 qualitative and 7 quantitative).

Fig.1. Cassava germplasm field view

Among the 552 accessions, plant height ranged from 17 - 380 cm. A maximum of 475 accessions had the height range 100-300 cm. Plant type varied as compact (102), cylindrical (108), open (310) and umbrella (32). Shape of the plant was erect (124), spreading (306) and top spreading (122). Growth habit of young stem was straight (47) and zigzag (505). The level of branching was dichotomous (206), trichotomous (211), tetrachotomous (2) and erect (128). Branching angle varied as 30-80^{o} and height of first branching ranged from 19-279 cm. Young stem colour was green (232), light green (153), dark green (20), greenish purple (82), purplish green (58) and purple (7). Mature stem showed wide range of colour variations from brown (143), light brown (227), cream (28), ranges of green (67), silver green (82), purplish green (4) and orange (1).

Leaf scar was prominent (219) and semi prominent (333). Colour of apical leaves, varied from green (19), dark green (3), light green (223), purple (34), light purple (1), purplish green (261) to greenish purple (11). The distance between leaf scars ranged from 1-10 cm, of which, 362, 132, 49, 6 and 3 accessions had 2-4, 1-2, 4-6, 6-8 and 8-10 cm respectively.

Mature leaf colour was dark green (326), green (225) and purple green (1). Number of leaf lobes in 328 accessions were seven, in 112 and 9 in 26, 5 in 8, 8 in 11, and was one and variable of 5, 6, 7, 8, 9 and 10 in 77 accessions. Length of central leaf lobe ranged from10.5 - 27 cm and width as 0.5 cm in narrow leaved to 8.5 cm in broad leaf types. Leaf lobe margin was smooth in 527 and winding in 25 accessions. Leaf vein colour ranged from green in 516 accessions to purplish green in eight and purple in 28 accessions. The colour of the lamina petiole joint was green in 323, purple in 118, light purple in 101, green purple in six and purple green in four accessions.

Petiole orientation was found drooping (64), upwards (267), straight (147) and irregular (74). Petiole base, middle and top colour, showed wide range of variations from green, dark green, light green, purple, light purple, dark purple, green purple to purple green. Dark purple was the prominent petiole colour in base (140), light green (156) and purple (150). The petiole middle colour was purple in 145 accessions. The petiole top was light green in 128 accessions. Petiole length ranged from 8-47 cm and 313, 137, 96, 5 and 1 accessions respectively had petiole length as 20-30, 30-40, 10-20, 40-50 and 1-10 cm.

Flowering and fruiting characteristics are depicted in Fig.2 and cassava mosaic disease (CMD) incidence in Fig.3.

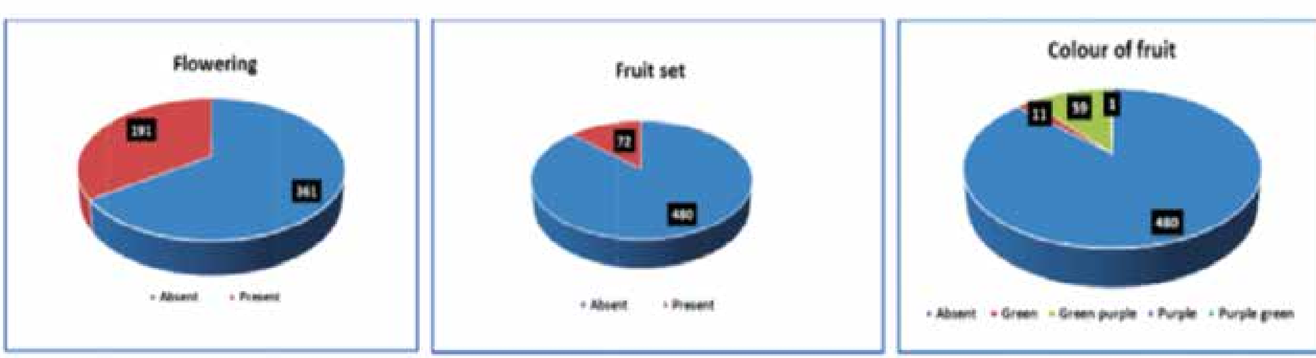


Fig. 2. Flowering and fruiting characteristics in 552 accessions of cassava

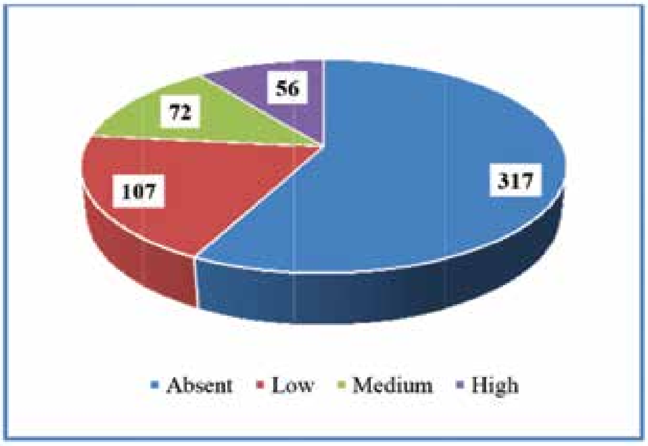


Fig. 3. CMD incidence in 552 accessions of cassava

Sweet potato

A total of 1110 accessions are maintained in the National Active Germplasm (NAG) site of ICAR-CTCRI. Seven new accessions (two from Tamil Nadu and five from Kerala) were added. Morphological characterization of 100 pre breeding lines were recorded based on IPGRI descriptors and the data were analyzed using Multivariate Statistical Package (MVSP 3.22). The UPGMA cluster analysis based on 18 descriptors separated all the accessions into two principal clusters at a Euclidean distance of 1.2. The PC1 accounted for 49% of the variation. Immature leaf colour was the trait included in PC2, PC3 and PC4. Morphological characters like vine colour, leaf lobes type, shape of central leaf lobe, immature leaf colour and petiole pigmentation were important in distinguishing the accessions. The UPGMA dendrogram based on six ISSR markers using Jaccard's similarity coefficient separated the accessions into two principal clusters at a coefficient of 0.63. In the first principal cluster, SV-280/9 and S1619 were grouped together with 84% similarity and was the most similar accessions.

Yams

A total of 1121 accessions of yams comprising greater yam (600), white yam (158), lesser yam (222), potato yam (6) and wild yams (135) are maintained in the FGB. Twelve new accessions of greater yam including eight accessions from Andaman, one accession each of potato yam and lesser yam (Fig.4a, b) were added to the FGB. These lines were planted in the field for characterization as per DUS guidelines.

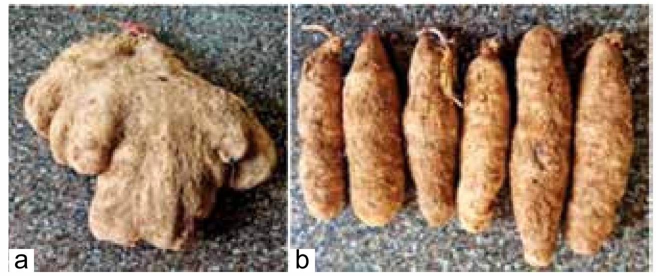


Fig. 4. New collections yams
a. *Kaduvakkayyan* b. *Nanakizhangu*

Molecular characterization of 42 accessions of greater yam was carried out using 15 ISSR and 10 SSR primers.

Among the greater yam accessions, yield ranged from 0.30 (Da-42) - 9.5 kg plant^{-1} (Da-319). Five high yielding accessions *viz.,* TCA-103A (8.1 kg plant^{-1}), Gy-24 (6.1 kg plant^{-1}), DaK-1(6.3 kg plant^{-1}), Da-319 (9.5 kg plant^{-1}) and Da-17 (7.2 kg plant^{-1}) were identified for further evaluation. Among 158 white yam accessions, the tuber yield ranged from 0.35 (Dr-353) - 7.2 kg plant^{-1} (Dr-328). The Dr-29 has compact tuber shape, while Dr-87, Dr-98 and Dr-113 had excellent cooking quality. In lesser yam, the tuber yield per plant ranged from 0.3 (CTDE-232) - 4.2 kg (CTDE-62). The CTDE-62 (Fig. 5) tuber had the maximum length (33 cm) and girth

Fig.5. Lesser yam accession: CTDE-62

(21 cm) with the highest single tuber weight (600 g). The lesser yam accession CTCDE 244 (*Mukkizhangu)* recorded an average tuber length of 49 cm, tuber girth of 64 cm with a single tuber weighing of 6.09 kg. At RS, Odisha, seven yam lines collected from Port Blair, Andaman & Nicobar islands were added to the existing collection (Fig. 6).

Fig. 6. New addition of yams from Andaman & Nicobar islands at RS, Odisha

Edible aroids

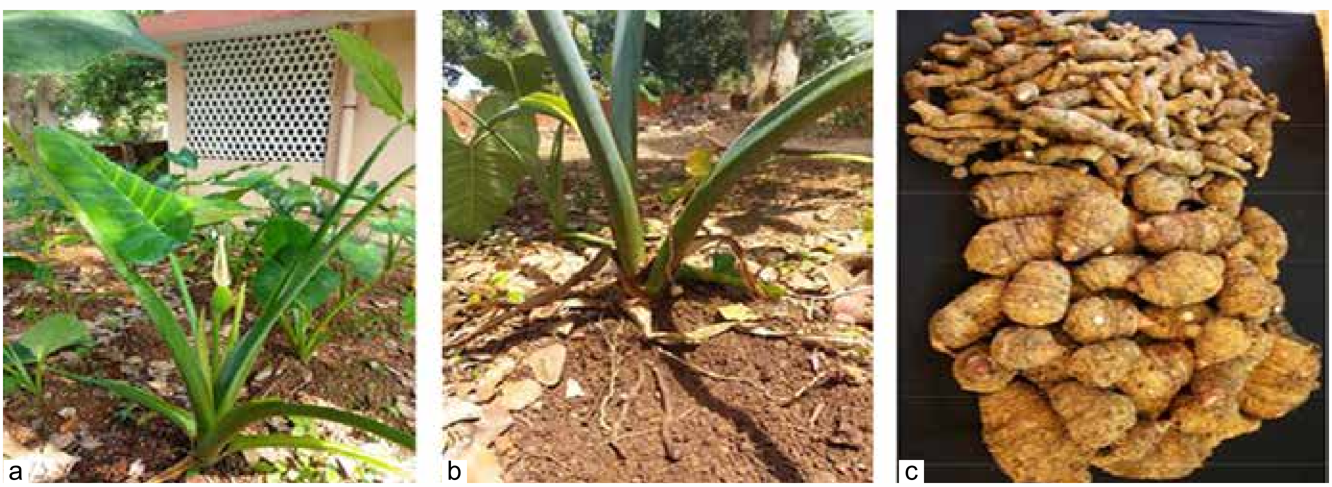


Fig.7. a. Tannia collection Miz/20-8 with flower b. Cormel c. Cormels and corms of TTn14-6

The edible aroid germplasm was augmented with a total of 20 edible aroids comprising taro (12), tannia (2), *Alocacia* (1), giant arum (1) and elephant foot yam (4) accessions from Andhra Pradesh, Tripura, Tamil Nadu and Kerala. The FGB of aroids has 683 collections, comprising taro (429), elephant foot yam (203), tannia (48) and *Alocasia* (3) accessions. During this year, seven early maturing taro accessions (*viz*., CA-61, CA-62, CA-63, CA-64, CA-65, CA-67, CA-68) which matures in five months and also three flowering accessions (TCR-947A, IC-420620 and TTr-17-1) were identified. In tannia, the two flowering accessions (TTn-14-6, Miz-20-8) had stout pencil like cormels (Fig.7 a,b,c). Among the 51 elephant foot yam accessions screened for resistance to collar rot disease, none was found resistant.

Fig.8 . High yielding taro lines identified at RS, Odisha

At RS, Odisha, four high yielding lines of taro (CE-558, CE-334357, CE-416937, CE-807949) were identified with maximum yield in CE-558 (710 g plant^{-1}) followed by CE-334357 (690 g plant^{-1}), CE-416937 (650 g plant^{-1}) and CE-807949 (640 g plant^{-1}) (Fig. 8).

Minor tuber crops

The important minor tuber crops collected, conserved and characterised were Chinese potato, tikhur, winged bean and yam bean.

Chinese potato (*Solenostemon rotundifolius* (Poir.) J. K. Morton)

One new accession from Kanthalloor, Idukki district, Kerala with oval to long tasty tubers having good skin peelability was added. Top shoot cuttings raised from tubers of 30 accessions planted during June 2020 (Fig. 9) in 3 replications were characterized for plant height, number of primary and secondary branches, branch length, stem pigmentation, leaf colour, petiole length of mature leaf, lamina length and lamina width. There was no flowering in four accessions. In the flowered accessions, spike length, peduncle length and pigmentation were recorded.

Tuber weight of three tubers was highest in SAASV-15 (108.67 g) and lowest in JAS-17 (13.33 g). Number of marketable tubers ranged from 12 (ASAKI-1, SAASV-14) - 45 (ASAKI-4). Tuber skin colour was brown and flesh colour was cream in all the accessions. The tuber shape was round in 21, while elongated in 9 accessions.

In these 30 accessions, the tuber yield ranged from 5.25 (TCR-144) - 34.90 t ha^{-1} (SAASV-15) and 16 accessions recorded higher tuber yield (15.95-34.90 t ha^{-1}) than the check variety (Sree Dhara) (15.65 t ha^{-1}) (Fig.10). The dry matter content of these accessions ranged from 22.32 (TCR-141) - 33.46% (TCR-110). Six accessions *viz.,* ASAKI-1 (29.92%), ASAKI-3 (31.56%), ASAKI-4 (30.97%), ASAKI-5 (29.87%), ASAKI-8 (29.67%) and SAASV-6 (30.12%) were identified as promising with respect to dry matter percentage compared to the check variety Sree Dhara (29.54%) (Fig.11).

Six genotypes of Chinese potato collected from farmer's fields of Varavoor, Kunnamkulam (Thrissur), Kovilpatti-1, Rajakumari, Kovilpatti-2 and Cumbum (Fig.12) were documented for their tuber/seedling variation. Accessions from Tamil Nadu possessed significantly high moisture content, tuber weight and more sprouts. The accession Rajakumari had cylindrical tuber shape, red skin colour and reddish colour sprouts. Number of main branches of these sprouts were high (2.4) in Kovilpatti-1 and least (1.4) in Rajakumari (Fig.13.). The dry matter percentage of the tuber is comparatively high (16.41%) in Kunnamkulam followed by Kovilpatti-1(12.06%) and Kovilpatti-2 (11.03%) (Fig 14).

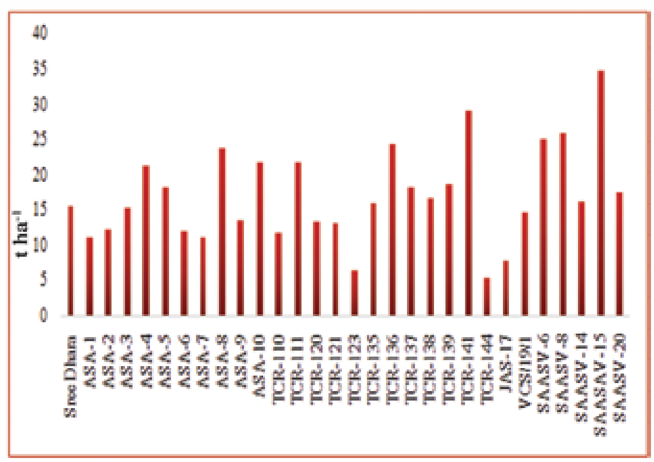


Fig.10. Tuber yield in Chinese potato accessions


Fig.9: Field view of Chinese potato germplasm and tubers

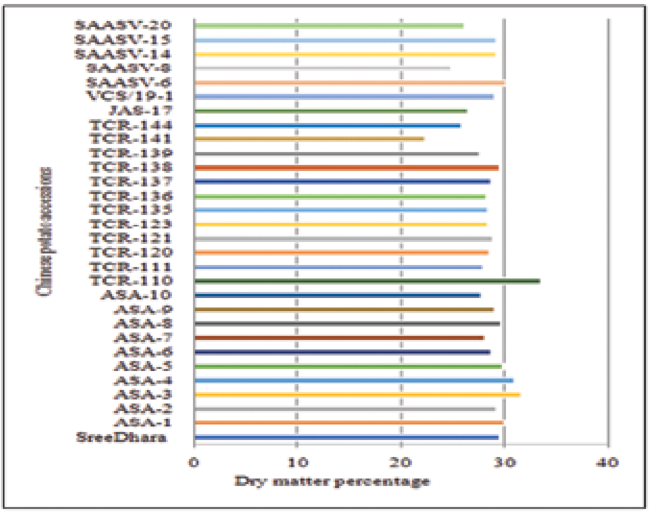


Fig.11. Dry matter percentage in Chinese potato accessions

Fig.12. Tuber variation in farmer's varieties

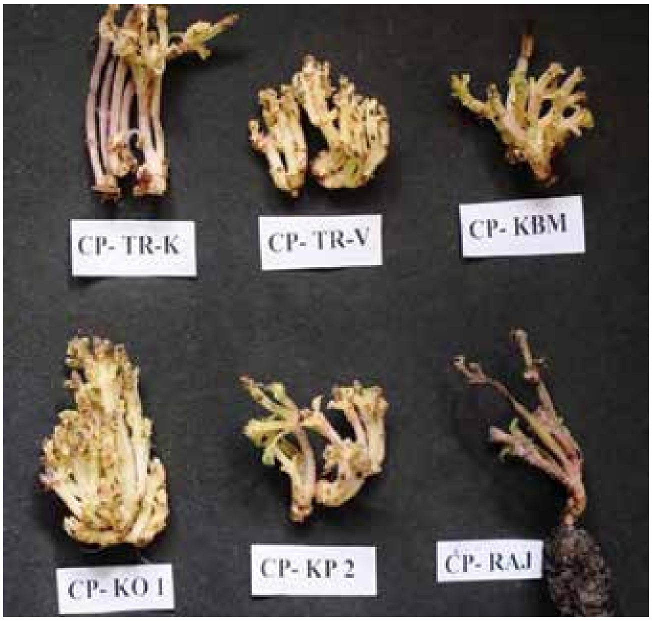


Fig 13. Germinated sprouts of farmer's varieties

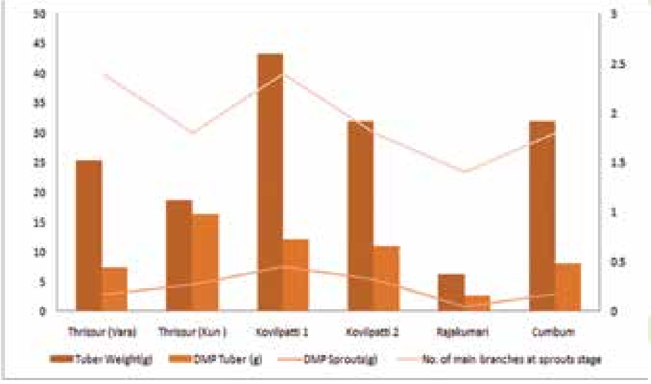


Fig. 14. Tuber/ seedling variation in the new accessions of Chinese potato

Tikhur (*Curcuma angustifolia*)

The rhizomes of pre selected local accessions of four starchy wild *Curcuma* and one *Curcuma zedoaria* were compared with the Chhattisgarh state variety *C. angustifolia* (tikhur-1) (Fig.15) for documenting variability of phytochemicals. The percentage of different bioactive components observed in six germplasm accessions were given in Fig.16. Tikhur-1 (IGBT-10-2) contained epicurzerene (17%) as major compound whereas Chhattisgarh local (IGBT 10-4) had isopropyl myristate (23.24%) as the major compound. In the Thiruvananthapuram accession (IC- 641836), gamma elemene (17.27%) was found abundantly. The wild accessions from Nedumangad (IC-641837), Idukki-1 (IC- 641838) and Idukki-2 (IC-6418399) (*C. zedoaria)* contained major components *viz*., (*E*) labda-8 (17) and 12-diene-15,16 dial which are floral compounds with antifungal and cytotoxic properties. Individual content of (*E*) labda-8 (17) was highest in Nedumangad variety (52%) followed by Idukki-1. Essential oil recovery studied by adopting IS1797-1985 method showed the highest percentage was recovered from *C. zedoaria* (2.0%) followed by Nedumangad (1.74%) and tikhur-1 (0.37%). Thiruvananthapuram and Chhattisgarh local had oil recovery of 0.21 and 0.24 % respectively.

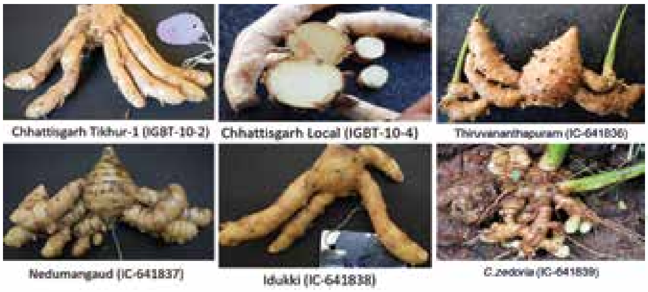


Fig 15: Rhizomes of *Curcuma angustifolia* and *Curcuma zedoaria*

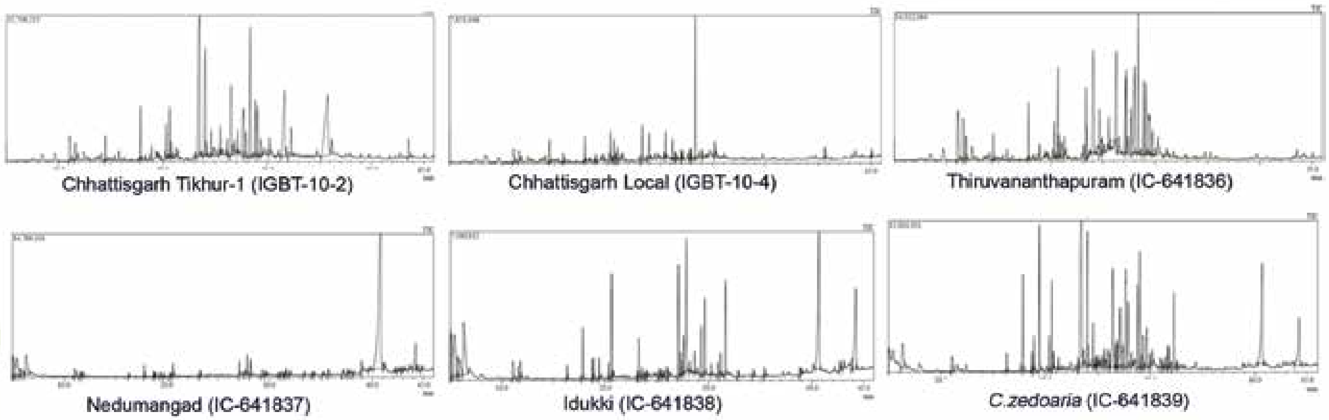


Fig. 16. GCMS analysis of starchy *Curcuma* for phytochemicals

Winged bean (*Psophocarpus tetragonolobus)*

Ten accessions of winged bean seeds *viz.,* TCAWB-1 to TCAWB-10 obtained from AICRP-CAU, Dholi centre during 2019 was tested for seed viability and germination in 2021 after storing for two years, revealed that, overall germination declined from 75 to 12%. TCAWB-10 maintained germination as 40-95% where as TCAWB-5 and TCAWB-7 maintained to the extent of 16.5 and 18.5% respectively from the initial germination of 85 and 89%. The TCAWB-2, TCAWB-6 and TCAWB-9 recorded moderate initial germination of 65, 65 and 62%, respectively and no germination was seen after two years of storage (Fig.17, 18) indicating germination potential and its continued viability is a genotypic character.

Fig. 17. Seed germination test of winged bean

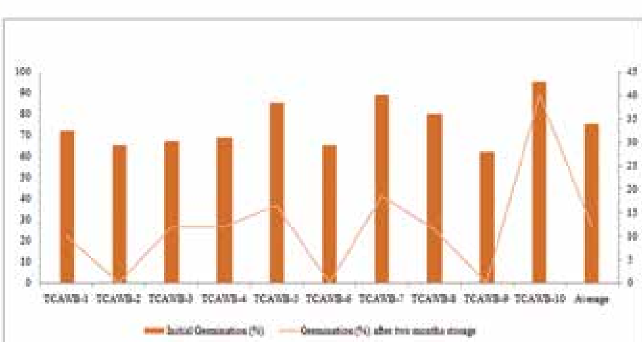


Fig.18. Seed germination of winged bean accessions initially and after two years of storage

A total of 12 germplasm of minor tuber crops were added to the Institute FGB consisting of seven Chinese potato and four arrowroot and one C. *zedoaria* and were allotted IC numbers from ICAR- NBPGR.

Yam bean (*Pachyrhizus erosus*)

Genetic variations were studied in 30 yam bean cultivars using 10 SSR molecular markers at RS, Odisha. The SSR primer AIP 23 yielded the best polymorphic bands. The mean Polymorphic Information Content (PIC) value for the SSR markers used was 0.374 and the mean frequency of the major allele was 0.518. The mean observed heterozygosity value observed was 0.943 which was more than the mean expected heterozygosity value (0.498). The cluster containing three cultivars *viz.,* YBBL15, YBBL12 and EC100544 were highly diverse compared to the rest making them suitable candidates for crop improvement and development of variety. Dendrogram was generated using UPGMA for the 30 yam bean cultivars using 10 SSR markers based on Jaccard's similarity coefficients and is presented in Fig.19.

Biochemical characteristics analysed showed maximum starch in EC100566 (14.32%) with a mean of 11.28±0.99 %, sugar in YBBL-7 (6.21%) with a mean of 5.31±0.51%, ascorbic acid in ECIW562 (15.48%) with a mean of 13.94±0.97%, dry matter percentage in EC100542 (10.97%) with a mean of 8.82±1.27%.

Proton- induced X-ray emission (PIXE) technique (Fig. 20) was employed for the first time to determine

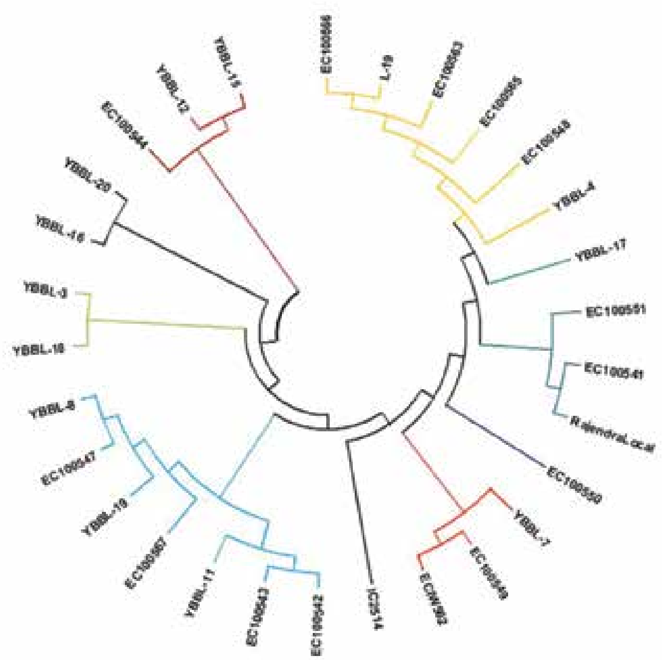


Fig.19. Dendrogram showing clusters of the 30 yam bean cultivars

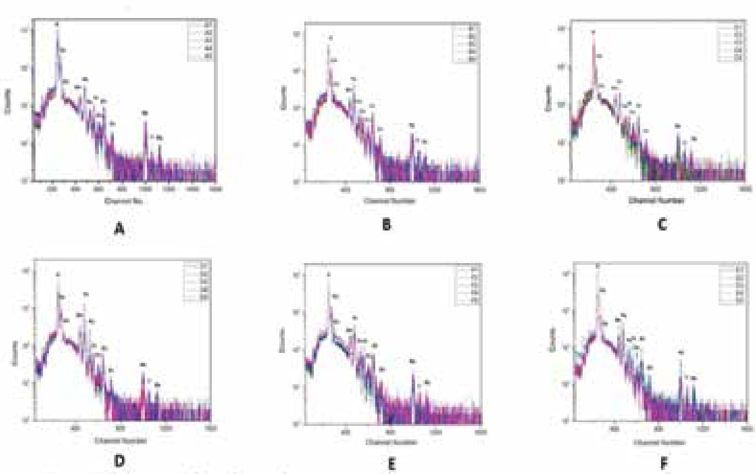


Fig. 20. PIXE spectrum of 30 yam bean genotypes

the nutrients present in 30 yam bean genotypes. Minor and trace element concentration were quantified using the software package (GUPIX-2000). Among the genotypes, YBBL-20 had the highest K (3%), Ca (0.204%), Mn (129 mg kg^{-1}), Cu (18.5 mg kg^{-1}), Zn (29.4 mg kg^{-1}), Rb (63.1 mg kg^{-1}) and Sr (9.74 mg kg^{-1}) whereas the highest content of P (0.968%), S (0.36 %), Ni (28.2 mg kg^{-1}), Fe (395 mg kg^{-1}) and Ti (35.2 mg kg^{-1}) were found in EC100549, YBBL-2, EC100567 and EC100551 respectively on dry weight basis.

In vitro conservation of tuber crops germplasm

At HQ, the *in vitro* cultures conserved included released, pre released and exotic lines comprising 25 cassava, 58 sweet potato, 62 yams, 5 taro and 5 minor tuber crops.

At RS, Odisha, 1000 cultures of released, pre released and exotic lines comprising 10, 11, 5, 4, 2, 4 varieties of cassava, sweet potato, taro, yams, EFY and Chinese potato respectively were maintained *in vitro* (Fig. 21).

Fig. 21. *In vitro* conservation of tuber crops germplasm at RS, Odisha

Gene bioprospecting for novel traits in tuber crops

Water extract of the leaves and tubers of sweet potato accessions *viz.,* Bhu Sona, Bhu Krishna, Sree Kanaka, Sree Arun and S-1467 were analyzed for antibacterial effects against *E. coli* and *Staphylococcus aureus* using disc diffusion assay. Sree Kanaka showed moderate antibacterial effects against *E. coli*. whereas the other sweet potato extracts showed only lesser antibacterial effects (Fig. 22). Antibacterial effects of Bhu Krishna were most prominent among the other four accessions against *S. aureus*. Methanolic extract prepared from *Curcuma angustifolia* accessions and the accessions of Chhattisgarh had the most prominent antimicrobial effects against *Klebsiella pneumoniae, Salmonella typhi, Vibrio cholerae, Mycobacterium smegmatis* and *Staphylococcus aureus* and also against the fungi, *Candida albicans* (Fig. 23, 24).

Fig. 22. Antibacterial effects of *Curcuma angustifolia* accessions against *different bacterial strains*

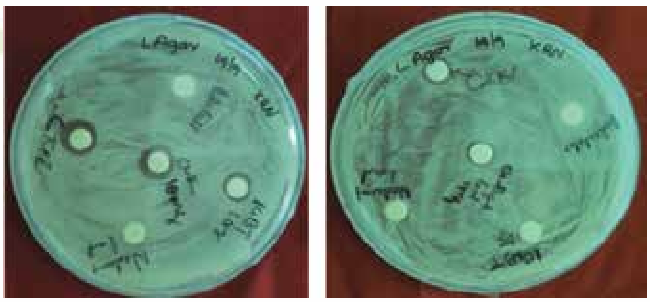


Fig. 23. Dose dependent effects of *C. angustifolia* accessions against *S. aureus*.

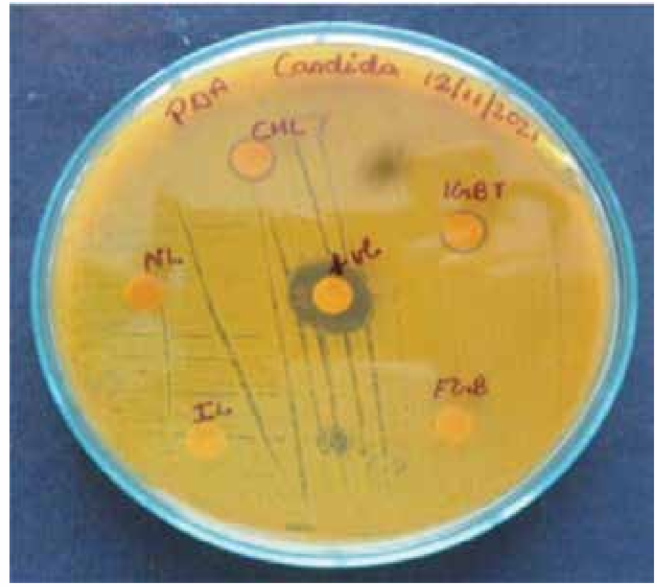


Fig. 24. Anti fungal effect of *C. angustifolia* accessions against *Candida albicans*

Institute Project II

Genetic improvement of tuber crops through conventional breeding and molecular approaches

Activity 1: Breeding to evolve trait specific varieties in cassava, yams and arrowroot for productivity, earliness, quality and resistance to biotic stress (M.N. Sheela)

Cassava

Two early bulking cassava varieties, D-48 and 15S 409 which recorded significantly higher tuber yield than the check short duration variety, Vellayani Hraswa, were identified for on farm trial. The D-48 also recorded higher starch content (32.0%) than Vellayani Hraswa (29.6%). In the evaluation of CMD resistant varieties with high dry matter, D-247 recorded the highest dry matter percentage (47.52%) followed by 15S 42 (46.8%).

Among the CMD resistant varieties with good culinary quality, 15S 184 recorded the highest yield (74.9 t ha^{-1}) followed by 15S 284 (63.9 t ha^{-1}). The seedlings developed through pyramiding of resistance from multiple sources were evaluated for tuber yield, dry matter and culinary quality. The highest dry matter was recorded by MS 1000 (53.2%) followed by 20S 1 (49.8%) and 20S 21 (45.8%). In the evaluation of low starch varieties with good culinary quality, 20S 16 recorded the lowest dry matter (23.4%) followed by 17S 204 (26.8%) and 17S 256 (27.8%).

A new cassava variety namely 8S 501(Sree Kaveri) (Fig. 25 a,b) with CMD resistance, high yield (61.30 t ha^{-1}), drought tolerance, good tuber shape

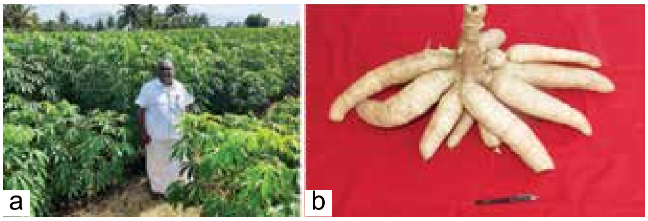


Fig. 25. a. Seed multiplication of 8S 501 b. Tuber of 8S 501

with cream skin and flesh colour was recommended by AICRP (TC) for central release for Kerala, Tamil Nadu and Andhra Pradesh for industrial use. This has close morphological similarity to the popular cassava variety, H-226 and have good industrial use.

Yams

The crop under the evaluation trials were planted during April 2020 at HQ as rainfed crop. In the advanced yield trial (AYT) of greater yam, entries *viz.,* DaS-43 recorded the highest tuber yield (89.1 tha^{-1}) followed by DaS-23 (75.6 t ha^{-1}) and DaS-45 (69.1 t ha^{-1}). In the AYT of white yam, entries *viz.,* DrS-1047 (Fig. 26) recorded the highest tuber yield (88.5 t ha^{-1}) followed by DrS-146 (85.2 t ha^{-1}). Among the non trailing yams, white yam clones, DrD-1112 recorded the highest dry matter (44.2%) while SD-15 (Fig. 27 a,b) recorded the lowest (27.6%). In the on farm trials, the non trailing white yam, SD-15 recorded high yield (44.72 t ha^{-1}).

Fig. 26. DRS-1047

Fig. 27. a. SD-15 tuber b. Non trailing SD-15 plant

Arrowroot

The AYT during IV year was conducted with seven arrowroot genotypes replicated thrice in RBD (Fig. 28). The yield ranged from 23.69 (M5) - 28.35 (M7) t ha^{-1}. The starch, sugar, fibre, ash and dry matter ranged as 18.20 (M5) - 20.37% (M3), 0.11 (M1, M7) - 0.15% (M5, M6), 0.83 (M5) - 1.09% (M1, M7), 0.77 (M5) - 0.95% (M2, M3) and 33.22 (M6) - 38.93% (M5) respectively.

Fig. 28. Field view of arrowroot trial

Among the seven genotypes, the promising genotypes were M-7 having high yield, M-3 having high starch and M-5 having high dry matter and low fibre content. (Fig. 29)

Fig. 29. Tubers of the promising arrowroot genotypes M-7, M-3 and M-5

Activity 2: Genetic analysis of drought tolerance in cassava (A.V.V Koundinya)

Two highly tolerant (8S 501, CR43-7) and two highly susceptible (H 97, M4) genotypes were used for studying the carbohydrate dynamics under drought conditions. Observations taken indicated significant correlation between mass and volume of pith in tolerant genotypes, whereas it was non significant in susceptible genotypes (Fig. 30 a, 30 b) and the distribution of spongy parenchyma tissue showed non uniformity in the pith region of the stem in susceptible genotypes (Fig. 31). Tolerant genotypes had higher partitioning index at 0, 2 and 4 months after inducing stress (MAS) than susceptible genotypes. Early

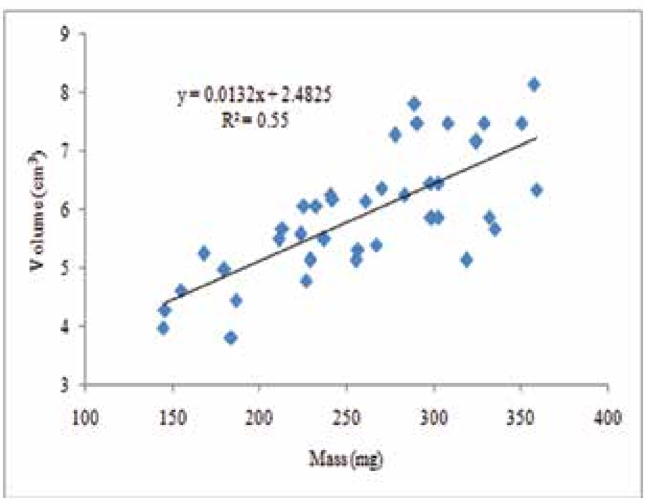


Fig. 30. a. Relation between mass and volume of pith region of stem (tolerant genotypes)

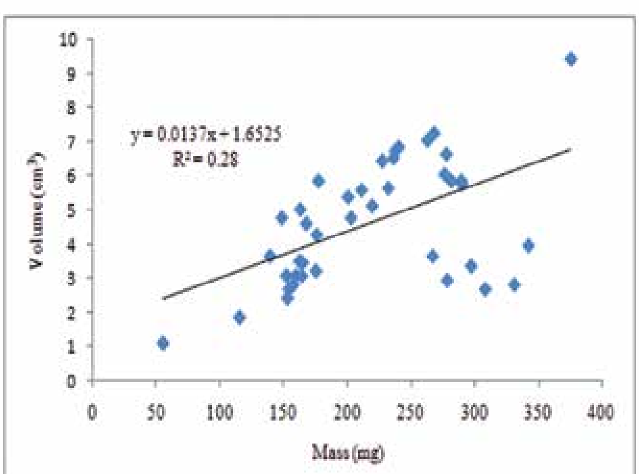


Fig. 30. b. Relation between mass and volume of pith region of stem (susceptible genotypes)

Fig. 31. Vertical cross section of stem showing distribution pattern of spongy parenchyma in pith region of stem

tuber bulking helps in drought tolerance of cassava. The effect of drought on dry matter and total carbohydrate content of leaf and pith was prominent in the later stages of stress than initial stages. At initial stages of stress (2 MAS), carbohydrate accumulation in leaf and pith was observed and their mobilization to the tubers was observed in the later stages of stress (4 MAS).

Transcriptome sequencing of 8S 501 and H 97 revealed that, 126 genes were upregulated and 129 genes were downregulated in both the genotypes and 2916 genes were upregulated in the genotype 8S 501 under stress conditions when compared with control conditions (Fig. 32). Hybridization made between tolerant and susceptible genotypes and among tolerant genotypes (2482 crosses) resulted in 1253 hybrid seeds. The average percentage of fruit set and seed set were 23 and 73.1 respectively. The average number of seeds per fruit was 2.19.

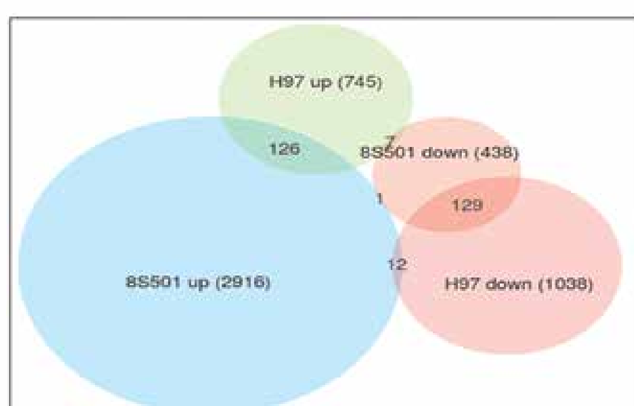


Fig.32. Venn diagram showing differential gene expression between tolerant (8S 501) and susceptible (H 97) genotypes under moisture stress conditions

Activity 3: Map based cloning of CMD resistant gene(s) and identification of marker(s) associated with high starch content of cassava (C. Mohan)

CMD mapping population

CMD resistant mapping population of 800 F_1 seeds were developed using resistant/susceptible parents *viz.,* 9S 127 and Sree Jaya. These F_1 seeds were sown in the nursery for raising seedlings and in this cross, 495 seedlings were developed and transplanted in the main field for CMD evaluation and SSR marker studies. The DNA isolated from the leaf samples of the F_1 seedling population was used for identification of true F_1 progenies of the parents using SSR markers. The parental screening of SSR primers to identify the polymorphic bands between the parents is in progress.

The CMD resistant variety Sree Padmanabha (MNga-1) was used as a parent to develop selfed (S_1) progenies, to isolate homozygous resistant lines for future breeding and to study the gene action. The three parents (Sree Jaya, 9S 127 and Sree Padmanabha) will be used for transcriptome profiling using leaf mRNA for identification of CMD resistant and starch genes through differential gene expression analysis, functional annotation, SSR and SNP mining.

Starch mapping population

Sree Vijaya was used as the female parent and 9S-127 was used as the male parent for developing starch mapping population. From the F_1 seeds sown in the nursery for raising seedlings, 125 seedlings were transplanted in the main field. Molecular marker work for starch content will be carried out with this population.

Activity 4: Genetic analysis and QTL mapping for determining genetic basis of post harvest physiological deterioration (PPD) tolerance and enhanced shelf life in cassava (C. Visalakshi Chandra)

The F_1 hybrid seeds collected from crosses made between parents contrasting for PPD during 2020-21 were sown and maintained in grow bags under net house conditions. The germination percentage of F_1 hybrid seeds was 81.1%. The mean seedling length, seedling girth and seedling vigor (0 to 5 scale) was 17.31 cm, 1.1 cm and 3.78 respectively.

The seedlings were shifted to the main field and data was recorded on seedling height, girth, vigor and CMD resistance. The seedling height and girth at 3MAP ranged between 19.1-63.7cm and 1.8-6.1cm respectively. The seedling vigor ranged from 1-5 with an average of 3.4. The average CMD score recorded was 1.12.

The F_1 seedlings of 2019-20 cross were harvested and replanted as clonal progenies. The average plant height recorded was 230.34 cm and average CMD score was 2.48. The tuber yield per plant ranged from 0.54 to 11.12 kg with an average yield of 3.62 kg (Fig. 33 a).

Fig. 33 a. Tuber yield of F_1seedling progenies

The F_1 clonal progenies of the crosses made during 2018-19 were planted in field for evaluation of PPD tolerance and other traits. The yield traits such as number of tubers per plant, tuber yield per plant and individual tuber weight of the clonal population was recorded along with PPD evaluation.

The tuber yield per plant ranged from 0.87 to 7.03 kg with an average of 3.67 kg. The number of tubers per

Fig. 33 b. Tuber yield of F_1 clonal progenies

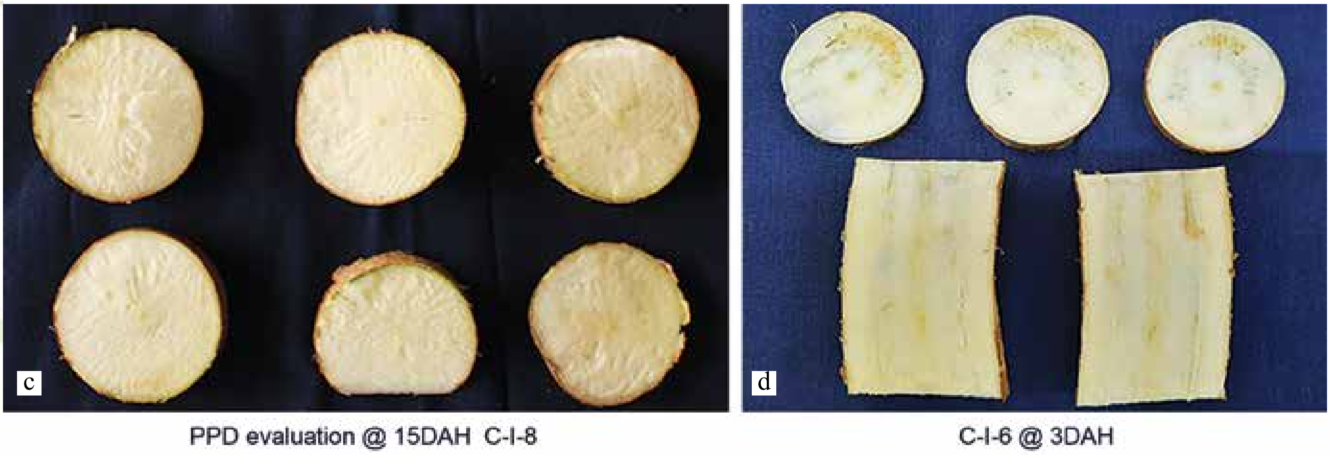


Fig. 33 c. High tolerance observed in F_1 clonal progenies. d. High susceptibility observed in F_1 clonal progenies

plant and individual tuber weight ranged between 3-17 and 0.21-0.73 kg respectively (Fig. 33 b).

F_1 clonal progenies showed wide segregation for PPD tolerance from low to high at 15 days after harvest (DAH) and 3 DAH (Fig. 33 c,d). The average CMD score of the clonal progenies was 2.07. Parental polymorphism study was conducted with new SSR markers and is being continued.

Activity 5: Genome analysis, identification and functional characterization of early bulking genes in cassava, abiotic stress and tuberization responsive genes in sweet potato (K.M. Senthilkumar)

The *glutathione-S-transferases* (GSTs) gene family is one of the largest families of heterogeneous enzymes that plays major role in catalyzing the cellular detoxification during stress conditions. Genome analysis using known GST sequences led to identification of 73*MeGST* family genes in cassava. The genes are distributed in all the 18 chromosomes of cassava except chromosome number 17. Sub cellular localization prediction studies showed the distribution of *MeGST* members in different sub cellular compartments including the cytoplasm, mitochondria, chloroplast, endoplasmic reticulum, peroxisomes. *Cis*-regulatory analysis showed the presence of tissue specific, stress, light responsive, circadian and cell cycle responsive *cis*-regulatory elements in the promoter regions of the *MeGST* genes. Study on the expression of selected set of genes is under progress.

Activity 6: Gene editing in Indian cassava varieties to produce high value waxy starch (N. Krishna Radhika)

Using the whole genome sequence data of two cassava accessions, 9S127 and 8S 501, *gbss* gene was elucidated. The sequences identified were compared with the *gbss* gene sequence available in public database. Binary vectors pCBC-DT1T2 and pHSE 401 were multiplied in suitable media and maintained as glycerol stock. Using CRISPR-PV 2.0 design tool, searched and identified 23-bp sequence (5'-N20NGG-3') targeting the *gbss* gene within exons of genomic DNA. Identified 30 guide sequences with off target effects restricted to introns and intergenic regions only and none in coding sequence. Out of this, 2 guide sequences with minimal off target effects were selected and used as targets for primer designing. A set of four primers were designed to incorporate two target sites in *gbss* gene and developed a guide RNA module vector with pCBC-DT1T2 vector.

Activity 7: Breeding and evaluation for development of high yielding nutritionally enriched, photo insensitive, processable and multipurpose sweet potato (Shirly Raichal Anil)

An evaluation trial with 366 orange fleshed sweet potato (OFSP) hybrids, selected from controlled crosses along with Sree Kanaka and Bhu Sona as controls were laid out in lowland in augmented design for preliminary evaluation during July and harvested in November 2020.

The yield ranged between 23-904 g plant^{-1}. Among these, hybrids *viz.,*465/4 (904.6 g plant^{-1}), 517/2 (904.6 g plant^{-1}), 59/4 (798.2 g plant^{-1}), 473/8 (743.5 g plant^{-1}), 448/1 (737.9 g plant^{-1}) and 562/32 (732.4 g plant^{-1}) were found promising. The dry matter of these hybrids ranged as 11.05-35.83%.

The same trial was repeated during November 2020 and harvested in March 2021. Hybrids *viz.,* 50/71, 352/14, 95/1, 364/6 and 50/63 with tuber yield as 834, 715.2, 709.0, 667.3 and 542.3 g plant^{-1} with dry matter percent of 21.6, 27.35, 30.62, 26.85 and 32.63 respectively were found promising. The starch and total carotenoids (Fig. 34) were estimated for selected hybrids. The boiled storage roots of 70 hybrids were assessed for consistency, undesirable colour, texture, sweetness and taste based on IPGRI descriptors. Based on the above trials, three accessions H-473/8, H-562/32 and H-43/83 were recommended for AICRP trials.

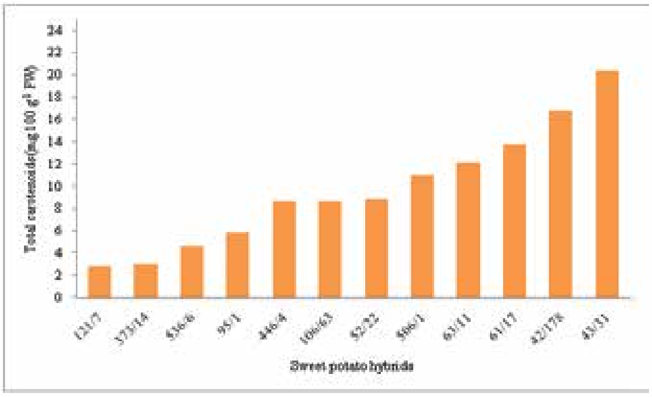


Fig 34: Total carotenoids in selected biofortified hybrids

Two trials with 10 promising purple fleshed sweet potato hybrids identified were laid out for evaluation of yield and dry matter with Bhu Krishna as control. The hybrid 38/46 recorded an yield of 354.17 g plant^{-1} during kharif and 333.33 g plant^{-1} during rabi season with good culinary quality. Another two hybrids *viz.,* 110/28 during rabi and 110/14 during kharif produced yields as 379.16 g plant^{-1} and 666.7 g plant^{-1} respectively were also promising yielders and contained both anthocyanin and β-carotene (Fig. 35). The H-38/46,110/28,38/15 had good taste.

Five sweet potato genotypes *viz.,* CO3-4, S-1609, S-1603, S-27 and S-1712 were identified as suitable for processing from 2018-19 and 2019-20 evaluations were characterized for starch, sugar, crude fibre, fat, ash, flour, moisture content and peel loss on FWB and the content

Fig. 35. Selected sweet potato hybrid accessions

varied as 17.17-23.13%; 0.75- 1.86%; 0.13-0.25%; 3.5 - 4.75%; 0.02 - 0.04%; 26-16-33.87%; 62.74 - 82.6% and 1.91-16.18% respectively. The CO3-4 had highest starch (23.13%) and lowest sugar content (0.75%) and S 1609 showed the highest ash (0.04%) and moisture (82.6%) content and lowest starch (17.17%), fat (3.5%), crude fibre (0.13%) and flour (26.16%) content. S 27 possessed the highest sugar (1.86%), peel loss (16.18%) and lowest fat (3.5%), ash (0.02%) and moisture (62.74%) content. S-1712 had the maximum crude fibre (0.25%), fat (4.75%) and flour (33.87%) content and minimum peel loss (1.91%). The parental lines with processing traits were selected for hybridization and multiplied. A pollination block was laid out with 14 identified parents for hybridization.

Activity 8: Breeding for development of high starch, anthocyanin and β carotene rich varieties in sweet potato and high yielding nutritionally rich varieties in yam bean (Kalidas Pati)

Thirteen sweet potato hybrid lines including four white fleshed (SPH 65, SPH 19, SPH 61, SPH 60), four orange fleshed (SPH 44, SPH 21, SPH 52, SPH 40) (Fig. 36) and five purple fleshed (SPH 31, SPH 30, SPH 29, SPH 15, SPH 14) (Fig. 37) were harvested from the experiment laid out at RS, Odisha during February 2021 and evaluated for yield and other qualitative traits. The highest β carotene content on DWB was found in SPH 52 (11.23 mg100g^{-1}) followed by SPH 44 (11.13 mg 100g^{-1}) and SPH 21 (8.75 mg100g^{-1}) with yield ranged from 20-22 t ha^{-1}.

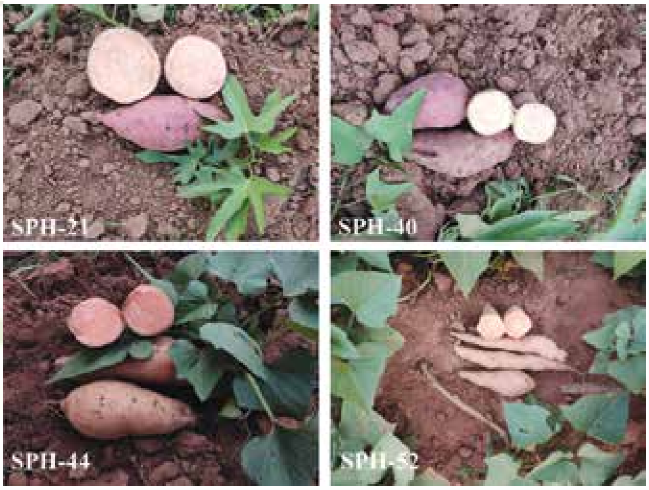


Fig. 36. Orange fleshed sweet potato hybrid lines

Fig.37. Purple fleshed sweet potato hybrid lines

The anthocyanin content was 94.68 mg $100g^{-1}$ (SPH 15) followed by 80.90 mg $100g^{-1}$ on DWB (SPH 14) and yield ranged from 20-24 t ha^{-1}. The anthocyanin powder extracted from tubers of SPH 31 showed maximum colour retention after drying with the highest anthocyanin content (133.57mg $100g^{-1}$on DWB).

The β carotene rich lines (SPH 29, SPH 30) and anthocyanin rich lines (SPH 44, SPH 52) were identified for chips making (Fig. 38).

Fig. 38. Processed chips from orange and purple fleshed sweet potato tubers

Thirteen sweet potato hybrid lines were planted during October 2021 under OFT by RS, Odisha for evaluation of yield and other biochemical traits.

Five best yam bean hybrid lines (3×5, 3×8, 3×9, 3×10 and 9×10) along with check variety (RM-1) were harvested during February 2021 and evaluated for yield and other qualitative traits. Tuber yield ranged from 32-35 t $ha^{-1}$with the highest yield in 3×8 (35.44 t ha^{-1}), followed by 3×9 (33.46 t ha^{-1}) (Fig. 39). Another set of 60 yam bean lines were evaluated for nutrient content in tubers *viz*., phosphorous (P), potassium (K), manganese (Mn) and zinc (Zn). P, K, Mn and Zn content in the tuber ranged as 0.09-0.31%, 04-1.36%, 15.8-52.2 and 17.6-87.6 ppm respectively.

3 x 8 3 x 9

Fig 39. Best yam bean hybrid lines

These hybrid lines, together with the control variety RM-1 were sown again in October 2021 under OFT to assess yield and biochemical traits *viz.,* ascorbic acid, total phenol and total flavonoids.

Activity 9: Genetic improvement for drought tolerance in sweet potato and high yielding, disease tolerant nutritionally rich lines in taro (V.B.S. Chauhan)

Sweet potato

Selected 100 lines of sweet potato were planted in field for screening for drought tolerance. These lines were inoculated with different concentrations of polyethylene glycol (PEG) mediated MS medium in *in-vitro* condition. *In vitro*, observations on shoot length, root length, number of leaves, number of roots and fresh plant weight were taken. Six genotypes *viz.,* Denkanal local-2, SBBPLR-46, SB 5/61, Megh-2, RS-III-3 and Basta-42 performed best at 15 g l^{-1} of PEG in MS medium and identified as drought tolerant.

The same set of the selected 100 lines of sweet potato were again planted in the next season in field during September 2020 for screening drought tolerant genotypes. The same observations made indicated better performance with the genotypes *viz.,* S-162, BP-2, B × 102, Denkanal local-2, Megh-2 , SBBPLR/46, SP-123, RS-III-3, Megh-22, Ganjam local, SB/21/57 and B × 7. It is observed that, there is no definite relation between field performance and *in vitro* screening with respect to drought tolerance. Some genotypes which performed well in *in vitro,* under field, gave very low yield but were able to survive for longer duration without water as these lines were having thin roots which were penetrating very deep and have very small leaves. Considering the yield, out of the 100 genotypes, DB/21/57 (17.00 t ha^{-1}), RS-III-3 (16.60 t ha^{-1}), B×7 (15.44 t ha^{-1}), SP-123 (13.37 t ha^{-1}) and S-162 (12.88 t ha^{-1}) (Fig. 40) were identified as best genotypes suited for drought condition. These identified lines were planted in pollination block for hybridization with other high yielding lines and is yet to harvest.

Fig. 40. Sweet potato genotypes identified for drought tolerance

Taro

Clonal generation (C-2) of seven taro F$_1$ crosses *viz.,*18×TCR-369, Nycle × 224, 12 × TCR-369, 12 × TCR-429, 12 × IC022067, TCR-369 × TCR-429 and TCR-813 × IC419746 were planted in July 2020 at RS, Odisha and harvested in January 2021. Clones of all the crosses were evaluated for their nutritional traits such as antioxidant activity (DPPH and CUPRAC), total phenolics, sugar, starch, crude protein, P, K, Fe, Cu, Zn and Mn in corms. Similarly, these clones were planted during July 2021 and leaves collected during September were subjected to the above analysis. A comparison of the biochemical traits of corms and leaves indicated that, the leaves had more DPPH (79.19%) , CUPRAC (74.51 µmol trolox g^{-1}), total phenolics (48.82 mg gallic acid g^{-1}), crude protein (15.58%) and Fe (13.74 mg 100g^{-1}) compared to corms.

In another experiment of taro for transfer of leaf blight tolerant gene from variety Muktakeshi to high yielding early line Telia, hybridization was done and collected F$_1$ seeds. These were under experimentation for raising seedlings for further studies.

Activity 10: Mapping anthracnose resistance gene(s) in greater yam using molecular markers (Vivek Hegde)

Screened 370 greater yam genotypes for anthracnose resistance under field condition. The disease intensity was increased during October to December. Among the genotypes screened, four accessions, Sree Karthika, SHY 132, S 53 and Da 11 were found resistant, 138 were tolerant, 70 were susceptible and 158 were highly susceptible (Fig. 41).

The resistant genotype, Sree Karthika was selected as male and the susceptible genotype Orissa Elite was selected as female parent for the development of mapping population. Genomic DNA from five susceptible and seven resistant genotypes of *Dioscorea alata* was isolated and screened using ten ISSR and five SSR primers. Seven clusters were analysed based on cluster analysis of the molecular data obtained from ISSR primers (Fig. 42).

The results showed variation between resistant and susceptible genotypes against anthracnose disease and seen monomorphic bands among the genotypes in all SSR primers tested (Fig. 43). Availability of high

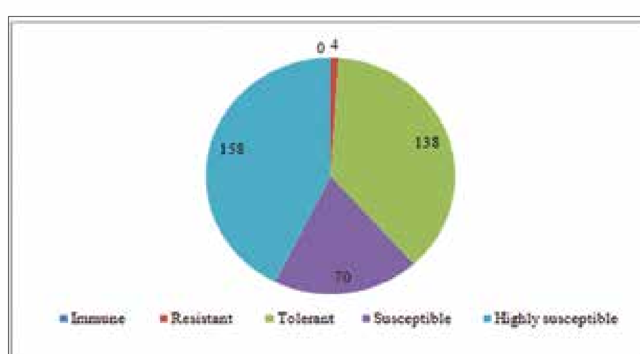


Fig 41. Intensity of anthracnose in greater yam genotypes under field condition

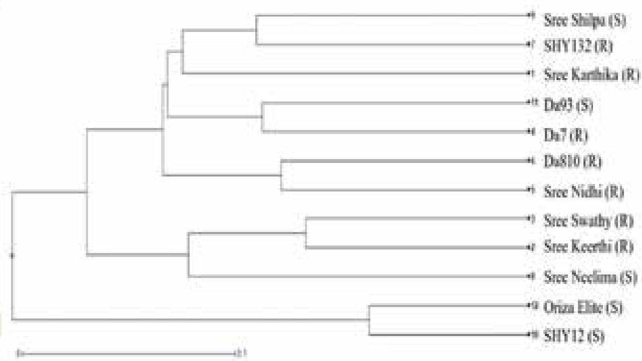


Fig. 42. Dendrogram under ISSR markers with greater yam genotypes

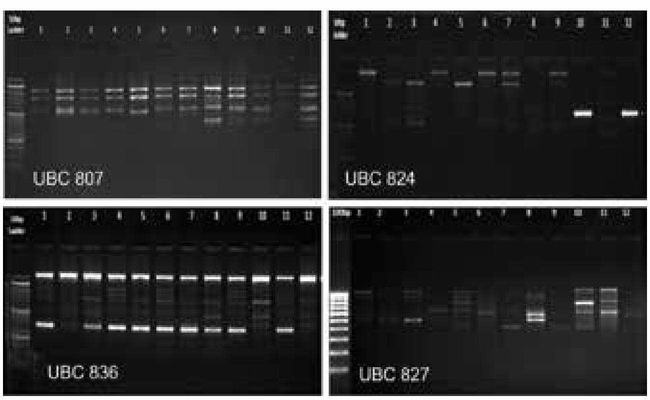


Fig 43. Polymorphism among the greater yam genotypes for ISSR primers

quality sequence information is necessary for designing molecular markers associated with anthracnose resistance. Therefore, analysis of expressed sequence tags (transcriptome sequencing) may be done for developing SSR and SNP markers to map anthracnose resistant gene(s)

Pollen from the variety Sree Karthika was collected from the freshly opened flowers and evaluated for their viability using acetocarmine staining test and *in vitro* pollen germination tests. The pollen staining of freshly collected yam pollen recorded a germination of 81.43%. Study was carried out with different culture media to optimize the pollen germination media and maximum pollen germination (41.67%) was recorded in a modified Brewbaker and Kwack medium containing 15.0% sucrose.

Non synchronous and late flowering of the resistant male, Sree Karthika and susceptible female, Orissa Elite were the major hindrances faced during hybridization. Hence, freshly collected male flowers were stored at different storage conditions (room temperature, 4°C, 20°C, 80°C). Total loss of pollen viability was observed after a day of storage in different conditions.

Activity 11: Genetic improvement of edible aroids for resistance to biotic stress and quality parameters (A. Asha Devi)

Taro

A new trial was initiated in 2020, where 14 selected taro entries were multiplied. During 2021, these entries were planted along with check (Sree Rashmi) in RBD with two replications for preliminary evaluation. The cormel yield ranged as 1.12 - 9.05 t ha^{-1}, whereas the total yield ranged as 1.83 - 12.58 t ha^{-1} in a local collection from Odisha and C-553 respectively. Three entries *viz.,* C-553, H-2 and C-167 were statistically superior. Fourteen taro accessions were subjected to artificial screening for identification of taro leaf blight resistant lines.

Elephant foot yam

For identification of collar rot resistant lines in elephant foot yam, 51 accessions were subjected to artificial screening and found none resistant to collar rot. A total of 20 hybrid corms from a cross (2019) between ADS/2019-1 as female parent and Puttur local I as male parent was planted and harvested during January-February 2022. Forty five hybrid corms selected and carried forward from previous crosses gave an yield ranging from 8.0 g - 1.47 kg plant^{-1}. H-102-2015 (1.47 kg plant^{-1}) and H-107-

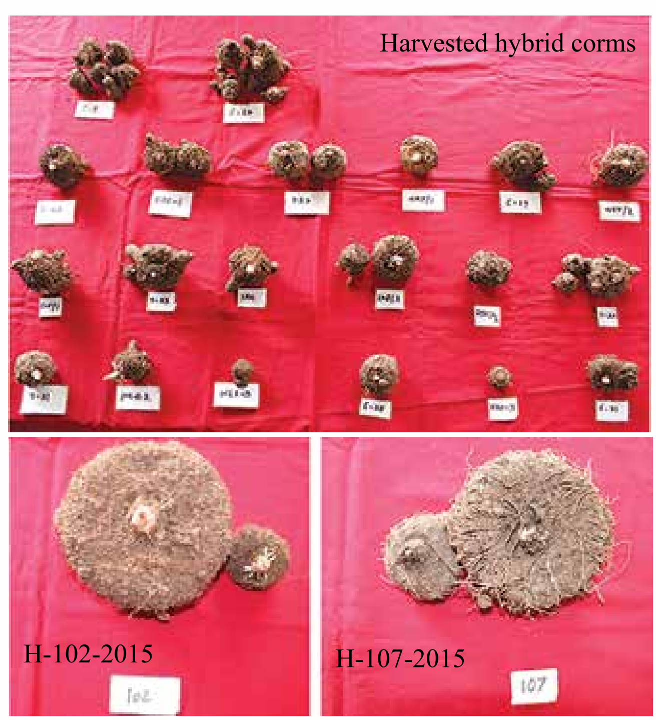


Fig. 44. Selected high yielding hybrids of elephant foot yam

2015 (0.88 kg plant^{-1}) belonged to the cross of Am159 (♂) and Am158 (♀) and H-6-34-2017 (0.85 kg plant^{-1}) and H-6-7-2017 (1.19 kg plant^{-1}) belonged to the cross between Am158 (♂) and Am156 (♀) (Fig. 44). Apart from these, the crosses between Am-41 and Am-141 as female parents with pollen from the male parent, which is a hybrid between Sree Padma 2 and Gajendra made during 2020 was not successful. During 2020-21, none of the accessions flowered.

Under a new trial for developing high yielding lines, 14 accessions were evaluated with Sree Padma as the check and found that, Am-141 (11.56 t ha^{-1}) was found superior over Sree Padma (9.37 t ha^{-1}). Four accessions *viz.,* Am-39, NL/2014-3, H-64 and Peerumedu local were on par with Sree Padma.

Tannia

For standardization of *in vitro* micro propagation protocol in tannia, three accessions were tested. A local tannia collection started producing *in vitro* shoots in MS media supplemented with BA (1 mg l^{-1}). Under the evaluation trial for tannia, selected tannia lines were multiplied on station.

Activity 12: Developing breeder seed standards and precocity of genetic vigor for tuber crops (P. Murugesan)

Seed quality was evaluated for the RM1 variety of yam bean to develop breeder seed standards as a part of seed quality control system. Seeds were classified as light brown, dark brown, brown, black and dark black (Fig. 45) manually and using Royal Horticultural Society (RHS) colour chart. Moisture content, purity, 100 seed weight and germination percentage were assessed as per standard procedures. Seed health of five lots were tested by the blotter test (ISTA, 2021) (Fig.46). During incubation, lighting was provided to stimulate sporulation of fungi and the petri dishes containing seeds were carefully observed for its colour and growth habit under stereo binocular microscope to identify the frequency of occurrence of different fungi associated with the seeds.

Fig. 45. Seed quality: Five seed coat colors

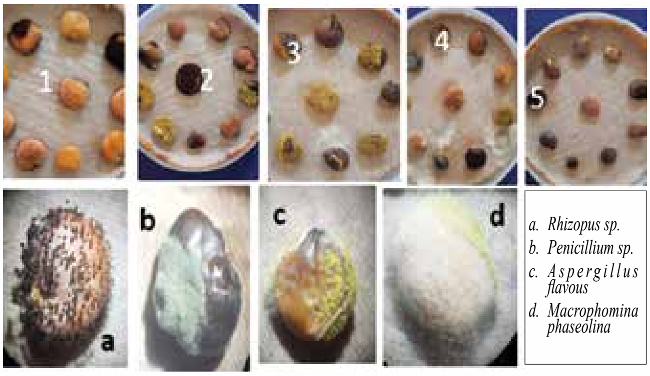


Fig.46. Seed health: Blotter test

The top class grade light brown coloured seeds showed significantly the highest 100 seed weight (24.94 g), germination percentage (98 %), purity (98 %) and other seed quality parameters compared to the other seed coat colours. Microorganisms *viz., Rhizopus* sp, *Aspergillus flavous*, *Penicillium* sp. and *Macrophomina phaseolina* were observed in the seed health test. Top class brown seeds showed only *Rhizopus* sp. whereas the intermediary grades had both *Rhizopus* sp. and *Aspergillus* sp. In the last grade, *Penicillium* sp. and *Macrophomina phaseolina* were also seen. It was concluded that, among the five colour seed coats, light brown colour is better in seed quality parameters for RM1 variety of yam bean.

External Funded Projects

Development of standards of DUS testing for varietal gene bank in elephant foot yam (EFY) and taro (Kalidas Pati)

A total of 21 taro and 18 EFY lines are maintained in the FGB at RS, Odisha as per DUS testing guidelines. Characterization of two taro entries *viz.,* Guchedar and Narendra Ghuiya received from PPV& FRA were done for the first year in 2021 (Fig. 47). Two new taro lines were received from PPV&FRA, New Delhi during December 2021. All the reference varieties were replanted. Characterization of Tikabali lines of EFY is in progress (Fig. 48).

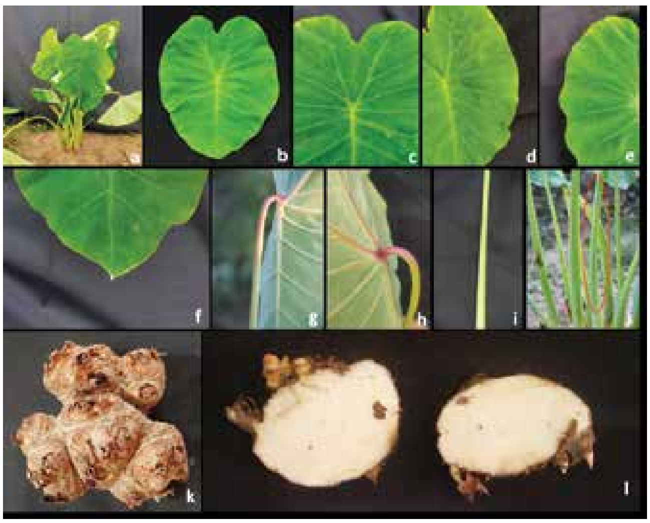


Fig. 47. Distinctive characteristics of Guchedar: a. Fasciate habit b. Green leaf c. Y shaped vein d. Yellowish green margin e. Undulate margin f. Slightly pointed tip g. Large petiole junction h. Purple petiole junction i. Green petiole j. Large sheath k. Flat and multifaced corm l. White coloured corm

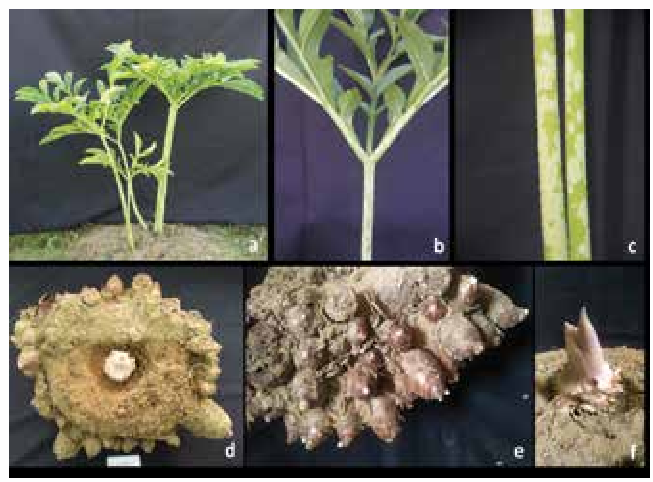


Fig. 48. Different distinctive characteristics of Tikabali EFY-1: a. Upright plant b. Y pattern rachis c. Moderately rough petiole d. Round to elliptic shaped corm e. Cormlets f. Bud with light pink coloured bract

Development of standards of DUS testing for varietal gene bank in yam bean (*Pachyrhizus erosus*) and greater yam (*Dioscorea alata*) (M.N. Sheela, Kalidas Pati)

A total of 14 greater yam and 20 yam bean lines were maintained in the FGB at RS, Odisha. Seven Nicobari Aloo (greater yam) received from ICAR-CIARI, Port Blair, Andaman and Nicobar island were planted for characterization. All the reference varieties were replanted (Fig. 49). Updating of the pre harvest morphological and post harvest characterization of both greater yam and yam bean is in progress.

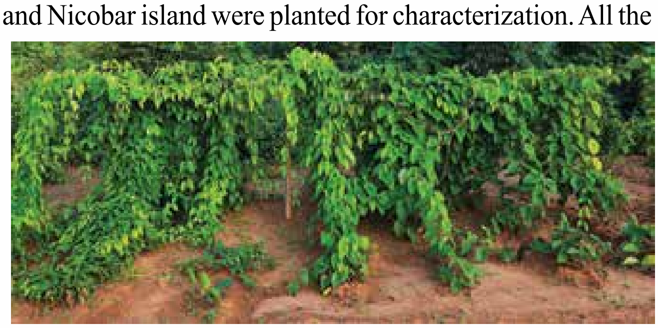


Fig. 49. Greater yam gene bank under DUS at RS, Odisha

Establishment of varietal gene bank and development of standards of DUS testing in cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*) (M.N. Sheela)

At RS, Odisha, 43 sweet potato (Fig. 50) and 14 cassava lines are maintained in the FGB. All the reference varieties were replanted. One farmer variety of cassava was received at HQ and was planted in the FGB for maintenance. Pre harvest morphological and post harvest characterization of both cassava and sweet potato are in progress.

Fig. 50. Sweet potato gene bank under DUS at RS, Odisha

In vitro quality planting material production of tuber crops to meet the demand of Odisha (V.B.S. Chauhan)

Development of *in vitro* plant regeneration protocol for high yielding taro early line Telia

Healthy corms of the taro line, 'Telia' were inoculated on MS basal medium supplemented with different concentrations and combinations of growth regulators. Shoots were initiated from all explants within one week of inoculation and found the regeneration of shoot initiation and proliferation varying with the media. Maximum number of shoots were regenerated from nodal segments on MS basal medium supplemented with TDZ @ 0.5 mg l^{-1} after four weeks of culturing. *In vitro* regenerated shoots produced roots on half strength MS medium supplemented with IBA @ 0.5 mg l^{-1}. The rooted *in vitro* plantlets after proper cleaning were planted in small paper glass containing sand, soil and cocopeat (1:1:1) and covered with polyethylene bag to maintain humidity. After two weeks of acclimatization, the polyethylene bag

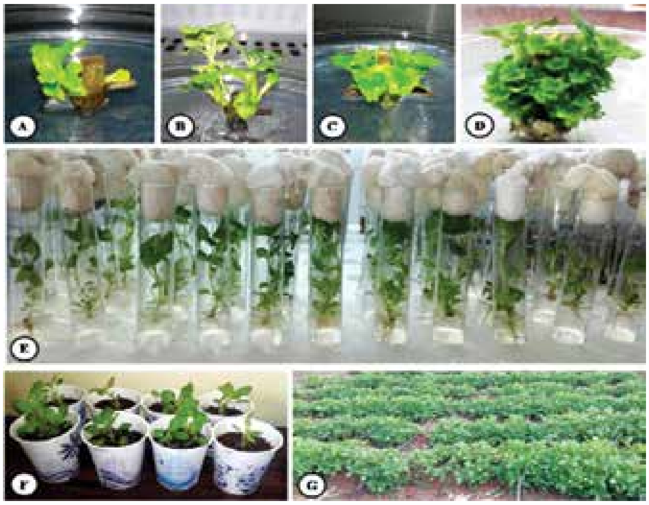
A. Tuber of taro B. Explant preparation for inoculation C, D, E. Shoot bud initiation and elongation F. Multiple shoot proliferation and elongation G. Rooting H. Primary hardening of *in vitro* regenerated plants I, J. Secondary hardening of *in vitro* regenerated plants

Fig. 51. Micropropagation of Telia

was pouched to reduce humidity and were completely removed. Acclimatized plants were transferred to clay pot and kept in shade house for one week prior to transferring under full sun for two weeks. All plants were acclimatized successfully (Fig. 51).

Development of *in vitro* plant regeneration protocol for Chinese potato var. Sree Dhara

In Chinese potato, young stems of the *var.* Sree Dhara were selected and the leaves were excised from stem and cut into small segments having one nodal region. Nodal explants after pre treatments (as in the case of Telia)



A, B. Shoot bud initiation and elongation C. Multiple shoot initiation D. Multiple shoot proliferation E. Rooting F. Hardening of *in vitro* regenerated plants G. Established *in vitro* plants in the field

Fig. 52. Micropropagation of Chinese potato

were inoculated on MS basal medium supplemented with different concentrations and combinations of N6- benzyl adenine (BA) (1.0 - 5.0 mg l^{-1}), meta topolin (mT) (1.0-5.0 mg l^{-1}) and Zeatin (Z) (1.0-5.0 mg l^{-1}). Shoots were initiated from all explants within one week of inoculation and the response of explants to shoot initiation and proliferation found varying with the supplements given in the basal medium. Maximum number of shoots were regenerated from nodal segments supplemented with BA @1.0 mg l^{-1} after four weeks of culturing. *In vitro* regenerated shoots produced roots on ½ MS medium supplemented with IBA @ 0.5 mg l^{-1}. The same procedure as in the case of Telia was followed till planting in the main field (Fig. 52).

Quality planting material production

Tissue cultured true to type disease free plants of sweet potato (Bhu Krishna, Bhu Sona, Kishan, Gouri), taro (Muktakeshi), yam (Odisha elite), cassava (Sree Jaya) and Chinese potato (Sree Dhara) were maintained in net house and further planted. Sweet potato (0.2 ha), cassava, yams, taro (0.05 ha each), Chinese potato (0.025 ha) was grown in the field for multiplication and distribution to farmers. From these, disease free planting materials of sweet potato (4.5 lakh vine cuttings), cassava (10000 stem cuttings) were produced in field nursery and given to farmers. The first generation (G_1) tubers of yam, taro and Chinese potato were kept for further field multiplication. Simultaneously, tissue culture plants of these crops are maintained in net house for multiplication in field for further distribution (Fig. 53).

Fig. 53. View of the *in vitro* produced plantlets of tuber crops in net house

ICAR-CTCRI-CIP Collaborative work plan activity on crop improvement and varietal selection of sweet potato (Shirly Raichal Anil)

Approximately 20000 hybrid seeds (controlled crosses) from CIP, Peru through NBPGR in June 2018 was the source material for further research. Standardization of germination of seeds was carried out in a phased manner and the methodology was standardized. Treating with concentrated H_2SO_4 for 40 minutes was ideal for scarification in obtaining maximum germination (90%). Germination was observed within 6-24 hours of scarification. The seedlings after 14 days were transferred to an open fenced plot for tuberization and these seedlings produced tubers after 5 months. The tubers were screened for flesh colour and dry matter. Those with orange fleshed tubers and high dry matter percentage based on visual observation and mouth feel were selected and multiplied in bigger polybags for final evaluation. From the four batches of around 13188 seeds, 601 hybrids were selected based on flesh colour (orange) and dry matter percent including few anthocyanin rich hybrids.

Preliminary Yield Trials (PYT) of the selected hybrid clones were laid out in upland during 2020 and in lowland during kharif and rabi seasons of 2020-21. The experiment was laid out in augmented design with

Fig. 54. View of the harvested tubers of orange fleshed hybrids

two controls *viz.,* Sree Kanaka and Bhu Sona. During kharif, maximum yield was obtained for the hybrid 465/4 (904 g plant^{-1}) and in rabi, for the hybrid 50/71 (834 g plant^{-1}) (Fig. 54). Dry matter percent ranged as 11.05-35.83%. From the fourth batch of 4000 seeds, 160 hybrid clones selected were planted in field for PYT during rabi in October 2021. The genotypes with adjusted yield >350 g plant^{-1} were selected in comparison to Sree Kanaka and Bhu Sona as checks (Rabi season 2020-2021) (Fig. 55).

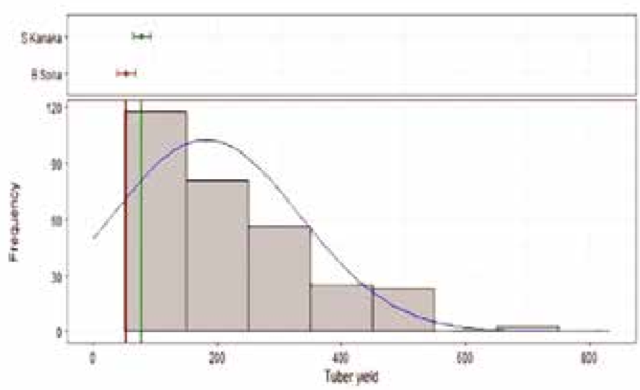


Fig. 55. Frequency of hybrids *vs*. tuber yield in PYT

Applied mutagenesis in cassava for improved agronomic, disease resistance and post harvest traits (A.V.V. Koundinya)

Profuse flowering mutants of Sree Jaya and H226 were identified (Fig. 56 a, b). The mutant clones SJ 15-3, SJ 15-9, SJ 15-15 and SJ 30-4 had more average number of female flowers per cluster as 10, 7.37, 10.2 and 8.29 respectively than that of control, Sree Jaya (5.25). Hybridization between few mutant flowering clones in M_1V_2 and disease resistant clones of South American resulted in 3737 crosses with 1061 hybrid seeds. The average fruit set and seed set were observed as 17.07 and 55.43% respectively. The average number of seeds per fruit was 1.70. The germination of hybrid seeds was 53.07% while the establishment after transplanting was 95.34%. Among the hybrids, 67 were susceptible and 480 were resistant to CMD.

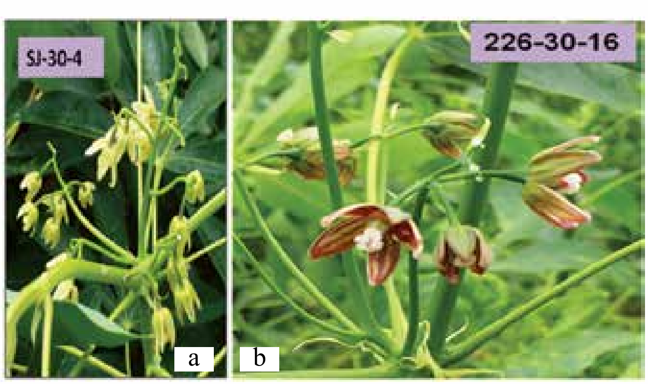


Fig 56: a. Flowering mutants of Sree Jaya b. H-226

Open pollinated seeds of mutants from M_1V_1 were collected for raising M_2 generation. A huge variation was also observed in the colour of apical leaf, petiole colour, pigmentation on shoot, leaf shape and area (Fig. 57) in M_2 generation of Sree Jaya. Contrasting to the parent H-226 and its M_1V_1 mutants, some of the M_2 mutants had coloured apical leaves and petiole. A new apical leaf colour variant 'violet' which is not usual was observed in H-226 mutants (226-15-15-12, 226-15-15-14, 226-15-16-6, 226-15-19-1) in M_2 generation (Fig. 58, 59). Another mutant 226-15-2-1 had the largest single leaf area.

Fig. 57: Variation in mature leaf colour, size and shape in M_2 of Sree Jaya

Fig. 58: Variation in apical leaf colour in M_2 of H-226

Fig. 59: Variation in mature leaf colour, size and shape in M_2 of H-226

7.2 Crop Production

Theme Areas

- Cropping systems research
- Nutrient management
- Water and weed management
- Climate smart agriculture
- Quality planting material production

Achievements

- Identified cropping system model involving rice-cassava-cluster bean as the best
- Developed decision support system for SSNM of taro and elephant foot yam
- Arrived soil B critical level for tuber cracking in sweet potato as below 0.5 ppm
- Evolved irrigation schedule for sweet potato and fertigation schedule and water saving technique for taro
- Established 13 seed villages and registered 19 decentralized seed multipliers for quality planting material production

Institute Projects

Sl. No.	Project code | Project title | PI	Co-PIs
III.	HORTCTCRISIL 202001101465 | **Resource management and climate smart agriculture for sustainable production of tropical tuber crops** | **G. Suja**	G. Byju, J. Suresh Kumar, S. Sunitha, K. Laxminarayana, K. Susan John, V. Ramesh, Sanket J. More, Saravanan Raju, V. Ravi, M. Nedunchezhiyan, R. Muthuraj, K. Sunilkumar, K. I. Asha, D. Jaganathan, E. R. Harish, J. Sreekumar, Kalidas Pati, P. Prakash, S.S. Veena, Shirly Raichal Anil, T. Krishnakumar, T. Makeshkumar, V.B.S. Chauhan
IV.	HORTCTCRISIL 202001201468 | **Quality planting material production of tropical tuber crops** | **R. Muthuraj**	K. Sunilkumar, V. Ravi, G. Byju, M. Nedunchezhiyan, G. Suja, K. Susan John, S. Sunitha, Saravanan Raju, V. Ramesh, A. Asha Devi, D. Jaganathan, V. B.S. Chauhan, E. R. Harish, H. Kesava Kumar, M. N. Sheela, M. L. Jeeva, S. S. Veena, Shirly Raichal Anil, T. Krishnakumar, T. Makeshkumar, K.I. Asha

External Funded Projects

Sl. No.	Title | PI | Co-PIs	Funding agency
1	**All India Network Programme on Organic Farming (AI NP-OF)** | **G. Suja** | G. Byju, S. Sunitha, S. S. Veena, A. N. Jyothi, M. N. Sheela, D. Jaganathan	ICAR – Indian Institute of Farming Systems Research, Modipuram, Meerut, U.P.
2	**Potential impact of climate change on tropical tuber crops yield in major growing areas of India** | **G. Byju (Scientist mentor)** | P. Raji (Woman scientist)	Department of Science and Technology - Women Scientist - A (DST-WOS-A), Govt. of India
3	**Higher productivity and profitability from coconut gardens through soil health management in tuber crops** | **G. Byju, G. Suja** | D. Jaganathan	Coconut Development Board, Govt. of India
4	**Popularization of climate resilient and nutritionally rich varieties of tuber crops for economic development and nutritional security of farmers of Odisha** | **M. Nedunchezhiyan** | K. Laxminarayana, Kalidas Pati, V.B.S. Chauhan, K. Hanume Gowda, Sheela Immanuel, G. Byju, P. Sethuraman Sivakumar, D. Jaganathan, B. K. Sahoo, Bibhudi Das	Rashtriya Krishi Vikas Yojana (RKVY), Govt. of Odisha

5	**Area expansion of sweet potato in Angul, Bolangir, Boudh, Deogarh, Keonjhar and Mayurbhanj districts of Odisha** | **M. Nedunchezhiyan** | K. Laxminarayana, Kalidas Pati, V.B.S. Chauhan	RKVY, Govt. of Odisha
6	**Chlorophyll fluorescence kinetics and monitoring of photochemical efficiency in cassava (*Manihot esculenta* Crantz) genotypes for energy efficient cassava** | **Saravanan Raju (Scientist mentor)** | V. Ravi | Raji S. Nair (Woman scientist)	Kerala State Council for Science, Technology and Environment (KSCSTE), Govt. of Kerala
7	**Popularization of climate resilient improved varieties of tuber crops for food, nutrition and doubling income with emphasis on wellness of tribal and marginal farmers in Kerala** | **K. Sunilkumar, G. Byju, J. Sreekumar** | M.N. Sheela, C.A. Jayaprakas, Sheela Immanuel, G. Suja, K. Susan John, V. Ramesh, R. Muthuraj, Saravanan Raju, Sanket J. More, D. Jaganathan	RKVY-RAFTAAR, Govt. of Kerala

Institute Project III

Resource management and climate smart agriculture for sustainable production of tropical tuber crops

Activity 1: Crop diversification involving tropical tuber crops (G. Suja)

Cropping systems involving tropical tuber crops

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

The field experiment to evaluate the feasibility of intercropping short duration cassava with leguminous vegetables and oilseed in rice based cropping system was carried out at ICAR-CTCRI-HQ. Short duration rice var. Manu Ratna was taken up as the first crop followed by short duration cassava (var. Sree Vijaya and Vellayani Hraswa) intercropped with leguminous vegetables *viz*., cluster bean (var. Gloria), french bean (var. Crystal) and oilseed crop *viz*., groundnut (var. Co-7) at two fertility levels of cassava *viz.,* FYM @ 12.5 t ha^{-1} + NPK @ 100:0:100 kg ha^{-1} and FYM @ 6.25 t ha^{-1} + NPK @ 50:0:100 kg ha^{-1}. Sole crops of the two varieties of cassava under full fertility level were also included for comparison. Grain yield of 2.30 t ha^{-1} and straw yield of 7.0 t ha^{-1} was obtained from rice. Of the three systems involving legumes, rice-short duration cassava (var. Vellayani Hraswa) + cluster bean was the most productive (tuber equivalent yield: 35 t ha^{-1}, production efficiency: 97.11 kg ha^{-1} day^{-1}), profitable (net return : ₹ 286147 ha^{-1}, added profit : ₹ 97740 ha^{-1}) and energy efficient (230.03 × 10^3 MJ ha^{-1}), besides nutrient saving to the extent of half FYM, half N and full P to cassava. The pH, organic C, electrical conductivity, available P, K and S status of the soil was unaffected and available N status of the soil was significantly higher under full fertility level.

Studies on intercropping in taro

A field experiment was conducted during 2021 at ICAR-CTCRI-RS, Odisha, to study the effect of intercropping vegetables in taro on yield potential, biological efficiency and economics. The experiment was laid out in RBD with three replications. The experiment consisted of seven treatments, T_1-sole taro (var. Muktakeshi); T_2-sole okra (var. Arka Anamika); T_3-sole vegetable cowpea (var. Arka Garima); T_4-sole cluster bean (USM-Deepthi); T_5-taro+okra (1:1); T_6-taro + vegetable cowpea (1:1); T_7-taro + cluster bean (1:1). All the sole crops were planted at 60×30 cm spacing. In between two taro plants, one plant of intercrop (okra/vegetable cowpea/cluster bean) was sown. All the crops were planted/sown on the same day. The sole crop of taro and okra were applied a fertilizer dose of NPK @ 80:60:80 kg ha^{-1}, whereas in vegetable cowpea and cluster bean, NPK @ 25:50:25 kg ha^{-1} were applied. In intercropping, the recommended dose of fertilizers of respective crops as per net sown area basis was applied. Fruits/pods of okra, vegetable cowpea and cluster bean were harvested as and when matured. In vegetable cowpea and cluster bean, final harvest of pods, followed by shoot removal was done at 90 days after sowing. In okra, final fruit harvest, followed by shoot cutting was done at 105 days after sowing. Taro was harvested 165 days after planting (DAP).

The results revealed that, intercropping of vegetables in taro resulted in greater cormel equivalent yield than cultivation of sole crops. The treatment, taro + vegetable cowpea resulted in significantly greater cormel equivalent yield (23.54 t ha^{-1}). The next best treatment was taro + cluster bean (18.94 t ha^{-1}). The land equivalent ratio (LER) computed for taro + vegetable cowpea, taro + cluster bean and taro + okra were >1 (Fig. 60), indicating all the above intercropping systems as biologically efficient. Taro + vegetable cowpea resulted in greater gross (₹ 353100 ha^{-1}) and net returns (₹ 226500 ha^{-1}) and B:C ratio (2.79) compared to all the other intercropping systems as well as sole crops.

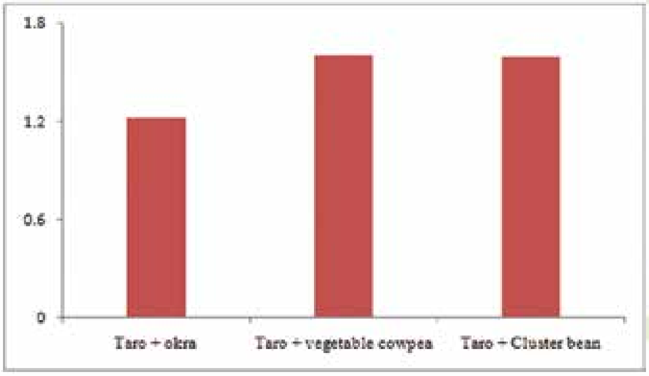


Fig. 60. Effect of intercropping vegetables in taro on LER

Organic farming of tuber crops based systems

Organic farming of elephant foot yam based cropping systems

A field experiment in split plot design with elephant foot yam (var. Gajendra) + vegetables (*Amaranthus*, okra, cucumber) in main plots and five management options


Elephant foot yam + okra


Elephant foot yam after harvest of intercrops

Fig. 61. Organic farming of elephant foot yam + vegetables

viz., 100% organic, 75% organic + innovative practices (3% *Panchagavya* + cow urine), integrated-1 (75% organic + 25% inorganic), integrated-2 (50% organic + 50% inorganic) and the present package of practices (PoP) of the respective crops in subplots was carried out for the first year (Fig. 61). The vegetable intercrops performed better under both the organic practices. The yield of *Amaranthus* (9.98 t ha^{-1}) and cucumber (14.80 t ha^{-1}) was the higest in 100% organic than okra in 75% organic + innovative practices (10.93 t ha^{-1}) (Fig. 62).

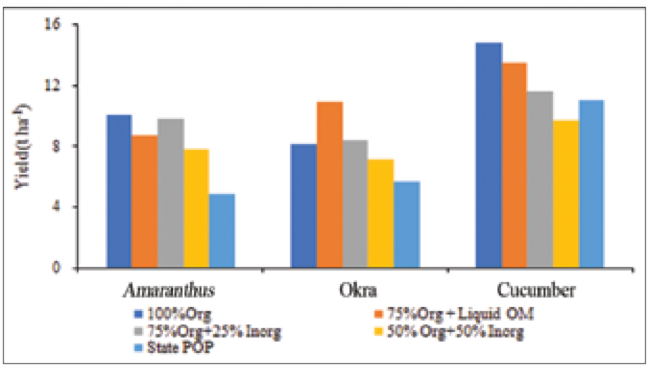


Fig. 62. Effect of management options on the yield of vegetables intercropped in elephant foot yam

Vertical farming of tropical tuber crops

Standardization of nutrient solution for hydroponics based vertical farming of sweet potato

Nutrient Film Technique (NFT) system, a prototype of hydroponic modified dutch bucket system was established in the net house in Block 1 for sweet potato. Tuberization has started from the hydroponically grown sweet potato plants. Second batch has been started one month after the first batch with modified Steiner solution and the crop is in good condition (Fig. 63).

Fig. 63 Crop view at 56 DAP in net house

Activity 2: Weed management in tropical tuber crops (J. Suresh Kumar)

Integrated weed management (IWM) in taro

Use of weed control ground cover perforated mat (nursery men mat) (120 gsm) influenced the crop growth, resulting in higher plant height as 53.33, 62.33 cm, number of leaves as 6.28, 10.93 per hill and leaf area index (1.10, 1.32) at 2 and 4 MAP respectively along with the least weed density and weed dry weight. The following weed flora were noticed, *Cyanodon dactylon* (L.) Pers., *Setaria glauca* (L.) Beauv., *Pennisetum polystachion* (L.) Schultes., *Pennisetum pedicellatum* Syn., *Cenchrus pedicellatus* (Trin.) Morrone., *Mimosa pudica* L., *Indoneesiella echioides* L., *Euphorbia hirta* L., *Alternanthera paronychioides* A. St. Hil., *Atylosia scarabaeoides* (L.) Benth. Of the treatments, weed control ground cover promoted the corm and cormel yield as 7.54 t ha^{-1} and 18.31 t ha^{-1} respectively with higher gross and net returns and B:C ratio (2.76) as compared to the rest of the treatments (Fig. 64).

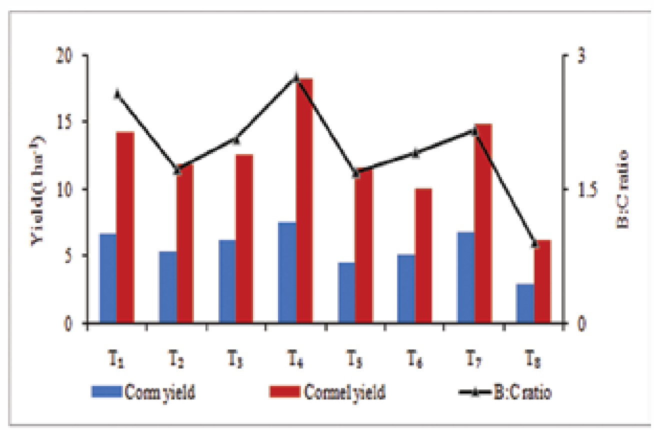


Fig. 64. Effect of integrated weed management methods on yield and economics of taro

Biointensive weed management in taro

The field experiment to study the effect of bio intensive weed management in taro on yield and economics was conducted for the second season during 2021 at RS, Odisha. The experiment was laid out in split plot design with plant density in main plots (P_1-55500 plants ha^{-1}, 60 cm × 30 cm; P_2-74000 plants ha^{-1}, 45 cm × 30 cm) and weed management options in subplots (M_1-sunhemp live mulching; M_2-*Daincha* live mulching; M_3-cowpea live mulching; M_4-paddy straw mulching; M_5-hand weeding at 30, 60 and 90 DAP; M_6-control). The treatments were replicated thrice. FYM @ 25 t ha^{-1} was applied at final ploughing and ridges and furrows were made for planting.

The results revealed that, increasing taro plant density decreased weed dry weight, though there was no significant difference. Paddy straw mulching resulted in significantly the highest tuber yield (25.8 t ha^{-1}) and lower weed dry weight (10.9 g m^{-2}). Planting density of 74000 plants ha^{-1} resulted in a tuber yield of 17.4 t ha^{-1}. The result also revealed that, live mulching alone was not sufficient for controlling the weeds in taro as indicated by higher weed dry weight and lower tuber yield in all the live mulching treatments compared to hand weeding treatment done at 30, 60 and 90 DAP. Plant density exerted no significant effect on B:C ratio. The interaction effect showed that, the planting density of 74000 plants ha^{-1} along with paddy straw mulching resulted in lower weed dry weight, greater tuber yield, gross and net returns. However, B:C ratio was higher in the planting density of 55500 plants ha^{-1} along with paddy straw mulching (Fig. 65).

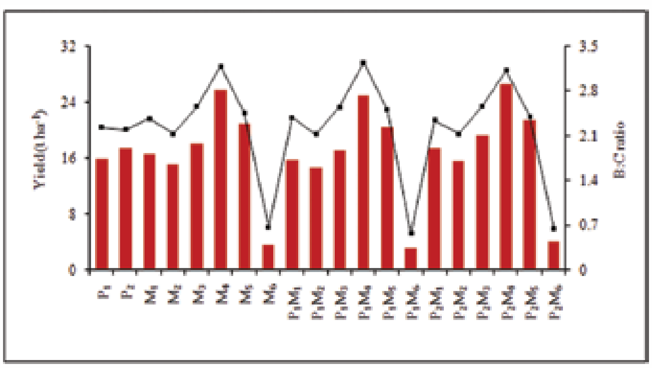


Fig. 65. Effect of bio intensive weed management on taro yield and B:C ratio

Activity 3: Water and nutrient management in tropical tuber crops through precision approaches (S. Sunitha)

Water management studies in sweet potato

A field experiment was initiated during January 2021 to standardize a suitable irrigation schedule in sweet potato with eight treatments in RBD, replicated thrice. The treatments comprised drip irrigation @ 75% (T_1), 100% (T_2), 125% (T_3) and 150% of cumulative pan evaporation (CPE) (T_4), sprinkler irrigation @ 5 mm (T_5), furrow irrigation @ 5 mm (T_6) and a rainfed control (T_7). Though there was statistically significant

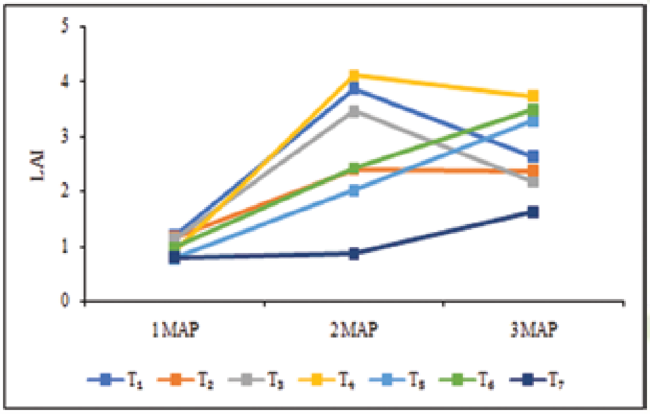


Fig. 66. LAI at various stages of growth under different irrigation treatments

variation among drip irrigation and furrow irrigation for tuber yield, no significant difference was noticed among the various drip irrigation levels. The highest tuber yield (12.61 t ha^{-1}) was recorded in T_2, which was on par with T_1, T_3 and T_4. During the second season, the initial growth parameters *viz*., length of vines, number of leaves and leaf area were recorded higher at lower irrigation levels, but increased eventually at later stages with the increase in the level of irrigation (Fig. 66.). Supplementing sweet potato plants with drip irrigation @ 125% CPE produced highest tuber yield (16.1 t ha^{-1}). However, it was not significantly different from T_2, T_4 and also furrow irrigation. The experiment for the third season is in progress.

Water saving techniques in taro

The field experiment on water saving techniques in upland taro (var. Muktakeshi) was carried out for the second season (January 2021). The experiment was laid out with 10 treatments *viz*., 50% CPE + plastic porous ground cover (T_1), biomulching (T_2), soil application of coir pith (T_3), foliar application of anti transpirant (T_4), Pusa hydrogel (T_5), super absorbent polymer (synthetic) (T_6), drip irrigation at 50% CPE (T_7), drip irrigation at 100% CPE (T_8), flood irrigation (T_9) and rainfed control (T_{10}). Application of ground cover mulching and application of Pusa hydrogel resulted in early sprouting (within 24 days). Fifty percentage sprouting of cormels was observed during 44-48 DAP under different treatments. Plastic ground cover mulching with drip irrigation at 50% CPE resulted in the highest cormel yield (27.94 t ha^{-1}) and was on par with irrigation @ 100% CPE and flood irrigation resulting in an yield of 22.4 and 21.14 t ha^{-1} respectively. Rainfed crop yielded 8.04 t ha^{-1} of cormel

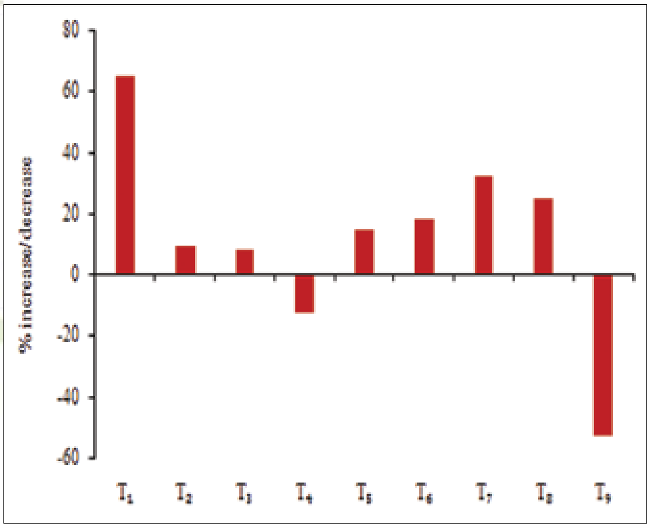


Fig. 67. Percentage change in cormel yield under different water saving treatments

yield. Ground cover mulching resulted in 65% increase in cormel yield as compared to 50% CPE without any water saving techniques (Fig. 67). Ground cover mulching significantly enhanced the cormel yield (+ 25%) with 50% saving in irrigation water, compared to drip irrigation at 100% CPE (Fig. 68).

Fig.68. Taro under drip irrigation with water saving treatments

Fertigation studies in taro

The second season trial on fertigation studies in taro was carried out in split plot design with four levels of nutrients in main plots (NPK @ M_1: 60:25:75; M_2: 60:25:100; M_3: 80:25:100; M_4: 80:25:125 kg ha $^{-1}$) and three schedules of fertilizer application in subplots (S_1: N, K @ 50% each before 60 DAP, N, K @ 25% each at 60-120 DAP, N, K @ 25% each at 120-150 DAP; S_2: N, K @ 50% each before 90 DAP, N, K @ 25% each at 90-120 DAP, N, K @ 25% each at 120-150 DAP; S_3: N, K @ 25% each before 60 DAP, N, K @ 50% each at 60-120 DAP, N, K @ 25% each at 120-150 DAP). Taro (var. Muktakeshi) was planted during April and fertigation was given as per schedule at weekly intervals. The crop was harvested during December 2021. As in the first season, there was no significant difference among the main plot or subplot treatments. Among the main plot treatments, M_3 and among the subplots, S_3 resulted in the highest cormel yield.

Drip irrigation and fertigation management in greater yam

Greater yam plants were planted during June 2020 to March 21 in split plot design with 3 replications to study the effect of drip irrigation (I) (main plot: I_1-100% CPE; I_2-80% CPE; I_3-60% CPE) and fertigation (F) (sub plot: N:P:K @ F_1-60:60:60; F_2-80:60:80; F_3-100:60:100 kg ha^{-1}) on tuber yield. Cut pieces of greater yam tubers weighing 200 g were planted on ridges formed at 90 × 90 cm spacing. These treatments were also compared with check (surface irrigation IW/CPE: 1.0 + NPK @ 80: 60: 80 kg ha^{-1}) and control (surface irrigation IW/CPE: 1.0 without NPK) treatments. Water soluble fertilizer through fertigation was given as per the treatments as basal (40%), at 30 (30%) and 60 (30%) DAP. In check, P_2O_5 was applied during the last plough. N and K were applied in 3 splits at basal (40%), 30 DAP (30%) and 60 DAP (30%). Farmyard manure (FYM) @ 10 t ha^{-1} was incorporated during the last plough for all the treatments, except control and check. Irrigation was given in alternate days as per treatments.

The results revealed that, increasing irrigation level increased the tuber yield (Fig. 69). The treatment I_1 resulted in highest tuber yield (34.8 t ha^{-1}), followed by

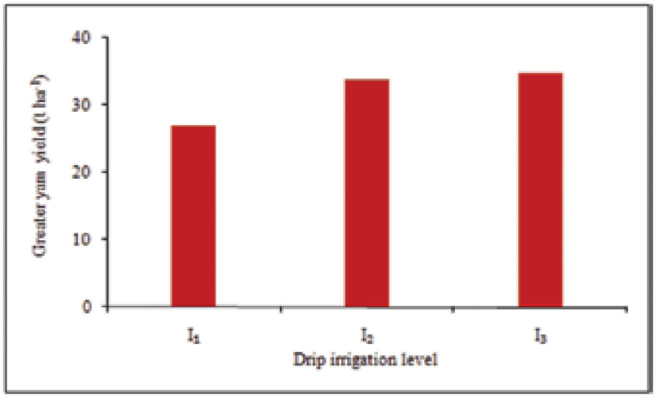


Fig. 69: Greater yam tuber yield as influenced by drip irrigation levels

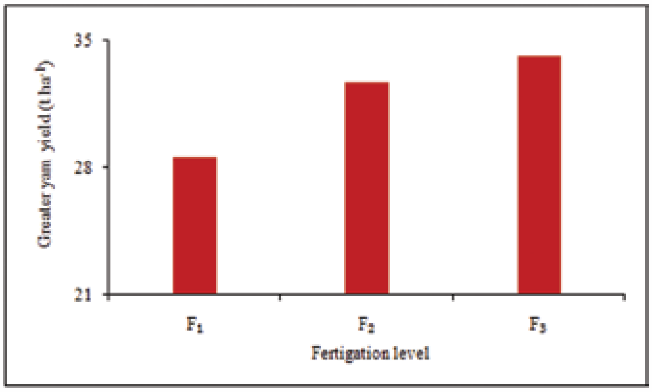


Fig. 70: Greater yam tuber yield as influenced by fertigation levels

I_2 (33.8 t ha^{-1}). The treatment F_3 resulted in significantly higher tuber yield (34.2 t ha^{-1}). The interactive effect of I × F was significant. The treatment I_1F_3 resulted in higher tuber yield and water use efficiency and was statistically on par with I_2F_3 and I_3F_2. The treatment I_3F_1 resulted in higher nutrient use efficiency, especially N and K. Higher P use efficiency and gross and net returns was noticed with the treatment I_1F_3 (Fig. 70). The second season experiment is underway.

Scaling up and scaling out of SSNM for sustainable tuber crops production and soil health

Five on station experiments on site specific nutrient management (SSNM) of cassava, elephant foot yam, greater yam, white yam and sweet potato were conducted. Analysis of soil and plant samples were done to improve the modified QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) model based on harvest index, indigenous nutrient supplies and nutrient use efficiency. In order to validate the LINTUL-Cassava-NPK model to improve nutrient recommendations for cassava under water limited conditions, required soil and plant data were generated. Fertilizer Best Management Practices (FBMP) by SSNM proved to be significantly superior over the present recommendation (PR) (cassava: SSNM - 30.75 t ha^{-1}, PR - 26.50 t ha^{-1}, increase - 16.30%; elephant foot yam: SSNM - 37.50 t ha^{-1}, PR - 32.75 t ha^{-1}, increase-14.5%; greater yam: 21.75 t ha^{-1}, PR - 18.30 ha^{-1}, increase-18.85%; white yam: SSNM - 20.60 t ha^{-1}, PR - 17.50 t ha^{-1}, increase-17.70%) (Fig. 71). Sweet potato is yet to be harvested. Farm surveys were conducted among 60 tuber crops growers in five different panchayats *viz*., Kootilangadi, Malappuram (cassava-10 farmers); Vadakkekara and Thiruvankulam, Ernakulam (elephant foot yam and taro-20 farmers) and Chenkal, Kulathoor and Karode, Thiruvananthapuram (cassava-30 farmers). Farmer participatory SSNM trials started during 2020 were completed in 60 farms spread across 6 panchayats in 4 districts of Kerala, whereas during 2021, 70 on farm demonstrations are being conducted in 8 panchayats in Kerala, Tamil Nadu and Andhra Pradesh (Fig. 72).

Fig. 72. Demonstration on customized fertilizers and micronutrient formulations in Chinese potato in Tirunelveli district

Activity 4: Sustainable nutrient management in tropical tuber crops (K. Laxminarayana)

INM in greater yam + maize system

Effect of integrated use of inorganic and organic sources on yield, proximate composition and soil quality in greater yam + maize system

The field experiment was conducted for the second year during *kharif* 2021-22 to study the effect

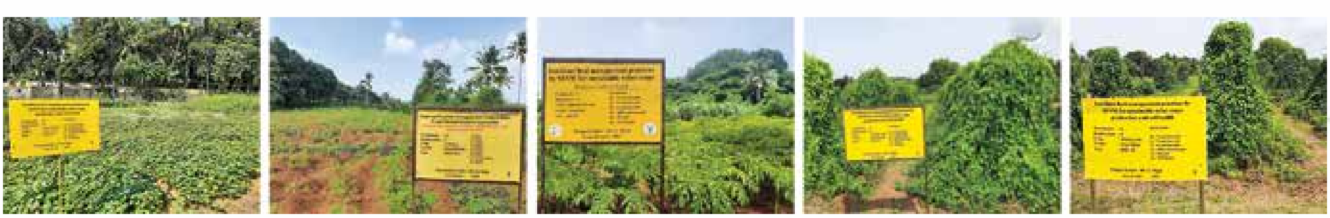


Fig. 71. On station experiments of SSNM in tropical tuber crops

of inorganic and organic manures on soil quality, yield and proximate composition of yam + maize cropping system in an Alfisol. There were 16 treatment combinations *viz*., control; N_{80}; P_{60}; K_{100}; $N_{80}+P_{60}$; $N_{80}+K_{100}$; $P_{60}+K_{100}$; $N_{80}P_{60}K_{100}$ (100% NPK); 50% NPK; 150% NPK; FYM @ 16 t ha^{-1}; vermicompost @ 5.0 t ha^{-1}; FYM + ½ NPK; vermicompost + ½ NPK; FYM + ½ NPK + $MgSO_4$ (25 kg ha^{-1}); FYM + ½ NPK + $ZnSO_4$ (10 kg ha^{-1}). Greater yam (var. Orissa elite) was planted at a spacing of 90 × 90 cm. Simultaneously maize (var. SUM sugar global) seeds were dibbled in between yams as an intercrop at a spacing of 45 × 30 cm.

The results of the first year experiment revealed that, application of K resulted in relatively higher tuber yield of greater yam (45%) over control rather than N (38%) and P (34%). Balanced application of N, P_2O_5 and K_2O @ 80:60:100 kg ha^{-1} resulted in higher yield (94%) over that of NK (52%), NP (46%) and PK (43%). Graded doses of NPK showed an increase in tuber yield as 40, 80 and 94% with the application of 50, 100 and 150% NPK respectively over control. Integrated application of FYM @ 16 t ha^{-1} in combination with N, P_2O_5, K_2O @ 40:30:50 kg ha^{-1} and $ZnSO_4$ @ 10 kg ha^{-1} resulted in significantly the highest tuber yield (33.29 t ha^{-1}) with an yield response of 101% over control, significantly highest starch (17.73%), total sugars (1.52%) and dry matter (27.59%) on par with FYM + ½ NPK + $MgSO_4$ (32.39 t ha^{-1}). Highest grain yield of maize was observed with combined application of FYM + NPK + $MgSO_4$ @ 25 kg ha^{-1} (31.91 t ha^{-1}).

Analysis of the post harvest soil samples for physico chemical properties showed significant increase in soil pH in all the treatments over the initial. The organic carbon content significantly decreased from the initial value of 0.684% after the crop cycle, but the total N and available N status of the experimental plots significantly increased. The available P and K showed decreasing trend from the initial status. Highest dehydrogenase and urease activities were found under application of N P K @ 80:60:80 kg ha^{-1}. However, integrated application of FYM along with NPK @ 40:30:50 kg ha^{-1} and $MgSO_4$ @ 25 kg ha^{-1} showed higher fluorescein diacetate hydrolysis assay (FDA) and acid phosphatase activities. Combined application of N and K resulted in higher urease activity than single application of N and K fertilizers. Application of FYM resulted in higher enzyme activities compared to vermicompost. Tuber yield of greater yam had positive and significant relationship with all the enzyme activities. Application of organic manure combined with half of the recommended doses of inorganic fertilizers and either $ZnSO_4$ or $MgSO_4$ not only helped to augment the crop yields but also influenced the proximate composition and sustained the soil fertility.

The second season experiment was laid out with the same set of treatments during June 2021and yet to be harvested.

Screening nutrient use efficient genotypes of sweet potato

Screening of elite sweet potato genotypes for physiological efficiency

The first season field experiment to identify nutrient use efficient (NUE) genotypes of sweet potato was laid out with 90 elite genotypes during 2020-21. The vine cuttings of sweet potato were planted in rows at a spacing of 60×20 cm without any inorganic fertilizers. The results revealed that, Sree Bhadra produced significantly the highest tuber yield (46.8 t ha^{-1}), followed by Sankar (42.9 t ha^{-1}), 912 (40.3 t ha^{-1}), Pusa Safed (38.0 t ha^{-1}) and SB 573/3 (36.3 t ha^{-1}). Highest vine yield (51.4 t ha^{-1}) was recorded in Sree Bhadra, followed by 912 (44.9 t ha^{-1}), Sankar (43.1 t ha^{-1}) and Pusa Safed (42.0 t ha^{-1}). The mean dry matter, starch and total sugar were 25.45, 20.65, 2.80% with values ranged as 21.42-27.58, 16.66-23.68, 2.24-3.17% on FWB respectively. Nutrient analysis of the tuber samples of these genotypes revealed that, the N, P and K ranges as 1.2-3.87, 0.083-0.267 and 2.77- 4.78 % respectively The micronutrients *viz.,* Fe, Cu, Mn and Zn ranged from 66.2-264.7, 3.4-20.8, 33.4-185.4 and 3.0-17.4 mg kg^{-1} respectively. Sweet potato genotypes *viz.,* SB 573/3, Sankar, Kalinga, Kishan, Bhu Sona, Bhu Krishna, Sree Bhadra, Pusa Safed, Kanjangad and Kamala Sundari had higher macro and micronutrients. The second season crop planted in *kharif* 2021-22 is yet to be harvested.

Standardization of package of practices (PoP) for naturally biofortified varieties of tuber crops

Nutrient management for naturally biofortified sweet potato varieties

A field experiment was laid out in RBD with 3 replications during 2021 to study the effect of various nutrient management practices on yield and proximate composition of biofortified sweet potato varieties. The treatments involved four varieties, *viz*., V_1-Bhu Krishna; V_2- Bhu Sona; V_3-Bhu Kanti; V_4-Bhu Ja and 4 nutrient management practices (T_1-FYM @ 5 t ha^{-1} + NPK @ 25:12.5:25 kg ha^{-1}; T_2-FYM @ 5 t ha^{-1}+ NPK @ 50:25:50 kg ha^{-1}; T_3-FYM @ 5 t ha^{-1}+ NPK @ 75:25:75 kg ha^{-1}; T_4- FYM @ 5 t ha^{-1}+ NPK @ 100:37.5:100 kg ha^{-1}). The soil is extremely acidic (pH 4.23), non-saline (0.611 dS m^{-1}), low in organic carbon (0.399%) and available N (136.19 kg ha^{-1}), high in available P_2O_5 (62.08 kg ha^{-1}) and K_2O (289.69 kg ha^{-1}) with available Fe, Cu, Mn and Zn to the tune of 6.26, 1.42, 6.27 and 1.37 mg kg^{-1} respectively. Well rotten farmyard manure @ 5 t ha^{-1} was applied before ploughing. N was applied in 3 splits at 0, 30 and 50 DAP, entire P as basal dose and K in 2 splits at 0 and 50 DAP as per the treatments. The vine cuttings were planted in December, 2021 and the crop is yet to be harvested.

Activity 5: Long term integrated nutrient management in tropical tuber crops (K. Susan John)

Long term effect of advanced integrated nutrient management (INM) practices on the sustainability of cassava

The major objective of this experiment was to study the sustainability of successful technologies / scientific information on INM practices in cassava from different nutrient management experiments including long term fertilizer experiments (LTFE) at HQ since 1977. The experiment was conducted with 20 treatments replicated thrice in RBD. The treatments were blanket recommendation (PoP), soil test based fertilizer cum manurial recommendation for primary (STBFR NPK), secondary (STBFR Mg) and micronutrients (STBFR Zn, STBFR B), soil and plant test based customized fertilizers, low input nutrient management strategy (LINMS), FYM, green manuring *in situ* with cowpea (GM), crop residue incorporation (CR), FYM + ash, use of NUE varieties/ genotypes (Sree Pavithra, 7III E3-5, CI-905, CI-906) with 25% recommended dose of NPK, soil/foliar application of P, K, Ca, Zn, Si on cassava mosaic disease (CMD) symptom management.

The first season results indicated, customized fertilizers resulted in the highest tuber yield (32.0 t ha^{-1}) on par with low input nutrient management (27.7 t ha^{-1}).

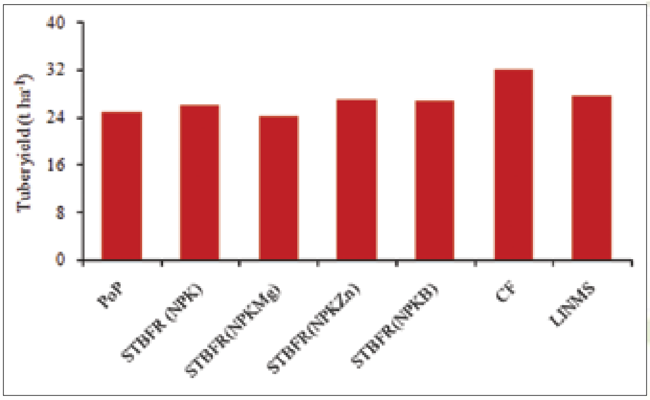


Fig. 73. Tuber yield under different nutrient management practices

PoP (FYM @ 12.5 t ha^{-1} + NPK @ 100:50:100 kg ha^{-1}) (24.9 t ha^{-1}) was on par with soil test based fertilizer cum manurial recommendation for major nutrients (FYM @ 5 t ha^{-1}+ NPK @ 71:12.5:60 kg ha^{-1}) (26.0 t ha^{-1}). Soil test based application of secondary nutrient (Mg) (24.2 t ha^{-1}) and micronutrients, Zn (26.9 t ha^{-1}) and B (26.8 t ha^{-1}) independently along with soil test based fertilizer cum manurial recommendation for major nutrients did not increase the tuber yield significantly over PoP (24.9 t ha^{-1}) (Fig. 73). Nutrient management approaches significantly influenced post harvest soil N, P, K, Ca, Mg, Zn and B. Customized fertilizers, low input nutrient management and absolute control caused significantly low soil P. Significant effect of different organic manures was seen for available N, P, K and Ca.

GM and CR resulted in a tuber yield of 27.8 t ha^{-1} and 23.0 t ha^{-1} respectively and remained on par with FYM @ 12.5 t ha^{-1} (24.9 t ha^{-1}). Application of FYM and ash alone without N P K fertilizers resulted in a tuber yield of 21.3 t ha^{-1} and was on par with PoP (24.9 t ha^{-1}). Among the organic manures, green manuring, crop residue and ash application resulted in significantly low soil P over PoP. Crop residue resulted in a significantly higher soil available K and application of ash and FYM resulted in significantly high soil exchangeable Ca.

Out of the four nutrient use efficient (NUE) genotypes, Sree Pavithra, CI-905, CI-906 and 7III E3-5 applied with 25% of the recommended NPK, Sree Pavithra resulted in significantly the highest tuber yield (34.2 t ha^{-1}), whereas CI-905, CI-906 and 7III E3-5 were on par with Sree Visakham at 100% NPK.

Soil and foliar application of nutrients *viz*., P, K, Ca, Zn and Si did not significantly affect the cassava tuber yield. Soil and foliar application of Zn significantly

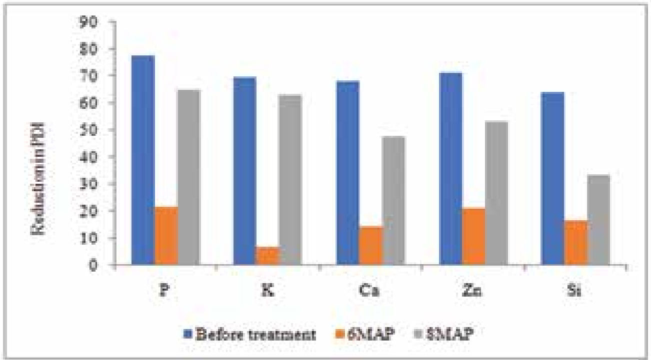


Fig. 74. Percentage reduction in CMD expression with nutrients at different growth stages

reduced the tuber cyanogen (18.4%) over soil test based NPK alone.

Statistical analysis of the data on cassava mosaic disease grading revealed that, the effect of application of nutrients remained non significant on disease grade before the application of treatments and the mean percentage disease incidence (PDI) was 70.19%. Significant difference in PDI symptom grade was observed during 6 and 8 MAP with mean values as 58.68 and 34.25% respectively. The mean percentage reduction in PDI was 16.4 and 51.2% during 6 and 8 MAP respectively (Fig. 74). In absolute control (AC), the tuber yield was 13.881 t ha^{-1} which was 55.75% of PoP.

Diagnosis and correction of emerging soil plant nutritional disorders in tropical tuber crops

Observational trial in yams to diagnose the suspected B deficiency

During the first year, among the three experiments, the observational trial laid out in yams (greater yam and white yam) to diagnose the tuber discolouration and hollowing was harvested during March 2021. The treatments included were mainly nutrients *viz*., B and calcium (Ca) through soil and foliar application along with PoP. Soil application of B was done as borax @ 25 kg ha^{-1}, half each as basal and at 3-4 MAP. Foliar application of B was done as solubor @ 0.1% thrice at maximum vegetative growth stage (3-4 MAP), tuber bulking stages (5-6 MAP) and 7-8 MAP. Ca as soil application was done through lime as basal @ 2 t ha^{-1} and foliar as calcium nitrate @ 1% during the above intervals. There were no symptoms in the tubers, irrespective of treatments (Fig. 75). The yield data did not show any significant difference among treatments.

Fig. 75. Appearance of the flesh of yam tubers under different treatments

During the second year, the field experiment on yam was continued with the same set of treatments. Soil and plant samples were collected at periodic intervals since 6 MAP to find out the status of critical nutrients to confirm whether the problem is nutrient related. The crop is yet to be harvested.

Arriving at the critical level of soil and plant B for tuber cracking in sweet potato

Another experiment in lysimeter tanks was also conducted to study the soil and plant critical levels of B for tuberization as well as to determine the soil B level below which there is cracking. From the first year appraisal of the B status of the different blocks of ICAR-CTCRI farm, soil samples ranging in B from 0.1-1.0 ppm were collected and filled in the lysimeter tanks.

Fig. 76. Tuber cracking observed at 0.3 and 0.4 ppm soil B

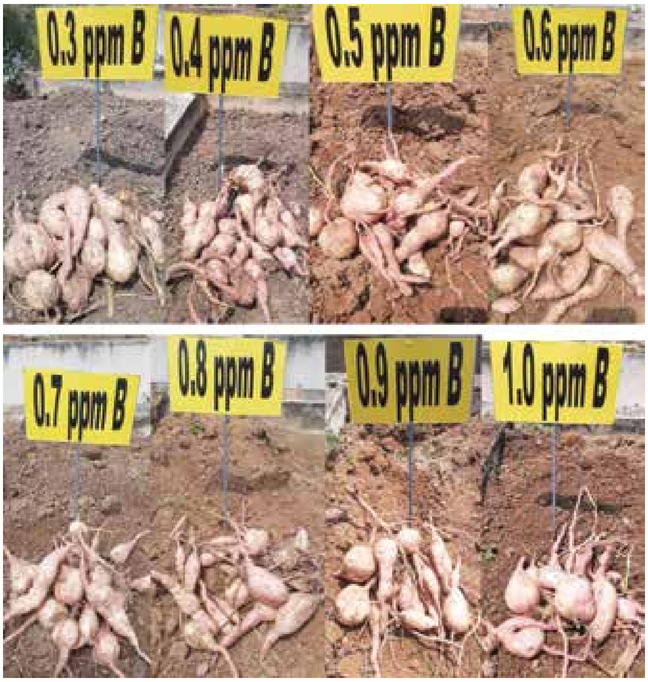


Fig. 77. View of the harvested tubers at soil B ranging from 0.3-1.0 ppm

Different soil B status was the main treatments and these were uniformly applied with recommended PoP alone and along with lime. Soil and plant samples were taken at periodic intervals of 15 days, since 45 DAP to arrive at their critical levels.

The harvest of the tubers done at 110 DAP clearly showed tuber cracking at soil B levels at 0.3 and 0.4 ppm (Fig. 76, 77).

Activity 6: Soil carbon quality and conservation studies in tropical tuber crops (V. Ramesh)

Geo-spatial soil samples were collected from Salem, Erode and Karur districts of Tamil Nadu and from the AICRP-TC centres at Yethapur, Navsari, Dapoli, Dharwad, Ranchi and Rajendranagar to characterize the soil physical characters. The soils are sandy loam to sandy clay in texture with bulk density ranging from 1.28 - 1.62 Mg m^{-3} and maximum water holding capacity from 36 - 52% (v/v). The soil C pools in four different soil types *viz*. laterites, red loams, clay loams and red soils indicated that, the soil organic carbon was maximum (7.8 g kg^{-1}) in laterite soils and lowest in red soils (5.8 g kg^{-1}). The labile carbon was maximum under clay loam (546.0 mg kg^{-1}) and lowest under laterites (263.5 mg kg^{-1}). The water soluble C was highest in laterites (23.4 mg kg^{-1}) and lowest in red soils (14.4 mg kg^{-1}) (Fig. 78). The organic carbon content of soils varied from 0.42 - 0.86% and the labile carbon varied from 12-18% of organic carbon values.

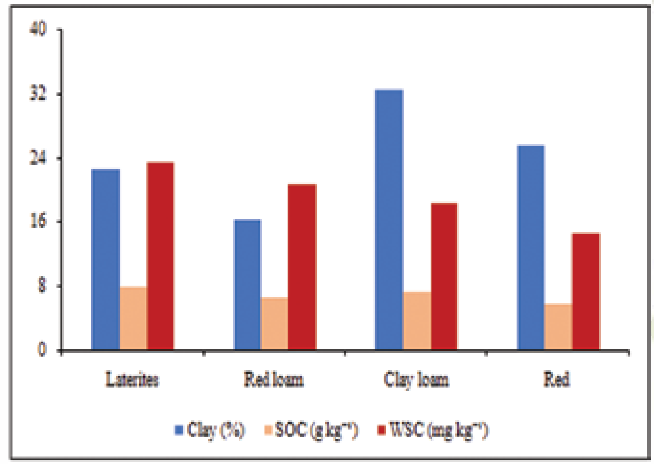


Fig. 78. Influence of soil types on different carbon fractions

Production of zeolites for testing for its quality (pH, CEC) was made and treated zeolites using caustic alkali mixtures had pH values of 6.8-7.2 and cation exchange capacity of 150-174 cmol $p^{(+)}$ kg^{-1}.

Activity 7: Climate change adaptation and mitigation in tropical tuber crops (Sanket J. More)

Climate smart agricultural practices for tropical tuber crops

Field experiment on climate smart agriculture (CSA) practices in cassava was laid out at HQ farm with two treatments, CSA and conventio nal practice (CP) (Fig. 79). Significantly higher tuber yield was recorded in CSA practice (29.50 t ha^{-1}) than conventional practice

Fig. 79. On station field experiment on climate smart agriculture

(25.40 t ha^{-1}). Green house gas (GHG) emission estimates of the two production systems using the GHG accounting tool, CCAFS-MOT, was worked out. Carbon foot print (CF) estimation and life cycle assessment (LCA) of the two production systems were done. The global warming potential (GWP) of CSA is found to be 194 kg carbon equivalent (CE) ha^{-1}, whereas it was 272 kg CE ha^{-1} for CP, which clearly showed the superiority of CSA in reducing GHG emission compared to the conventional practice.

Studies on drought tolerance in tropical tuber crops through mineral nutrition

The first season field experiment to study the role of nutrients in drought tolerance in cassava was undertaken at HQ during November 2020 to August 2021 using the variety Sree Swarna. The experiment was laid out in RBD with 11 treatments replicated thrice. The treatments were T_1: NPK @ 100:50:100 kg ha^{-1} (control); T_2: 1% solubor; T_3: 1% calcium chloride; T_4: 1% potassium sulphate; T_5: 1% potassium nitrate; T_6: 1% potassium chloride; T_7: 1% magnesium sulphate; T_8: 1% amonium molybdate; T_9: 1% calcium silicate; T_{10}: 1% selenium; T_{11}: 0.5% zinc sulphate. The crop was subjected to early season water deficit stress for 90 days during 3-5 MAP. The mineral nutrients were applied (foliar spray) twice at fortnightly intervals between 120-150 DAP. The crop was harvested at 10 MAP. The results revealed that, the foliar application of 1% KNO_3 enhanced the mean plant height (110.7 vs. 86.9 cm), leaf retention capacity (63.9 vs. 43.9%) and leaf area index (2.04 vs. 1.37), ultimately resulting in high photosynthetic efficiency (25.9 vs. 16.3 µmol CO_2 m^{-2} s^{-1}), total biomass (DWB) (193.6 vs. 161.2 g $plant^{-1}$) and partitioning index (0.50 vs. 0.40) compared to control at 5 MAP. At harvest, plants treated with 1% KNO_3 resulted in a higher harvest index (0.63), number of tubers per plant (9) and tuber yield (2.87 kg $plant^{-1}$) (Fig. 80). The KNO_3 also resulted in the lowest HCN content (42.29 ppm) in cassava tubers compared to control (81.85 ppm). The first year results showed that, foliar application of 1% KNO_3 during the water stress period of 3-5 MAP can enhance the above ground and below ground biomass accumulation capacity and partitioning index by virtue of its influence in the maintenance of higher photosynthetic efficiency and leaf area index.

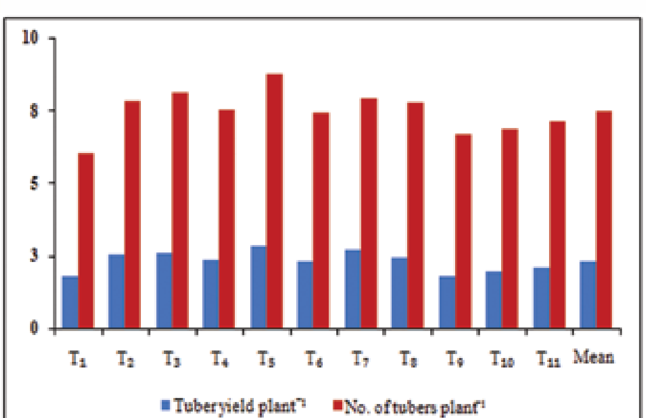


Fig. 80. Effect of nutrients on tuber number, tuber yield per plant of cassava under early season water deficit stress

Activity 8: Physiological studies related to climate change in tropical tuber crops (Saravanan Raju)

A field experiment was undertaken to study the response of cassava to different levels of soil moisture stress. There were 24 cassava genotypes subjected to three treatments *viz.,* control (well watered), mild stress and severe stress imposed at 3 MAP. Observations on plant growth characteristics, canopy temperature and photosynthetic parameters were taken at different stages of plant growth. Plant height taken at 4 MAP did not show any significant effect of water stress, whereas the number of leaves per plant was highest in control (72), followed by mild stress (67) and severe stress (66). Mean canopy temperature was lower (25.3°C) in control compared to mild and severe stress (Fig. 81). The net photosynthetic rate (P_n), stomatal conductance (g_s) and leaf transpiration rate (T_l) were recorded for the different genotypes under control and water stress treatments. Mean *Pn* was highest in the control (28.48 µmol CO_2 $m^{-2}s^{-1}$) followed by mild (25.22) and severe (24.20) stressed cassava genotypes

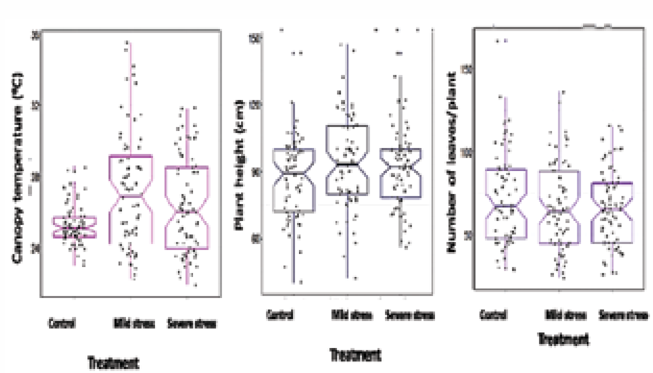


Fig. 81. Plant growth characteristics and canopy temperature in cassava genotypes under different moisture stress conditions at 4 MAP

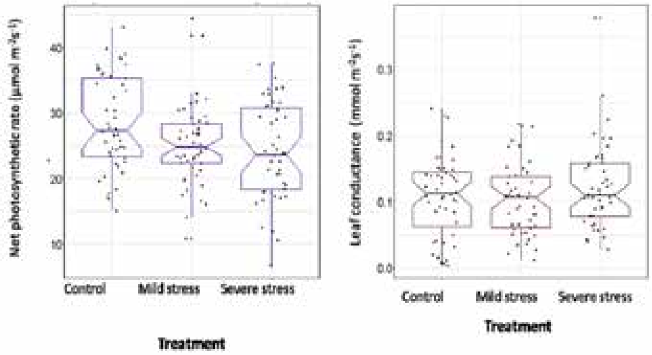


Fig. 82. Leaf gas exchange parameters of cassava genotypes under different moisture stress conditions at 4 MAP

respectively (Fig. 82). Significant differences were not observed for mean leaf conductance and leaf transpiration rates among the treatments.

Photosynthetic response of cassava varieties to eCO_2 and nitrogen application

A field experiment on response of cassava to elevated CO_2 (eCO_2) and nitrogen application was carried out during 2021. The net photosynthetic rate (*Pn*), stomatal conductance (*gs*) and intercellular CO_2 (*Ci*) was studied

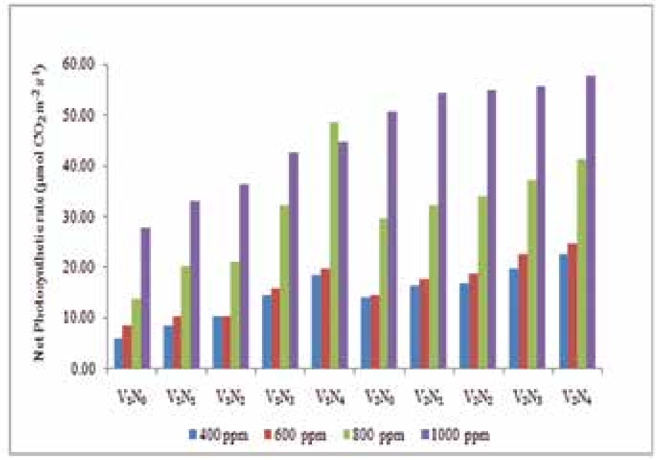


Fig. 83. Effect of different levels of nitrogen and eCO_2 on net photosynthetic rate of cassava varieties

in two varieties of cassava *viz.,* Sree Pavithra (V_1), Sree Reksha (V_2) with different doses of N [(N_0 (0%); N_1 (25%); N_2 (50%); N_3 (100%); N_4 (125%)] of the recommended PoP of N) under ambient (400 ppm) and eCO_2 (600, 800, 1000 ppm). The *Pn* steadily increased due to short term (10 minutes) exposure at eCO_2 concentrations between 400 and 1000 ppm (Fig. 83).

Institute Project IV

Quality planting material production of tropical tuber crops

Activity 1: Developing innovative techniques for seed production in tropical tuber crops and quality planting material production in cassava, sweet potato and Chinese potato (R. Muthuraj)

Virus free planting materials were produced through virus indexing, micropropagation, hardening and minisett multiplication under protected environment. This was further expanded by establishing seed villages in Kerala, Tamil Nadu, Andhra Pradesh, Odisha and North Eastern States in a farmer participatory mode. Farmers were sensitised for mass multiplication and popularization of disease free planting materials of improved varieties of these tuber crops. Seed producers were identified to extend the production of quality planting materials as well as to increase the area of tropical tuber crops in non traditional areas of the country.

Large scale multiplication of quality planting materials of cassava

Improved varieties of cassava *viz*., Sree Reksha, Sree Sakthi, Sree Suvarna, Sree Pavithra, Sree Vijaya and Sree Jaya were planted in an area

Fig. 84. Field view of quality planting material production of cassava (var. Sree Reksha)

of 7.50 acres in blocks III and V of ICAR- CTCRI- HQ during 2021-22 (Fig. 84).

Rapid multiplication of virus free planting materials was carried out through minisetts technique in cassava varieties *viz*., Sree Vijaya, Sree Jaya, Sree Pavithra and Sree Reksha. The minisetts were planted inside the net house for one month and then transplanted.

Effect of growth regulators on plant growth and yield parameters in cassava

A field experiment was conducted with nine treatments in RBD with five varieties *viz.,* Sree Reksha, Sree Pavithra, Sree Suvarna, Sree Vijaya and Sree Jaya at HQ, to study the effect of different growth regulators on growth and yield parameters in cassava. Cassava setts before planting were soaked for 30 minutes with different growth regulators *viz.,* GA_3 @ 100 ppm (T_1); GA_3 @ 200 ppm (T_2); IAA @ 100 ppm (T_3); IAA@ 200 ppm (T_4); potassium nitrate @ 1% (T_5); potassium nitrate @ 2% (T_6); thiourea @ 0.5% (T_7); thiourea @ 1% (T_8); control (T_9). Stems treated with GA_3 @ 200 ppm resulted in higher germination (92.85, 99.85 %) at 15 and 30 DAP respctively in Sree Reksha followed by IAA @ 200 ppm (85.75, 96.80 %). Application of GA_3 @ 100 ppm resulted in lengthy plants (85 cm) with thick stems (12 cm) and wide canopy spread (45 cm) in Sree Reksha followed by IAA @ 200 ppm at 90 DAP resulted in significantly higher tuber yield (38.75 t ha^{-1}) followed by GA_3 @200 ppm (31.25 t ha^{-1}).

Activity 2: *In vivo* and *in vitro* multiplication of planting materials of yams and aroids (K. Sunilkumar)

Refinement of micro/minisett method of multiplication in yams

An experiment was conducted in yam (var. Sree Nidhi, Sree Neelima) with pre treatments (T_1: *Trichoderma;* T_2: *Pseudomonas*; T_3: PGPR Mix-1; T_4: control (SAAF 1%); T_5: cowdung slurry) and sett size (S_1:10 g; S_2: 20 g; S_3: 30 g; S_4: 50 g) under factorial CRD. After pretreatment, the setts were planted in protrays filled with potting mixture consisting of cocopeat, FYM and soil in 1:1:1 ratio (Fig. 85).

Sett size resulted in significant variation in sprouting percentage and tuber yield. The highest mean tuber yield (1760.16 g $plant^{-1}$) was obtained with 50 g followed by

Fig. 85. Protrays raised greater yam seedlings (var. Sree Neelima)

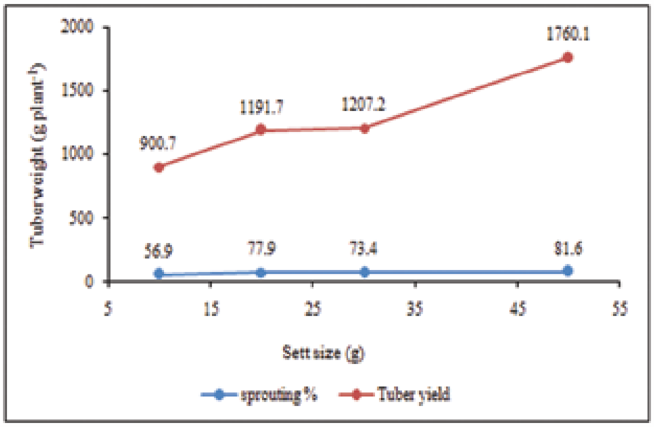


Fig. 86. Effect of sett size on sprouting percent and tuber yield in yams

Fig. 87. Effect of sett size on tuber development in greater yam (var. Sree Nidhi) at 2 MAP

30 g and 20 g. The lowest tuber yield (900.75 g plant[-1]) was seen with 10 g indicating that, the sett size of 20 g is sufficient for a targeted yield of 1 kg plant[-1] (Fig. 86, 87).

There was significant variation in sprouting percentage and tuber yield with respect to the sett pre treatments. The highest yield was recorded in setts subjected to SAAF pre treatment followed by PGPR Mix-1 and *Trichoderma* and the lowest under *Pseudomonas* and cow dung slurry treatments (Fig 88). A positive association of initial sprouting percentage was seen with final tuber yield. Field view of yams planted with minisetts is depicted in Fig. 89.

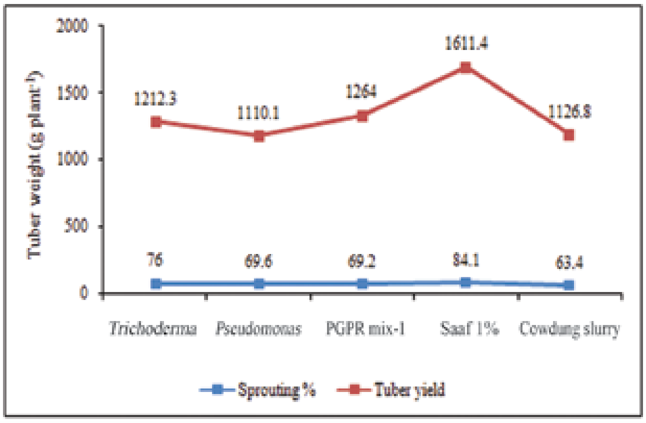


Fig. 88. Effect of sett pre treatments on sprouting percentage and tuber yield of yams


Fig. 89. Field view of yams planted with minisetts

Effect of growth regulators in elephant foot yam

A field experiment was conducted with nine treatments in RBD using the EFY (var. Gajendra). The treatments were GA_3 @ 100 ppm (T_1); GA_3 @ 200 ppm (T_2); IAA @ 100 ppm (T_3); IAA @ 200 ppm (T_4); KNO_3 @ 1% (T_5); KNO_3 @ 2% (T_6); thiourea @ 0.5% (T_7); thiourea @ 1% (T_8); control (T_9). GA_3 @ 200 ppm resulted in maximum sprouting (87.50, 99.98 %) at 15 and 40 DAP, followed by GA_3 @ 100 ppm (84.75%, 96.88%) respectively. At 90 DAP, GA_3 @ 200 resulted in lengthy plants (89 cm), with good pseudostem girth (32 cm) and wide canopy spread (89 cm) followed by GA_3 @100 ppm. Corm yield was the highest under GA_3 @ 200 ppm (38.65 t ha^{-1}) followed by IAA @ 200 ppm (31.50 t ha^{-1}).

Large scale multiplication of released varieties of tuber crops through Best Agricultural Practices (BAP)

Quality seed materials of released and popular varieties of tuber crops *viz.,* cassava, elephant foot yam, yams, taro, sweet potato, Chinese potato and yam bean produced (Fig. 90) are given in Annexure II.


Fig. 90. Quality planting material production of yams

Establishment of seed villages

A total of 13 seed villages benefitting 74 farmers were established in Tenkasi, Salem, Pudukottai, Namakkal and Tirunelveli districts of Tamil Nadu and Thiruvananthapuram district of Kerala for cassava, sweet potato, elephant foot yam and Chinese potato. Cassava stems of Sree Jaya, Sree Reksha, Sree Athulya and Sree Vijaya varieties were supplied to the tune of 43500 to 31 farmers, 35000 sweet potato vines of Sree Kanaka and Sree Arun to 13 farmers, 2.5 tonnes of EFY (var. Gajendra) to 15 farmers and 150000 vine cuttings of Sree Dhara variety of Chinese Potato to 15 farmers.

Decentralised Seed Multipliers (DSM)

The beneficiary farmers under different schemes with an area of up to one hectare were approved as DSM for quality planting material production. Regular agro advisories were given by the scientists as per the standard seed guidelines. A total of 19 DSMs were registered.

Promotion of tuber crops in non traditional areas

To promote and popularize tropical tuber crops in non traditional areas, 800 stems of cassava (var. Sree Reksha) were distributed in Rajasthan and 500 stems in Gujarat.

External Funded Projects

All India Network Programme on Organic Farming (AINP-OF) (G. Suja)

The major objectives were to evaluate organic, inorganic and integrated management practices in cropping systems involving tuber crops, to evaluate the response of cassava varieties to organic production system, to develop integrated organic farming system involving tuber crops and to conduct geo-referenced on farm characterization of organic growers. Besides these, cluster based demonstration of organic package under SCSP and on station and farmer participatory evaluation of natural farming in cassava based cropping systems are ongoing.

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

Economic analysis of the system indicated that, of the four systems evaluated, cassava-groundnut was the most remunerative. In cassava-groundnut, 50% organic + *Bheejamrit*, *Ghanajeevamrit* and *Jeevamrit* (BGJ) was the most profitable without and with premium price. In cassava-vegetable cowpea system, without and with premium price, 50% organic + 50% inorganic (towards organic) was profitable. Taro-green gram and taro-black gram too were productive and remunerative due to good yields from taro. Without and with premium price, 50% organic + BGJ was profitable in both the systems. In cassava-vegetable cowpea, 25% organic + 25% inorganic + BGJ resulted in the highest tuber equivalent yield, equivalent energy and production efficiency. In cassava-groundnut, taro-green gram and taro-black gram systems, 50% organic + BGJ resulted in the highest tuber equivalent yield, equivalent energy and production efficiency.

Evaluation of response of different varieties of cassava to organic farming

In the fifth consecutive year, cassava variety Sree Reksha produced significantly higher yield (36.61 t ha^{-1}) under organic management. Second highest yield was obtained from Sree Pavithra (25.93 t ha^{-1}). The varieties, Sree Reksha also generated higher profit. (₹ 507400 ha^{-1}) and B:C ratio (3.26), followed by Sree Pavithra (profit: ₹ 293867 ha^{-1}, B:C ratio: 2.31)


Hybrid napier fodder grass


Banana + cucumber


4 cows + 1 calf


Okra


General view of IOFS


Green gram

Fig. 91. A view of the few components of IOFS

under organic mode. Combined analysis over five years indicated that, varieties varied significantly under organic management. Sree Reksha yielded the highest (36.66 t ha^{-1}) followed by Sree Pavithra (25.53 t ha^{-1}).

Geo-referenced on farm characterization of organic growers

Geo-referenced survey of 30 farmers practicing organic farming in Thiruvananthapuram and Kollam districts of Kerala was conducted. The survey was carried out in Chadayamangalam block, Kollam and Kazhakuttam and Kilimanoor blocks, Thiruvananthapuram

Development of Integrated Organic Farming System (IOFS) model

Earlier developed Model 1 was refined into another IOFS model (Model 2) involving tuber crops and animal components, which has been established in 75 cents (0.3 ha) since October 2020 comprising, cropping systems involving horticulture crops and food crops, *viz*., banana + elephant foot yam (13%), cassava + vegetable cowpea/ *Amaranthus* (7% area), taro + maize (13%), vegetables (okra, *Amaranthus*, cucumber, cluster beans) - pulses (green gram, black gram, soybean) (20%), vegetables - oilseeds (groundnut) (7%), pineapple, *Moringa*, agathi (as hedge crops) (13%), hybrid napier grass (for fodder) (7%), dairy unit (4 cows & 1 calf) (13%), lemon grass and vermicompost unit (to be established (7%) (Fig. 91). Yet to account the complete productivity from Model 2. However, tuber equivalent yield of 20.20 tonnes and net returns of ₹ 15030 could be obtained from this newly established IOFS involving tuber crops from an area of 75 cents.

Evaluation of natural farming in cassava

The field experiment to evaluate natural farming practices (NF) in cassava + vegetable cowpea - green gram system was initiated with nine treatments replicated thrice in RBD. The treatments were T_1: control; T_2: complete NF (application of *Bheejamrit*, *Ghanajeevamrit* and *Jeevamrit* (BGJ) + crop residue mulching (CR) + intercropping (IC) + whapasa); T_3: NF-1 (without BGJ); T_4: NF-2 (without CR); T_5: NF-3 (without IC); T_6: NF-4 (without whapsa); T_7: AINP-OF package; T_8: Integrated crop management (ICM-1); T_9: ICM-2. First season results indicated that, the highest tuber yield of cassava was obtained under AINP-OF package on par with ICM practices and NF-3 and NF-4. The yield of the intercrop vegetable cowpea (bushy type) was the highest in complete NF, followed by NF-2. The lowest cost of cultivation and hence highest income was obtained in NF-4 . Weed density was lowest in ICM practices and AINP-OF package and was on par with the different NF practices, except NF without intercropping and whapasa. Highest weed density was recorded in control. System productivity and profitability need to be worked out for valid inference.

Farmer participatory natural farming and cluster based demonstration of organic farming package under SCSP

Farmer participatory validation of natural farming was conducted at Kariyil village, Kazhakkuttam, Thiruvananthapuram, with three treatments, *viz*., farmer's package, AINP-OF package and NF practice by 10 SCSP farmers. The yield of cassava was higher in AINP-OF package, but the net returns was higher in NF package.

Two trainings were also conducted under SCSP programme. Training Programme on 'Organic farming for self sufficiency in the homesteads of Kerala and distribution of organic inputs and agricultural implements' was organized in hybrid mode at ICAR-CTCRI-HQ on 12 August. Another one day training programme-cum-exhibition on 'Improved production and processing technologies of tuber crops' was organized at Adoor, Pathanamthitta, on 20 November (Fig. 92).

Fig. 92. Training under SCSP, AINP-OF at Adoor, Pathanamthitta, Kerala

Potential impact of climate change on tropical tuber crops over the major growing areas of India (G. Byju)

The impact of climate change on crop water requirement as well as irrigation requirement of cassava, sweet potato, greater yam, elephant foot yam and taro were analyzed over the major growing areas in India using the FAO-CROPWAT and LARS-weather generator for 2030 and 2050 (RCP-4.5). The increase/decrease in magnitudes of gross irrigation requirements for these crops to the current irrigation requirement was -2.6 to 291.1 mm, -0.3 to 18.4 mm, 5.3 to 392.1 mm, -33.6 to 311.2 mm and 100.8 to 263.8 mm respectively during 2030 and 2050. The optimum irrigation schedules were also developed for these crops.

The influence of climate model biases in the predictions of yield and water requirement of cassava was assessed using WOFOST and CROPWAT models for the scenarios of 2030, 2050 and 2070 (RCP-4.5). The percentage change in crop yield predictions with and without bias corrections of meteorological variables ranged from 7.6 - 10.8%, 1.6 - 5.4% and -3.0 - 4.0% respectively for 2030, 2050 and 2070. The bias corrections made an increment in the gross irrigation requirement of cassava as 16.5%, 17.8% and 16.0% in 2030, 2050 and 2070 respectively compared to the values without bias corrections. The study indicated that, raw meteorological variables directly from the climate models resulted over/under estimation of yield and irrigation requirements of cassava and the bias corrections helped to issue reliable crop yield predictions.

Study on the impact of climate change on yield of tropical root and tuber crops using WOFOST revealed that, the influence of changing climate varied from one location to another. As an overall outcome, cassava (-14 -13%; -21 - 12%), sweet potato (-35 - 18%; -43 - 13%), and greater yam (-15 - 9; -18 - 8) can be considered as future crops concerning their yield variations and their economics which is higher as compared to rice (-26 -15%; -50 - 18%) and potato (-37 - 7%; -59 - 8.5%) for both the RCPs (4.5 & 8.5). Elephant foot yam (-22 - 3%; -27 - 1%) and taro (-19 - 2%; -33 - 1%) can also be recommended for enhancing the availability of food. The geographical suitability of cassava and sweet potato was studied using the species distribution model, MaxEnt and QGIS. District wise geographical suitability indicated an increase in cassava area in future with percentage increase of 42, 41; 32, 43 and 33, 32 for 2030, 2050 and 2070 respectively for the two RCPs (4.5 and 8.5). The same for sweet potato was 32, 25; 27, 31 and 23, 21 respectively. The geographical suitability of rice and potato was analysed to understand the superiority of cassava and sweet potato indicated the percentage increase in rice suitability was 17, 15; 15, 17 and 13, 11 respectively for 2030, 2050 and 2070 for the two RCPs. The same for potato was 10, 11; 10, 9 and 10, 9% respectively. The results indicated the geographical suitability for cassava and sweet potato in future over rice and potato across India.

Higher productivity and profitability from coconut gardens through soil health management (G. Byju, G. Suja)

On farm validation of SSNM based customized fertilizers and organic farming was done in 10 coconut farms in Pathanamthitta district, Kerala. In cassava, SSNM resulted in higher yield over farmer's practice (FP) by 19.54% and PoP by 6.65%. In greater yam, SSNM performed better than FP by yielding 16.82% higher and PoP by 12.26%. In cassava, organic farming (OF) yielded higher over FP by 18.20% and PoP by 3.26%. In greater yam, OF yielded higher over FP by 13.89 % and PoP by 11.99 %. On farm trials and demonstrations established in three districts during the past three years revealed that, coconut + tuber crop system performed better with respect to yield, cost benefit analysis, soil health improvement and overall system productivity in all the 30 gardens of Thiruvananthapuram, Kollam and Pathanamthitta districts of Kerala. Customized fertilizers and organic farming technologies in tuber crops resulted in higher productivity and profitability of coconut. The validated technologies are transferred to KVKs, Department of Agriculture and other line departments for popularization and scaling up.

Popularization of climate resilient and nutritionally rich varieties of tuber crops for economic development and nutritional security of farmers of Odisha (M. Nedunchezhiyan)

Front line demonstrations (FLD) on tuber crops were conducted with six crops *viz*., sweet potato (118.3 ha.), cassava (23.6 ha.), yams (34.7 ha.), yam bean (50.2 ha.), elephant foot yam (19.1 ha.) and *Colocasia* (13.2 ha.) in an area of 259.10 ha involving 1360 beneficiary farmers (Fig. 93). Nucleus seed/planting materials were distributed to the farmers from RS, Odisha. Demonstration of sex pheromone trap for the control of sweet potato weevil was undertaken across 118.3 ha. Dehumidified storage shed was also constructed.

Fig. 93. Yam+maize intercropping in Barghad district

Area expansion of sweet potato in Angul, Bolangir, Boudh, Deogarh, Keonjhar and Mayurbhanj districts of Odisha (M. Nedunchezhiyan)

Six training programmes on sweet potato production and value addition were organized benefitting 300 stakeholders of the selected districs of Odisha with respect to different varieties and various snack foods developed from tropical tuber crops.

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

A field experiment with six cassava genotypes imposed with intermittent high light (IHL) treatment and control was carried out. Greater plant growth and above ground biomass were influenced by light treatment compared to ambient light condition. Variety Sree Suvarna had higher crop yield (4.31 ± 0.32 kg plant^{-1}) at controlled light treatment compared to IHL condition (4.11 ± 0.44 kg plant^{-1}) and was tolerant to light fluctuations. Higher average values of *Pn* measured was 34.04 ± 1.6 μ mol m^{-2} s^{-1} (control-Sree Suvarna), non photochemical chlorophyll fluorescence quenching (NPQ) was 2.12 ± 0.36 (IHL - Sree Athulya) and *qN* (non-photochemical chlorophyll fluorescence quenching) was 0.85 ± 0.03 (control: Sree Pavithra). High *Pn* in the genotype resulted in crop productivity under control conditions and higher NPQ was observed in leaves exposed to IHL indicated that, more energy was dissipated as heat, revealing that, these leaves suffered photo inhibition. Highest crop biomass obtained was correlated with the highest leaf chlorophyll (*Chl-a* and *Chl-b*) values measured in the variety Sree Suvarna under both control and IHL conditions. Significant differences in fluorescence parameters and crop yield were observed between the light conditions and also between the cassava varieties. It was inferred that, IHL obviously affected the rate of NPQ induction and relaxation.

Popularization of climate resilient improved varieties of tuber crops for food, nutrition and doubling income with emphazis on well ness of tribal and marginal farmers in Kerala (K. Sunilkumar)

Quality planting materials of elephant foot yam (var. Sree Padma, Gajendra), cassava (var. Sree Reksha,

Fig. 94. Distribution of planting materials at Poonjar South gramapanchayat, Kottayam, Kerala

Vellayani Hraswa, Sree Pavithra) and sweet potato (var. Sree Kanaka, Sree Arun and Bhu Krishna) were produced from 5.5, 2 and 0.5 acres respectively. Quality planting materials of sweet potato (200000 vine cuttings; Bhu Krishna, Sree Kanaka, Sree Arun, Kanjangad) and cassava (22000 stems; Sree Reksha, Sree Vijaya, Sree Pavithra, Vellayani Hraswa) were distributed to the beneficiary

Fig. 95. Distribution of planting materials at Idukki, Kerala

Fig. 96. Distribution of planting materials at Thalanadu gramapanchayat, Kottayam, Kerala

farmers. The Institute in association with Department of Agriculture Development and Farmers' Welfare, Govt of Kerala, organized four training programmes and distributed planting materials for seed villages in Kottayam and Idukki districts. About 22000 stems of improved cassava varieties and 1.00 lakh vine cuttings of sweet potato varieties were distributed in both districts (Fig. 94, 95, 96).

7.3 Crop Protection

Theme Areas

Disease diagnostics

Integrated pest & disease management

Transgenics

Disease forecasting

Biopesticides

Achievements

- Standardised combination of biopesticide and chemical insecticides against sweet potato weevil
- Evolved PCR technique for the presence of bacterial endosymbionts in whiteflies using specific bacterial primers
- Identified a new strain of an entomopathogenic nematode, *Heterorhabditis indica* from soils under elephant foot yam fields
- Identified *I. mauritiana* as tolerant to sweet potato weevil
- Developed polyclonal antibody for SLCMV, DsMV and SPFMV

Institute Projects		
Sl. No.	Project code | Project title | PI	Co-PIs
V.	HORTCTCRISIL 202001301469 |**Development of innovative technologies for the intensification of pest management in tuber crops through biorational approaches** | **C. A. Jayaprakas**	E.R. Harish, B.G. Sangeetha, H. Kesava Kumar, Shirly Raichal Anil, M.L. Jeeva, R. Arutselvan
VI.	HORTCTCRISIL 202001401470 | **Development and refinement of integrated disease management and forecasting system for improved tuber crops production** | **M. L. Jeeva**	S. S. Veena, T. Makeshkumar, M. N. Sheela, G. Byju, A. Asha Devi, V.S. Santhosh Mithra, R. Arutselvan, Shirly Raichal Anil, H. Kesava Kumar, B.G. Sangeetha, J. Sreekumar, M. Nedunchezhiyan, K. Laxminarayana, Kalidas Pati
External Funded Projects		
Sl. No.	Title | PI | Co-PIs	Funding agency
1	**Development and application of diagnostics to viruses infecting tuber crops (elephant foot yam, cassava, sweet potato and yams)** | **T. Makeshkumar** | M. L. Jeeva, R. Arutselvan R. Muthuraj	ICAR-Consortia of Research Platfom (CRP) on Vaccines and Diagnostics

Institute Project V

Development of innovative technologies for the intensification of pest management in tuber crops through biorational approaches

Activity 1: Development of biorational control measures for the management of insect pests of tuber crops (C. A. Jayaprakas)

Impact of biopesticides and synthetic insecticides on the mortality of sweet potato weevil

The biopesticide, *nanma*, along with other bioformulations *viz*., nimbecidine, abtech, guard, agro bioplus and neem oil at three concentrations (1, 3, 5%) were screened against sweet potato weevil (SPW) by filter paper assay method. Among the biopesticides, highest mortality was observed with agro bioplus (Fig. 97), where the mortality was 92% at 24 hours after treatment (HAT) followed by neem oil (56%). The mortality at 120 HAT in the agro bioplus was 98% followed by *nanma* (62%) as against 2% in control.

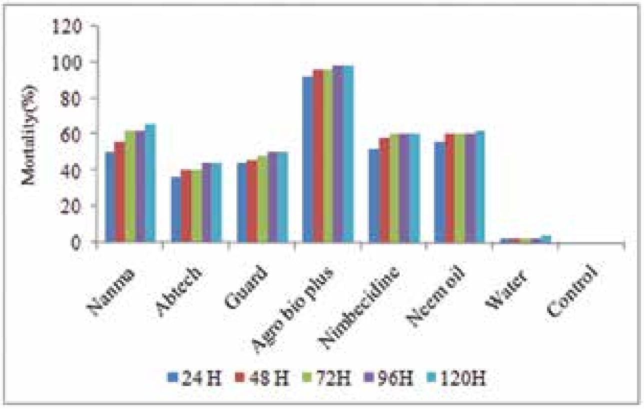


Fig. 97. Mortality of SPW with selected biopesticides at 1% concentration

At 5% concentration, 100% mortality was observed with agro bioplus and neem oil at 24 HAT, followed by *nanma* (94%) (Fig. 98). All the treatments showed over 50% mortality before 120 HAT. There was no significant difference among biopesticides *viz* ., agro bioplus, *nanma*, neem oil and nimbecidine during these intervals.

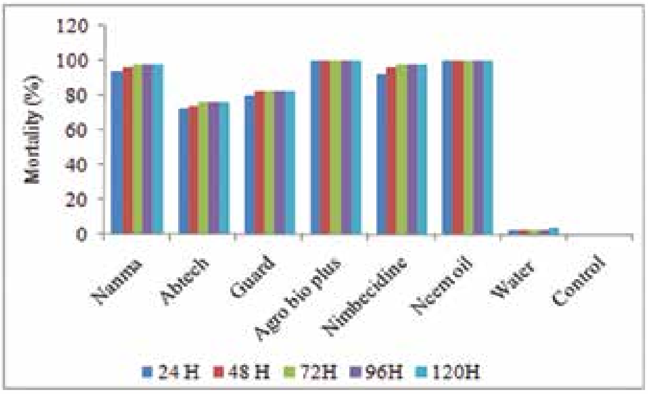


Fig. 98. Mortality of SPW with selected biopesticides at 5% concentration

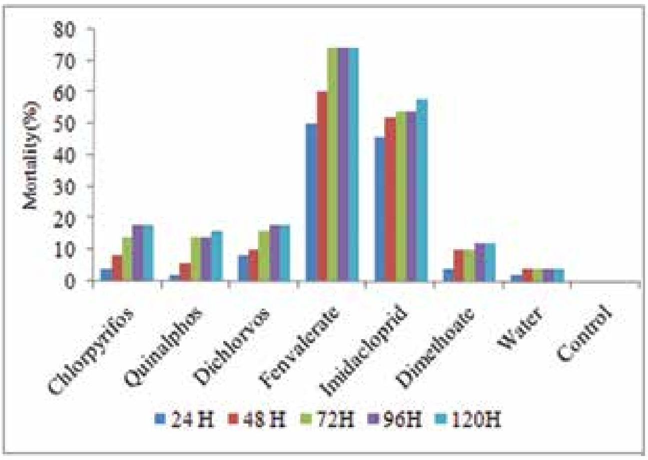


Fig. 99. Mortality of SPW with synthetic insecticides

Six synthetic insecticides *viz*., chlorpyrifos 20 EC, fenvalerate 20EC, dimethoate 30 EC, dichlorvos 76 EC, quinalphos 25EC and imidacloprid 17.8 SL in three concentrations (0.001, 0.01, 0.05%) were evaluated against SPW. Highest mortality was observed with fenvalerate (50%) and imidacloprid (46%). The mortality of SPW at 120 HAT under 0.001% concentration was highest under fenvalerate (74%) followed by imidacloprid (58%) (Fig. 99).

Effect of synthetic insecticides on adult population of spiralling whitefly in cassava

Six insecticides *viz*., chlorpyriphos, dimethoate, imidacloprid, dichlorvos, fenvalerate, quinalphos in three different concentrations (0.001. 0.01, 0.05%) were screened against spiralling whitefly (SWF) in cassava. Samples of leaves from the upper, middle and lower part of the plant showed no revisit of SWF in any treatment at 12 HAT under 0.01% concentration, but one day after treatment (DAT), SWF revisit was noticed in the upper leaves treated with dimethoate, dichlorvos and fenvalerate. Revisit was noticed in the middle and lower leaves, but its population density was significantly lower than control. On 7 DAT, dichlorvos and fenvalerate was on par with control and the lowest level of revisit was under dimethoate.

Activity 2: Management of important pests and documentation of emerging pests in tuber crops (E.R. Harish)

Bioassay of various promising insecticides and their combinations against cassava mealy bug showed that, combination of *nanma* with imidacloprid at 1:1 and 1:3 gave the best result within three days after application with 80-85% mortality, followed by the combination of spirotetramat 11.01% and imidacloprid 11.01% (Movento Energy 240 SC®) with 80% mortality and flonicamid 50% WG (Ulala®) with 60-65% mortality. All these were better than the commonly used insecticide imidacloprid which gave 60% mortality.

Survey of tuber crop pests in Thrissur and Malappuram districts of Kerala, showed the presence of a new emerging pest in EFY, *Sphenoraia hopei* (Alticinae, Chrysomelidae) causing more than 40% shoot damage (Fig. 100).

Studies on the sensitivity of endosymbionts from two mealy bugs to insecticides showed that, bacterial

Fig. 100. Chrysomelid beetle attack in EFY leaves

isolates, *Pseudomonas oryzihabitans* and *Staphylococcus* sp. from *Paracoccus marginatus* and *Clostridium lundense* from *Ferrisia virgata* are resistant to thiamethoxam, whereas *Paenibacillus alvei* and *Ralstonia* sp. isolated from *Ferrisia virgata* are resistant to malathion.

Diagnostic PCR for the presence of bacterial endosymbionts of whiteflies using specific bacterial primers showed *Portiera* at a fragment length of 1000 bp and *Wolbachia* at a fragment length of 650 bp were present in *Bemisia tabaci*, whereas in the case of *Aleurodicus dispersus*, presence of *Rickettsia* was noticed at 800bp (Fig. 101).

(M- 1kb plus ladder, P- *Portiera*, W- *Wolbachia*, A- *Arsenophonus*, R-*Rickettsia*, C-*Cardinium*, B-Blank. Lane 2-6 endosymbionts of *Bemisia tabaci*, Lane 8-11 endosymbionts from *Aleurodicus dispersus*)

Fig. 101. Diagnostic PCR for bacterial endosymbionts from whiteflies using specific primers

Activity 3: Characterization of defense related genes in sweet potato with respect to sweet potato weevil infestation (B.G. Sangeetha)

The intensity of feeding by SPW on tubers of different *Ipomoea* sp. was studied. Choice assay test was done with tubers of sweet potato and different *Ipomoea* sp. against weevil infestation. Among the different *Ipomoea* sp., SPW infestation was not found in *I. mauritiana* tubers. Roots of *I. palmata* and *I. obscura* were infested by SPW (Fig. 102 a, 102 b). Further, DNA was isolated from the roots of all the four different *Ipomoea* sp. and the PCR conditions were standardized. The DNA samples were amplified using different primers *viz*., cysteine proteinase inhibitor, proteinase inhibitor and kunitz trypsin inhibitor and the presence of proteinase inhibitor gene was confirmed in all the four *Ipomoea* sp. (Fig. 103).

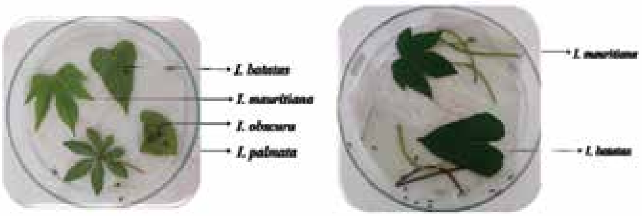
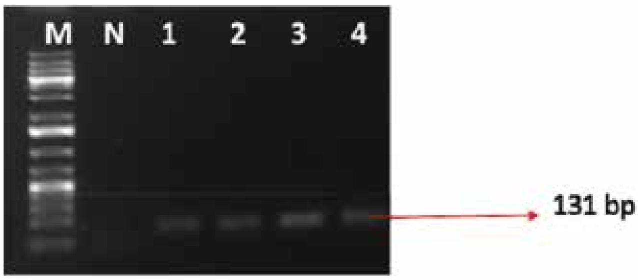


Fig. 102a. Morphological screening of leaves and vines of *Ipomoea batatas* and different *Ipomoea* sp. against SPW

Fig. 102b. Morphological screening of tubers of *Ipomoea batatas* and different *Ipomoea* sp. against SPW



M-1kb plus ladder, N-Non template control, 1- *I. mauritiana,* 2- *I. palmata,* 3- *I. obscura,* 4- *I. batatas*

Fig. 103. PCR amplification of proteinase inhibitor gene

Activity 4: Screening of newer molecules and biocontrol agents against nematodes in tuber crops (H. Kesava Kumar)

In vitro screening of new nematicides against root knot nematode

New nematicides *viz.*, fluensulfone, fluopyram and an insecticide, difenthiuron were evaluated against second stage infective juveniles of root knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood under laboratory conditions. Each chemical was tested at three doses, fluensulfone 2% G (nimitz) at 0.75,1.0, 1.25 ppm; fluopyram 34.48% SC (velum prime) at 0.25, 0.5, 0.75 ppm and diafenthiuron 50% WP (tag) at 0.6, 0.8, 1 ppm (Fig. 104). Fluopyram caused 100% mortality within 48 hrs, followed by fluensulfone (51.6 % mortality) within 72 hrs. Diafenthiuron caused only 23.3% mortality within 72 hrs. Further, a cent percentage hatching inhibition was exhibited by fluopyram at 0.5 and 0.75 ppm and fluensulfone at 1.25 ppm within 24 hrs. Diafenthiuron caused only 50% hatching inhibition within 72 hrs (Fig. 105). Further, the experiment needs validation under pot and field conditions.

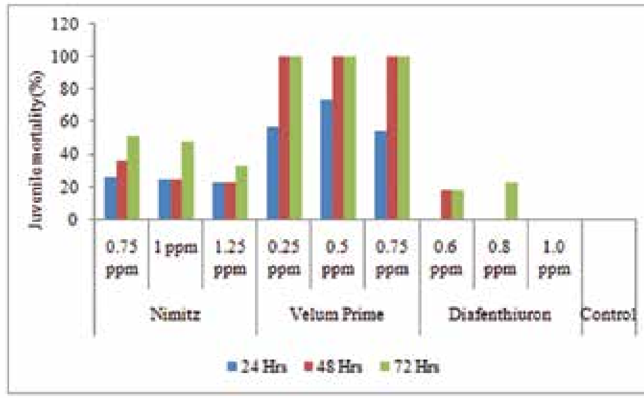


Fig.104. Effect of chemicals on juvenile mortality at different intervals

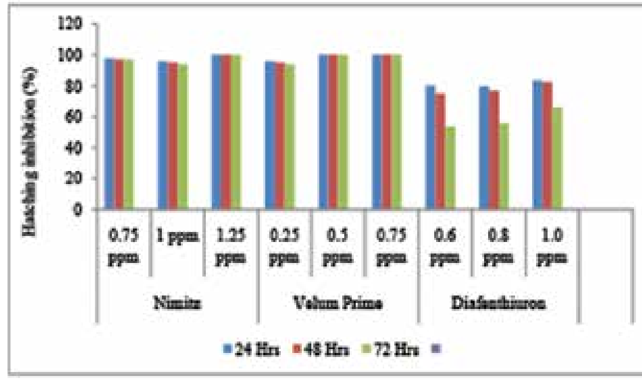


Fig.105. Effect of chemicals on hatching inhibition at different intervals

Compatibility studies of biocontrol agent with nematicide and biopesticide

The compatibility of the fungal bioagent *Trichoderma asperellum* (Tr-9) was tested *in vitro* against the nematicide (carbofuran 3G) at 50, 100, 200, 400, 800, 1000 ppm and cassava based biopesticide (*nanma*) at 5, 10, 25, 50, 75, 100 ppm. Carbofuran at 50, 100, 200 ppm concentrations caused no significant radial growth reduction of *T. asperellum*, while at 400, 800 and 1000 ppm, it caused 16.2%, 27.6% and 37.8% radial growth reduction. However, *nanma*, significantly affected the growth of *T. asperellum*. Cent percentage inhibition of *Trichoderma* was observed at 50, 75 and 100 ppm concentration of *nanma* and exhibited 71.9%, 72.9% and 78.9% inhibition at 5, 10 and 25 ppm concentrations of *nanma* respectively. Thus, it can be concluded that, *T. asperellum* is compatible with carbofuran and incompatible with *nanma*.

Institute Project VI

Development and refinement of integrated disease management and forecasting system for improved tuber crop production

Activity 1: Emerging fungal diseases and management strategies for major diseases of aroids (S.S. Veena)

Sample collection, isolation of pathogens associated with leaf and pseudostem rot in elephant foot yam (EFY)

Infected leaves/pseudostem of EFY with distinct symptoms were collected from ICAR-CTCRI-HQ experimental fields and farmer's fields at Thiruvananthapuram and Kottayam districts. The symptoms noticed were similar as in previous year from Thiruvananthapuram and Kollam districts (Fig. 106). Microbes associated with the samples were isolated and purified (Fig. 107). Eleven organisms were obtained and Koch's postulates were successfully proved with the isolates of *Phytophthora* sp., *Colletotrichum* sp. and *Fusarium* sp.

Fig. 106. Symptoms observed on the foliage and pseudostem of EFY

Fig. 107. Front and rear view of fungal isolates obtained from leaf and pseudostem rot affected samples

Field evaluation of various fungicides to manage collar rot in EFY

The experiment was laid out with seven treatments *viz*., resistant EFY variety (Sree Padma) (T_1); drenching with hexaconazole 0.1% (T_2); mancozeb 0.2% (T_3); combination fungicide of mancozeb, carbendazim 0.2% (T_4);

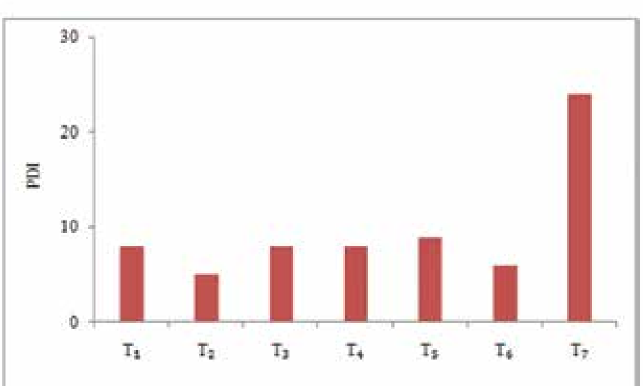


Fig. 108. Effect of treatments on collar rot incidence

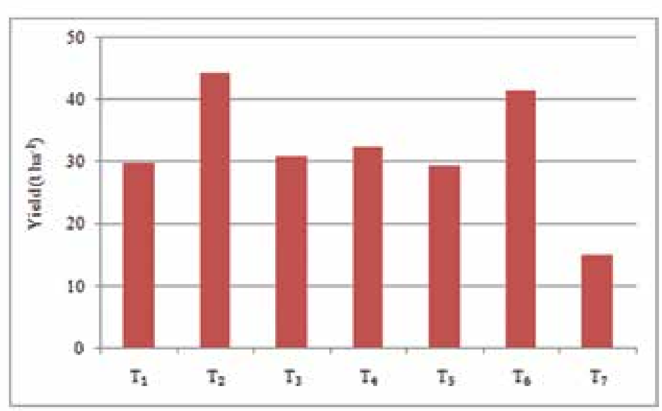


Fig. 109. Effect of treatments on corm yield

difenconazole 0.1% (T_5); propineb 0.1% (T_6) and control (T_7). The experiment was conducted with the EFY (var. Gajendra) except under treatment T_1 in RBD with three replications. The lowest disease incidence was noted under hexaconazole 0.1% (T_2) and propineb 0.1% (T_6) with 79.2% and 75% disease reduction respectively over control (Fig. 108). There was significant yield increase with hexaconazole 0.1% (T_2), mancozeb 0.2% (T_3), mancozeb + carbendazim 0.2% (T_4) and propineb 0.1% (T_6) over control (Fig. 109).

Field evaluation of various fungicides in the management of taro leaf blight

The experiment was laid out with ten treatments *viz*., spraying with 0.1% each of metalaxyl + mancozeb (T_1); difenconazole (T_2); metalaxyl-M + mancozeb (T_3); cymoxanil + mancozeb I (T_4); famoxadone + cymoxanil (T_5); cymoxanil + mancozeb II (T_6); 0.2% copper oxychloride (T_7); 0.1% metalaxyl - M + chlorothalonil (T_8); 0.3% potassium phosphonate (T_9) and control (T_{10}). All the treatments could significantly reduce the disease incidence (Fig. 110). The least percentage disease incidence (PDI) was observed with famoxadone + cymoxanil (T_5) followed by metalaxyl-M + mancozeb (T_3) and potassium phosphonate (T_9) with PDI of 20.5, 22.25 and 22.25 respectively against 34.2 in control (T_{10}). The highest yield increase over control was also observed with T_5 (57.1%) followed by T_9 (48.8%) and T_3 (46.8%) (Fig. 111).

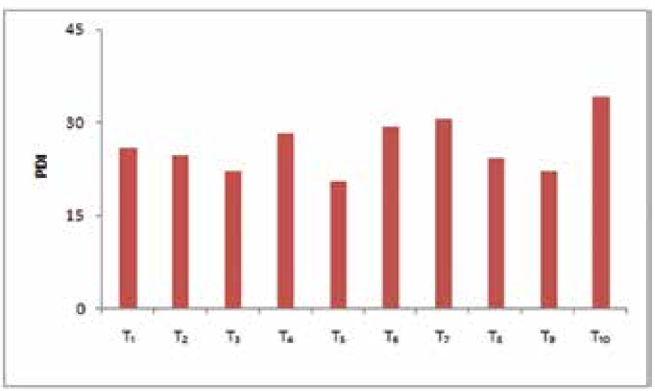


Fig. 110. Effect of treatments on taro leaf blight incidence

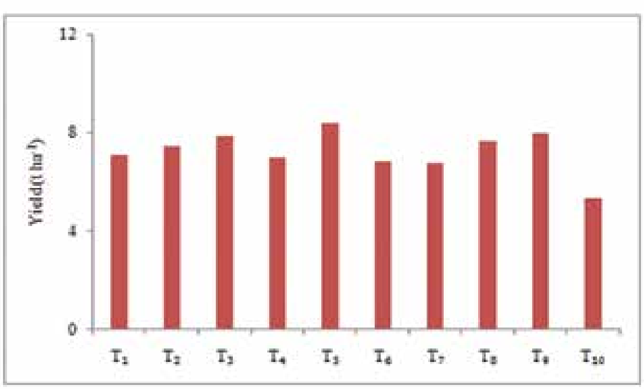


Fig. 111. Effect of treatments on taro cormel yield

Evaluation of fungicides against major fungal pathogens of aroids (*in vitro*)

Twelve fungicides *viz*., azoxystrobin, metalaxyl M + chlorothalonil, cymoxanil + famoxadone, difenconazole, hexaconazole, mefenoxam + mancozeb, mancozeb, cymoxanil + mancozeb, propineb, carbendazim, carbendazim + mancozeb and copper oxychloride were tested against *Phytophthora colocasiae, Sclerotium rolfsii* and *Colletotrichum gloeosporioides*, the pathogens causing taro leaf blight, collar rot and leaf rot in EFY respectively. The concentrations tested ranged from 3.125 µg ml^{-1} to 3200 µg ml^{-1} based on the antifungal activity of these fungicides. Cymoxanil+ famoxadone was most effective against *P. colocasiae*, which inhibited 100% mycelial growth at 6.25 µg ml^{-1}. This was followed by the fungicides, metalaxyl M + chlorothalonil, cymoxanil + mancozeb and mefenoxam + mancozeb (103.125 µg ml^{-1}). Difenconazole and carbendazim + mancozeb were most effective against *C. gloeosporioides*, which inhibited 100% mycelial growth at 18.75 µg ml^{-1}. Similarly, the fungicides, hexaconazole and difenconazole were most inhibitory to *S. rolfsii*, which inhibited 100% mycelial growth at 3.125 µg ml^{-1}.

Compatibility of *Trichoderma asperellum* with fungicides

Compatibility of *Trichoderma asperellum* studied with the above mentioned twelve fungicides at concentrations ranging from 3.125 µg ml^{-1} to 3200 µg ml^{-1} (based on the compatibility of the fungicides) indicated that, *T. asperellum* was least sensitive to the fungicides, *viz*., propineb, copper oxychloride, cymoxanil + mancozeb and cymoxanil + famoxadone. It has shown more than 50% mycelial growth even at a concentration of 1600 µg ml^{-1}. But it was most sensitive to the fungicides *viz*., carbendazim, carbendazim + mancozeb and hexaconazole where the concentration as low as 5µg ml^{-1} could inhibit more than 50% growth.

Development of Decision Support System (DSS) for taro leaf blight

Factors needed for predicting PDI of taro leaf blight were identified as crop age (MAP), minimum temperature (°C), mean temperature (°C), minimum relative humidity

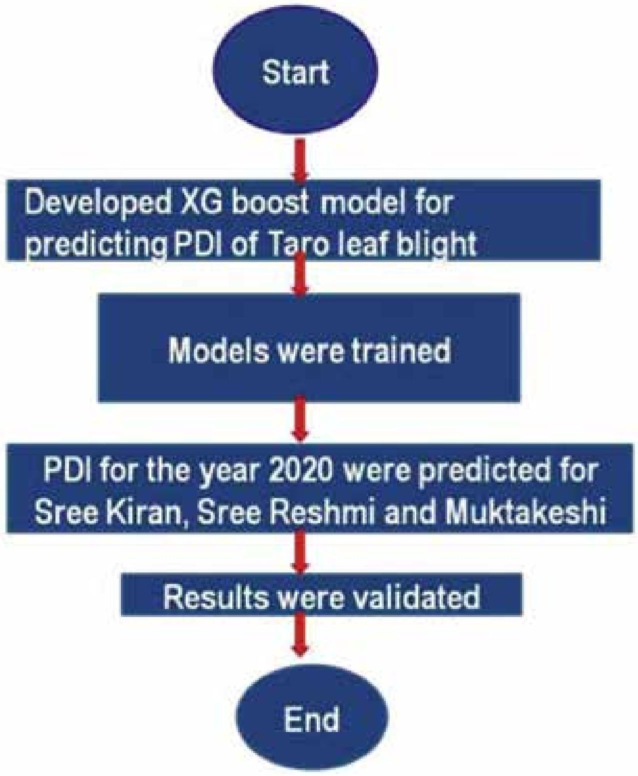


Fig. 112. DSS developed for taro leaf blight

(%) and wind speed (m s^{-1}). Based on these factors, XG boost model for predicting PDI of taro leaf blight was developed as shown above (Fig. 112). Three varieties *viz*., Sree Kiran, Sree Reshmi and Muktakeshi were used for studying TLB incidence.

Whole genome sequencing analysis of *Phytophthora colocasiae*

Phytophthora colocasiae isolate-7290 having 19853 scaffolds was used for assembly and 92.76% of the sequence reads were mapped with coverage of 94.84%. The analysis resulted in identification of 18096 genes. Based on the functional gene annotation, classified the associated genes into biological process (5872), cellular component (4307) and molecular function (7399).

Activity 2: Fungal pathogens and disease management in cassava and yams (M.L. Jeeva)

Survey and collection of cassava stem and root rot samples

In 2019, stem and root rot causing wilting in cassava fields were noticed in the wet lands of Kerala which was not like the tuber rot caused by *Phytophthora palmivora* reported in Tamil Nadu, which lacked foliage symptoms. Survey was conducted in different cassava root rot infected areas in the farmer's fields for the last two years. The symptoms expressed by infected plants were observed in various fields at various stages of the crop. General symptoms of the disease are wilting, stem, root and tuber rot. Cassava stems and roots with root rot symptoms were sampled from different districts. This year infected samples were collected from farmer's wet land fields at Kumarakom, Kottayam district, Kerala (Fig. 113). The average PDI was 40%.

Fig. 113. Cassava root and stem rot symptoms

Identification of pathogen causing cassava stem and root rot

The pathogen isolated from infected stem was identified as *Fusarium* sp. morphologically. Six isolates of *Fusarium* sp. obtained from different root and stem rot affected places in Kerala, *viz*., Pallichal (Thiruvananthapuram); Sadanandapuram, Kottarakara, Thalavoor and Thamarakudi (Kollam); Kumarakom (Kottayam) were identified using *Fusarium* specific primers, Fusa Tef- F: ATGGGTAAGGAGGACAAGAC and Fusa Tef -R: GGAAGTACCAGT GATCATGTT by amplifying the TEF 1α gene and sequencing (Applied Biosystems). The analysis through *Fusarium*- ID database revealed that, *Fusarium* sp. observed from the samples belonged to FSSC Clade 3 (*Fusarium solani* species complex).

On farm management of cassava stem and root rot

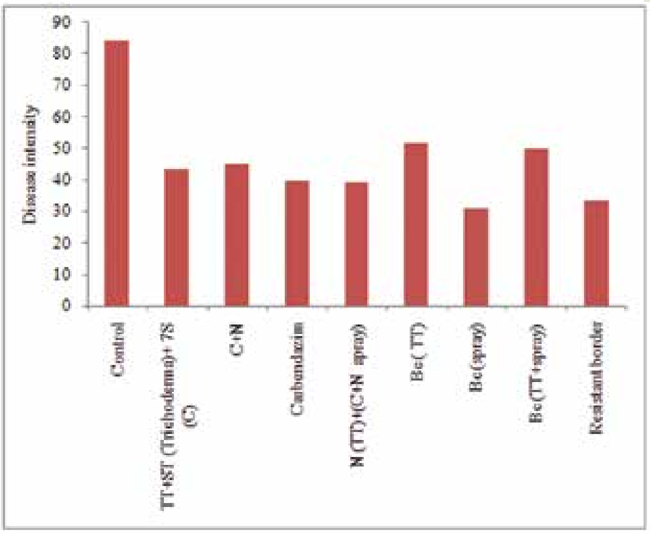
Efficacy of different treatments, *viz*., *Trichoderma asperellum* and fungicides, *viz*., copper oxychloride (0.2%), carbendazim (0.05%), *nanma* and propineb (0.2%) were tested in farmer's field at Pallichal, along with a control (Fig. 114). All treatments showed reduction in disease incidence compared to control. Carbendazim and propineb showed highest reduction (100%) followed by *nanma* (88%), *Trichoderma* (75%), copper oxychloride (60%). In the field, cassava var. Sree Reksha did not exhibit any stem and root rot symptoms (Fig. 115) while other local varieties showed 20 to 50 % infection.

Fig. 114. Application of treatments to manage cassava stem and root rot at Pallichal

Fig. 115. Sree Reksha variety without incidence of cassava stem and root rot

Management of greater yam anthracnose

Efficacy of cassava based biopesticides, *Trichoderma*, endophytes, fungicides and a resistant variety in border were tested against anthracnose in greater yam. Disease intensity was calculated by rating the symptom based on a 0-5 scale. Spraying of *Bacillus cereus*, an endophyte showed highest reduction in anthracnose intensity (63%) compared to control, which is on par with growing Sree Keerthi in the border (60%). This was followed by tuber treatment with *nanma* and spraying a combination of



C: Carbendazim (0.05%), N: *Nanma* (0.7%), TT: Tuber treatment, ST: Soil treatment, Bc: *Bacillus cereus*

Fig. 116. Effect of treatments on anthracnose intensity in greater yam (var. Orissa elite)

0.025% carbendazim and 0.7% *nanma* seven times (53%), spraying 0.025% carbendazim (53%) and the present package of soil and tuber treatment with *Trichoderma asperellum* along with seven sprays of 0.05% carbendazim (49%) (Fig. 116).

Activity 3: Virus and phytoplasma diseases of tropical tuber crops and their management (T. Makeshkumar)

Cassava Mosaic Disease (CMD)

Monitoring CMD incidence in different regions of Kerala

Leaf samples and stem cuttings were collected from cassava fields of different districts of Kerala *viz*., Kozhikode, Wayanad, Kollam, Thrissur, Kottayam and Thiruvananthapuram and the collected stem cuttings were planted inside the ICAR-CTCRI-HQ glass house. Total DNA was isolated from leaf samples as well as the first leaves emerged from the planted stem cuttings.

PCR done using multiplex primers showed mixed infection with Sri Lankan Cassava Mosaic Virus (SLCMV) and Indian Cassava Mosaic Virus (ICMV) in samples from Thiruvananthapuram (Tvm), Kozhikode (Kz) and Kottayam (Ko). But samples from Kollam (Q) district had only SLCMV infection and samples

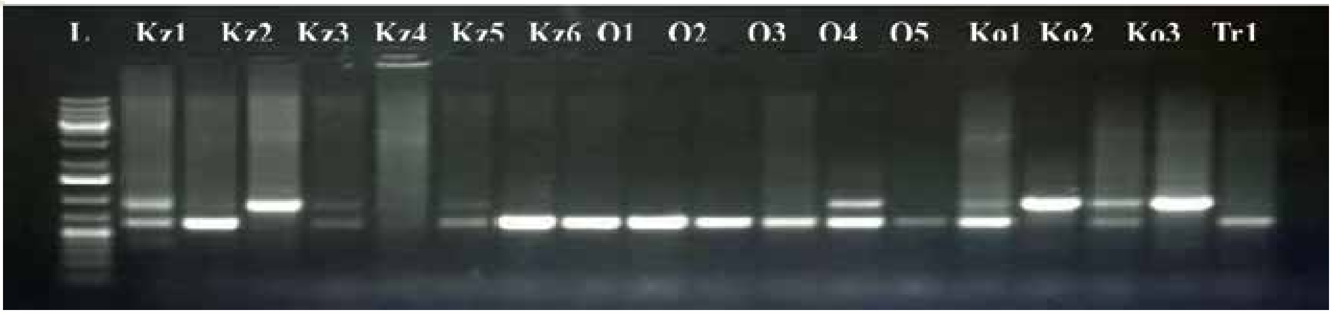


Fig. 117. PCR showing CMD infection in different districts of Kerala

from Thrissur (Tr1) district had only ICMV infection (Fig. 117).

Quantification of selected micro RNAs in cassava plants during SLCMV infection

Based on the results obtained from next generation sequencing of cassava, small RNA libraries, three conserved micro RNAs (miRNAs) *viz*., mes-miR394c, mes-miR160e, mes-miR159b were identified for experimental validation using RT-PCR (reverse transcription). The primers for the stem-loop sequences of these miRNAs were designed. Stem loop RT primers and forward-reverse primers for the above miRNAs were synthesized. Total RNA from symptomatic and asymptomatic cassava leaves were isolated using the trizol method and CTAB-lithium chloride method. Further optimization of small RNA isolation using PEG to separate low molecular weight miRNAs is in progress.

Editing of geminiviral genome for developing resistance to CMD

Annealing of guide RNA oligo nucleotides specific to target genes, AC1 and BV1 of SLCMV, were carried out using modified protocol. Each hybridized guide RNA oligos were then cloned into one step recipient vector for editing single target site at a time (Fig. 118). Single guide RNAs were cloned into shuttle vectors to create sgRNA transcription units for editing multiple target sites simultaneously. Successful clones were selected using specific antibiotic selection media. Validation of successful clones by sequencing is yet to be done.

L 1, L3, L5, L7, L9 and L12 represent intact vectors of 4375bp. L2, L4, L6, L8, L10 and L13 showing sgRNATU harboring vectors 2908 kb and L11 is 1kb DNA ladder.

Fig. 118. sgRNA shuttle vectors cloned with gRNAs specific to AC1 and BV1 of SLCMV

Dasheen Mosaic Disease (DsMV)

Yield loss assessment in elephant foot yam due to DsMV infection

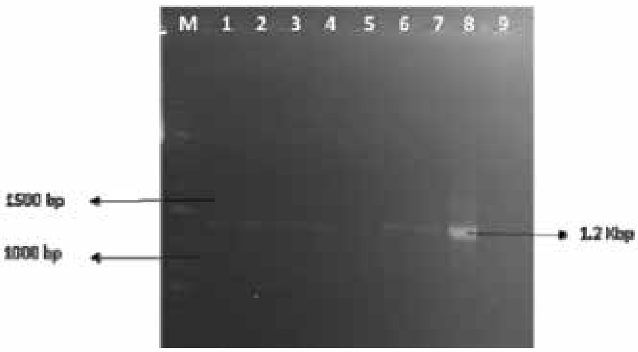
A significant reduction in the tuber yield was observed in diseased EFY due to infection by Dasheen Mosaic Virus (DsMV). The major symptoms noticed during field inspection were chlorosis, leaf curling and mosaic. The heavily infected plants showed stunted growth accompanied by chlorosis or mosaic pattern in leaves. The yield loss in infected elephant foot yam ranged from 25-83.5% based on the severity of infection which was determined by grading in a 1-5 disease scale.

Molecular variability analysis of DsMV in plant samples under geographical differences

The whole genome sequences of DsMV available in the NCBI database are aligned using Clustal W and found that, there are wide genome variation in the sequences which includes P1, P3, CI, NIa, NIb, CP regions. Primers were designed to sequence the region of NIb-CP junction, P1 protein (the most hypervariable regions) and NIa region. The amplification of gene spanning NIb-CP junction was performed using cDNA template and DsMV 9 primer which was further cloned into pTZ57R/T cloning vector .

Monitoring of DsMV intensity in elephant foot yam growing areas

EFY leaf samples (24 numbers) were collected from Kottayam and Pathanamthitta districts in Kerala and



M: 1 kb marker (or 1.2 kb), 1: Kottayam 1, 2: Kottayam 2, 3: Kottayam 3, 4: Kottayam 4, 5: Erode 1, 6:Erode 2, 7: Pathanamthitta sample, 8: Positive control, 9: Control (Water)

Fig. 119. RT-PCR amplification for diagnosis of DsMV in EFY samples from Kerala and Tamil Nadu

Erode district in Tamil Nadu and diagnosed for DsMV infection through PCR and found that, 19 samples showed positive reaction (Fig. 119).

Activity 4: Mass production and effective utilization of bioagents to manage fungal diseases of tuber crops: Identification of potential bioagents from eastern regions of India (R. Arutselvan)

Thirty soil samples (~250 g each) were taken from different ecological habitats (forest and agricultural area) of four districts of Tripura for the isolation of potential bioagents. Rhizosphere soil samples collected from the top 2-5 cm depth were subjected to usual procedure of isolation using *Trichoderma* in Selective Medium (TSM) and purification in Potato Dextrose Agar (PDA). The growth of the isolates observed on the plates were taken for studying colony characteristics, morphology and will be screened against major fungal pathogens infecting tropical tuber crops.

External Funded Projects

Development and application of diagnostics to viruses infecting tuber crops (elephant foot yam, cassava, sweet potato and yam) (T. Makeshkumar)

Validation of DsMV-IgG developed at ICAR-CTCRI for detecting DsMV

Infected EFY and taro samples were collected from fields of ICAR - CTCRI-HQ and ELISA was performed using the DsMV-IgG. All the samples tested under the two experiments turned positive in ELISA and hence proved the efficiency of the antibody in detecting DsMV infection.

Development of Recombinase Polymerase Amplification (RPA) based diagnosis for viruses infecting tuber crops

RPA TwistDx is an isothermal nucleic acid amplification method. RPA operates at a constant, medium temperature (optimally 37-42°C) and does

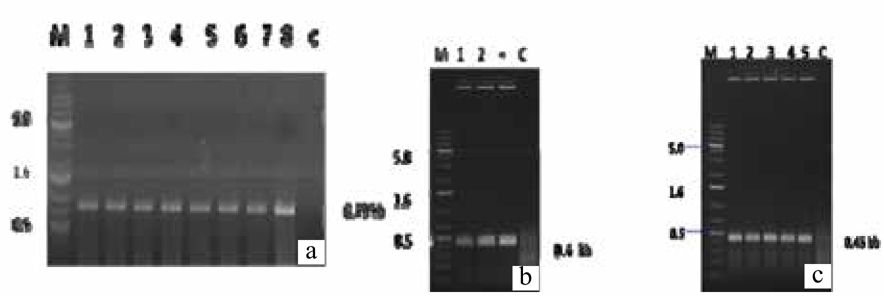
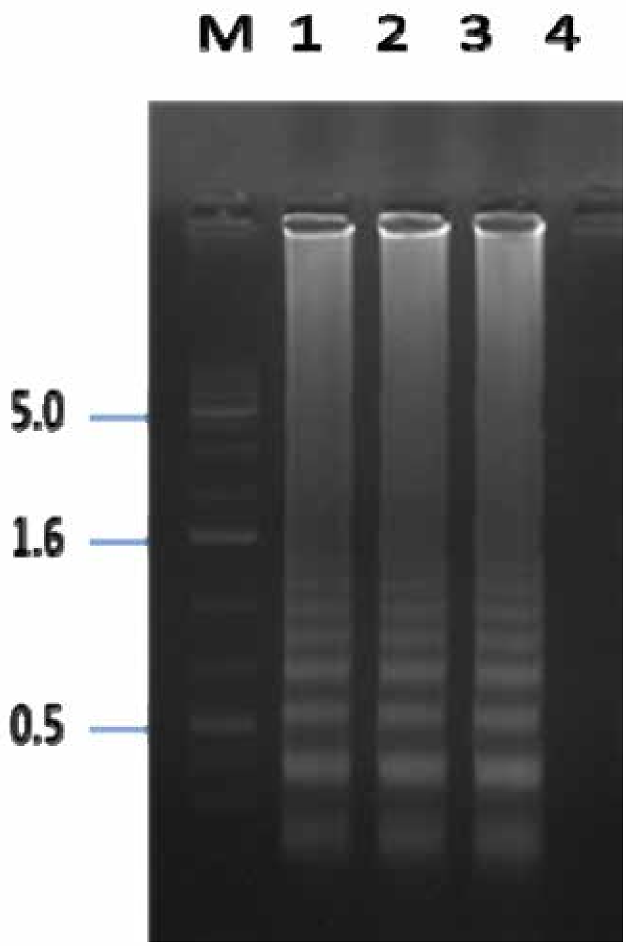


Fig. 120. RPA based diagnosis of virus infection. a. SLCMV, b. DsMV and c. SPFMV

not require expensive thermocycler. This diagnostic test was developed for detection of SLCMV, sweet potato feathery mottle virus (SPFMV) and DsMV. In RPA reaction primers, rehydration buffer, template DNA (100 ng) and nuclease free water and magnesium acetate were added and incubated at 40°C for 30 minutes. Upon agarose gel electrophoresis, 0.7 kb, 0.45 kb and 0.4 kb bands were amplified in SLCMV, DsMV and SPFMV samples respectively (Figure 120 a, b, c).

LAMP based diagnosis for SPFMV

LAMP assay was standardized for detection of SPFMV. A set of six primers, based on the coat protein gene sequence of the SPFMV virus were used. The assay was optimised to amplify SPFMV DNA under isothermal condition at 63°C for 60 minutes. LAMP amplification products were detected by the ladder-like appearance on a 2% agarose gel (Fig. 121).



1, 2 - Sweet potato leaf sample from field, 3 - Confirmed SPFMV infected sample, 4 - Healthy sweet potato sample (control)

Fig. 121. Detection of SPFMV infection through LAMP

Development of lateral flow device (LFD) assay for DsMV and SPFMV

The ICAR- CTCRI developed DsMV-IgG and SPFMV-IgG were used to develop lateral flow devices to detect DsMV and SPFMV from field infected EFY and sweet potato leaf samples. Test line and control line were lighted up in samples infected with DsMV (Fig. 122a) and SPFMV (Fig. 122b). The control line only was lighted up in uninfected control samples, indicating that, the device is working well to detect the infections.

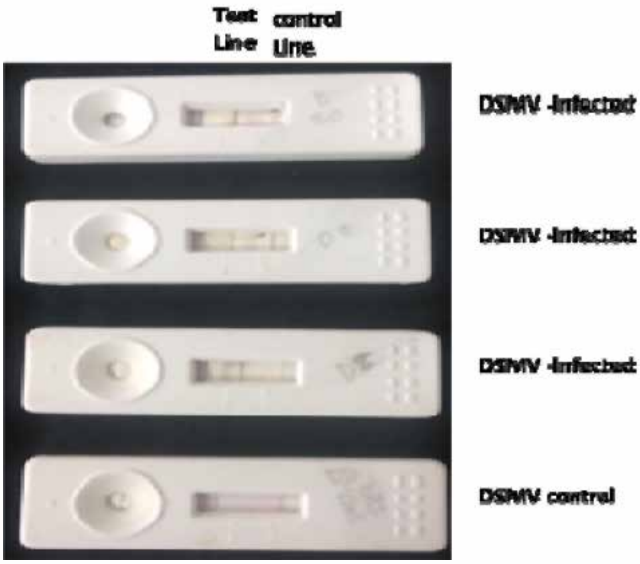


Fig. 122a. LFD based detection of DsMV in EFY leaf samples

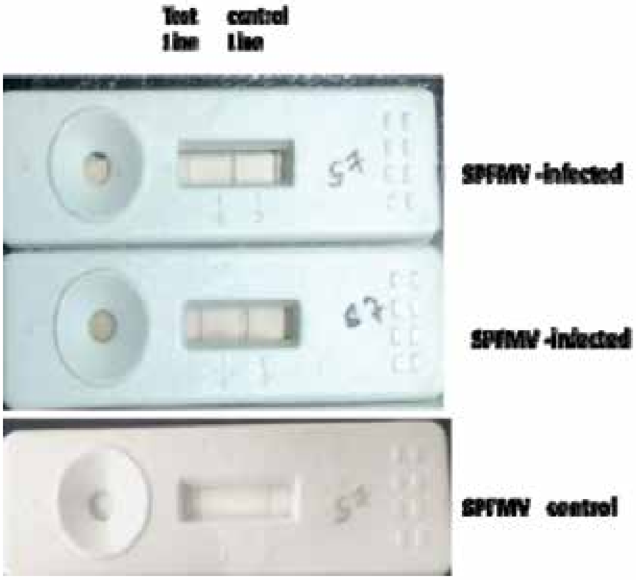


Fig 122 b. LFD based detection of SPFMV infection in sweet potato leaf samples

7.4 Crop Utilization

Theme Areas

Value added functional foods

Industrial products

Pre and post harvest machineries

Entrepreneurship development

Achievements

- Standardised starch extraction from cassava stem
- Prepared thermoplastic sheet from cassava starch-rice husk/paddy straw based composites
- Characterized biodegradable film based on cassava starch-graft and soybean oil maleate
- Synthesised and characterized cross linked cassava starch derivatives
- Developed a power operated Chinese potato grader
- Developed nutrient rich breakfast pancake mix with sweet potato

Institute Projects		
Sl. No.	**Project code | Project title | PI**	**Co-PIs**
VII.	HORTCTCRISIL2 02001501471 | **Pre and post harvest machinery, processing techniques and product diversification in tropical tuber crops** | **M. S. Sajeev**	A. N. Jyothi, V. V. Bansode, T. Krishnakumar, M. N. Sheela, G. Byju, S. S. Veena, A. Asha Devi, P. Prakash, C. Pradeepika, Saravanan Raju, C. Visalakshi Chandra
External Aided Projects		
Sl. No.	**Title | PI | Co-PIs**	**Funding agency**
1	**Techno-Incubation Centre** | **M. S. Sajeev** | T. Krishnakumar	Small Farmers Agribusiness Consortium, Govt. of Kerala
2	**Establishment of techno incubation centre at the ICAR-CTCRI, RS, Odisha for commercialization of value added products from sweet potato and other tuber crops** | **M. Nedunchezhian** | M.S. Sajeev, V.V. Bansode	RKVY, Govt. of Odisha

Institute Project VII

Pre and post harvest machinery, processing techniques and product diversification in tropical tuber crops

Activity 1: Non conventional applications of cassava starch in construction and building materials (M.S. Sajeev)

Extraction of starch from cassava stem

The proportion of the weight of the tubers, stem, peel and leaves per plant of different cassava varieties *viz.,* Sree Vijaya, Sree Jaya, Sree Pavithra, Sree Suvarna, Sree Reksha, Sree Prakash, Sree Athulya, CMR, M4 and Vellayani Hraswa were analyzed to find out their dry matter percentage in different plant parts. Tuber fresh weight percentage varied from 43.38 (Sree Vijaya) - 61.97 % (H-226) whereas the stem fresh weight ranged from 27.45 (H-226) - 42.23 % (Sree Suvarna). The leaf fresh weight percentage was maximum for Vellayani Hraswa (19.05%) and minimum for Sree Pavithra

(2.44%) whereas for peel, it varied as 2.59 (H-165) - 9.48% (Sree Jaya). Moisture content of the different parts of the cassava plants also varied among the varieties. In leaves, it ranged as 67.73 (Sree Pavithra) - 78.49% (Vellayani Hraswa), for tubers 53.94 (Sree Reksha) - 77.17 % (Sree Vijaya), for peel 65.36 (Sree Athulya) - 79.98% (Sree Vijaya) and for stem 63.41 (Sree Pavithra) - 74.01 % (Vellayani Hraswa).

Drying characteristics of cassava stem were studied under sun drying and mechanical drying at 50°C as per the standard method. The drying rate was calculated in gram of water $min.^{-1}$ 100 g^{-1} of bone dry material and the total drying time was calculated for each sample. During sun drying, the moisture content reduced from 181.58 - 8.26% (DWB) after 14 hours, whereas tray drying resulted in reduction of moisture content to 5.59 % after 9 hours of drying. The average drying rate of cassava stem was 0.358 g water $min.^{-1}$ 100 g^{-1} bone dry material under sun drying and in mechanical drying, it increased to 0.739 g water $min.^{-1}$ 100 g^{-1} bone dry material.

Starch was extracted from the dried and milled cassava stem by varying the size of the stem as fine, medium and large and soaking time as 8, 16 and 24 hours. The soaked stem was again ground with excess water and the slurry after filtration through 0.25µm mesh size was allowed to settle for two days with the addition of small amount of toluene to avoid microbial activity. After decanting the supernatant water, the sediment was collected and sun dried. The extracted starch was analysed for purity, biochemical, functional, rheological, viscometric and colour characteristics. The starch recovery from cassava stem ranged from 10.1-13.9% (WWB) by conventional settling. Stem particles of larger size (2-2.5cm) was found suitable for getting maximum recovery with moderately high starch purity and colour. Viscosity of the starch extracted from stem is lesser than that of tuber starch due to the presence of fibrous materials in stem.

Thermoplastic starch sheets with cassava starch-paddy husk/straw

Experiments were conducted to prepare thermoplastic starch sheets from cassava starch-rice husk composite flour as well as cassava starch-paddy straw composite flour. The physical (moisture and density), functional (solubility and expansion index) and water absorption properties at different relative humidity levels, water activity and colour properties of these sheets were analyzed. These experiments were designed using response surface methodology by employing Box-Behnken design.

In the case of cassava starch-rice husk composite flour, the variables used were amount of rice husk as 25, 50 and 75%, glycerol as 30, 40, 50 %, temperature of the die plate as 130, 140 and 150ºC and pressure of the die plate as 120, 130 and 140 bar. The optimized conditions for the production of thermoplastic sheet from cassava starch-rice husk composite as derived from the response surface analysis were 25% husk, 50% glycerol, 150ºC temperature and 140 bar pressure. The sheet produced at the optimum condition had a density: 1453 kg m^{-3}, moisture content: 12.12%, yellowness index: 51.15, hygroscopicity at 85% relative humidity (RH): 10.28% and hygroscopicity at 95% RH: 17.23%, water activity: 0.43, solubility: 29.87 % and expansion index after 2 hours: 28.02% (Fig. 123).

In the case of cassava starch-paddy straw composite flour, the variables used were amount of rice straw as 10, 20 and 30 %, glycerol as 20, 30 and 40%, temperature of the die plate as 120, 130 and 140ºC and pressure of the die plate as 130, 140 and 150 bar. The optimized conditions for the composite as derived from the response surface analysis were 13% straw, 25% glycerol, 125ºC temperature and 130 bar pressure. The sheet produced at the optimum condition had a density: 1138 kg m^{-3}, moisture content: 15.24%, yellowness index: 39.81, hygroscopicity at 85% RH: 16.94%, hygroscopicity at

Fig. 123. Thermoplastic starch sheet from cassava starch-rice husk composite flour

Fig 124. Thermoplastic starch sheet from cassava starch-paddy straw composite flour

95% RH: 19.41%, water activity: 0.43, solubility: 39.99% and expansion index after 2 hours:26.42% (Fig. 124).

Rheological properties of cement-starch mortar

The rheological properties of cement mortar added with native and modified starch like oxidised starch, acid modified starch, esterified starch, etherified starch and cross linked starch were analysed. Cement mortar was prepared by adding 7.5ml water in 10g cement to which starches were added @1% and 5%. They were soaked for 5, 10 and 15minutes and the resultant mortar was analyzed for storage modulus, loss modulus and viscosity.

In the case of cement mortar added with native starch as admixture and soaked for 5, 10 and 15 minutes, the storage modulus increased from 8620 - 12400 Pa, 18000 - 56300 Pa and 134500 - 136500 Pa, the loss modulus increased from 8800 - 11780 Pa, 8570 - 15150 Pa and 14200 - 16085 Pa and the viscosity increased from 45.6 - 54 Pas, 58.7 - 89.9 Pas and 110 - 217 Pas respectively.

For the cement mortar added with acid modified starch, prepared using sulphuric acid as admixture, the storage modulus varied from 2090 - 79800 Pa, 23600 - 30100 Pa and 41200 - 11300 Pa at the same setting time of 5, 10 and 15 minutes, with loss modulus varied from 8600 - 4230 Pa, 20500 - 7460 Pa and 12300 - 5760 Pa and the viscosity from 19.2 - 118 Pas, 51.2 - 49.6 Pas and 48.9 - 50.6 Pas and 67.5 - 19.4 Pas.

As regards to the cement mortar added with modified starch prepared using octenyl succinic anhydride, as admixture, the storage modulus varied from 68700 - 95600 Pa, 37000 - 96800 Pa and 156000 - 53900 Pa at the same setting time having loss modulus changed from 25300 - 8130 Pa, 12400 - 12100 Pa and 20000 - 8190 Pa and viscosity from 127 - 145 Pas, 67.8 - 165.9 Pas and 240 - 83.5 Pas.

In the case of the cement mortar added with modified starch prepared using epichlorohydrine as admixture, the storage modulus increased from 62700 - 251000 Pa, 87800 - 634000 Pa and 83000 - 201800 Pa and the loss modulus increased from 21160 - 33900 Pa, 13210 - 61200 Pa and 24200 - 41100 Pa and viscosity increased from 105 - 400 Pas, 122 - 1012 Pas and 134 - 332 Pas at the same setting time as above.

When the modified starch was oxidised starch using sodium hypochlorite as admixture added to the cement mortar at the above setting times, the storage modulus varied from 136000 - 9410 Pa, 55000 - 16600 Pa and 56500 - 60750 Pa, the loss modulus increased from 24300 - 26800 Pa, 22450 - 29850 Pa and 8650 - 13350 Pa and the viscosity changed from 208 - 35.2 Pas, 78.6 - 36.2 Pas and 82.5 - 89.40 Pas.

In the case of modified starch prepared using propylene oxide as admixture was added to cement mortar at the above setting time, the storage modulus varied from 8430 - 141800 Pa, 572100 - 2065000 Pa and 2280000 - 2314300 Pa, loss modulus increased from 7540 - 19180 Pa, 47350 - 121500 Pa and 90300 - 94500 Pa and viscosity increased from 11.5 - 238 Pas, 908 - 3140 Pas and 3520 - 3430 Pas.

These results showed that, the addition of starch either in native or modified form with cement mortar greatly influenced the rheological properties and modified starch had more influence than native starch.

Activity 2: Development and functional characterization of modified starches of cassava and lesser known tropical tuber starches for industrial application (A.N. Jyothi)

Synthesis and characterization of cassava starch-graft-soybean oil maleate and their testing as film forming materials

Soybean oil modified with maleic anhydride can react specifically with polyamides and consequently can be a very good alternative as a renewable source additive in the development of eco friendly polymer composites. Maleic anhydride based compatabilizing agents are popular due to their good chemical reactivity, low toxicity and low potential to polymerize itself under free radical grafting conditions. In this study, the free radical initiated *in situ* solid phase polymerization reaction of cassava starch was performed with maleic anhydride (to synthesize cassava starch-graft-soybean oil maleate), in a two step reaction. In the first step, soybean oil was allowed to react with maleic anhydride @ 10, 20 and 30% based on the weight of soybean oil using ceric ammonium nitrate as the free radical initiator to synthesize soybean oil maleate. It was then treated with cassava starch in four different proportions *viz.,* 0.25:1, 0.5:1, 0.75:1 and 1:1 to synthesize cassava starch-graft-soybean oil maleate (CS-SOMA). The yield of the products ranged from 90-96%. These polymers were found to have hydrophobic properties. The CS-SOMA was successfully tested for making degradable films as well as in liquid coating application. The films prepared from these grafted starches (Fig. 125 a,b) exhibited significantly

Fig.125. (a) Cassava starch-graft-soybean oil maleate (CS-SOMA) and (b) Biodegradable film prepared from CS-SOMA

lower moisture absorbability (<10% after 72 hours of exposure at 78% RH) than native cassava starch films. The aqueous solubility varied as 4.4 - 26.3% for different films. The CS-SOMA was found to be an effective liquid coating agent for fresh vegetables and fruits. The carrot coated with CS-SOMA remained fresh even after storage for more than 20 days under refrigerated conditions.

Synthesis and characterization of cross linked cassava starch

Cassava starch derivatives with different levels of cross linking were synthesized by using sodium tri poly phosphate (STPP) and sodium tri meta phosphate (STMP) reagents in different molar ratios. A wide variation was noticed in the paste viscosity of the modified starches which varied from about 100 cP for the highly cross

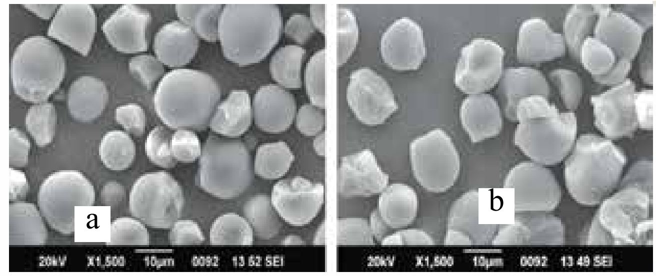


Fig. 126. Scanning electron micrograph of (a) native cassava starch and (b) cross linked cassava starch

linked starches to 4400 cP for the poorly cross linked ones, where substitution reaction predominated over cross linking reaction. Some of these cross linked starches could withstand high temperatures and were non gelatinizable. The substituted derivatives exhibited very high water binding capacity (150-350%). There was no loss of granularity after modification as seen from the scanning electron micrographic analysis, even though high level of cross linking brought about morphological changes of the granules including granular disruption (Fig. 126). X-ray diffraction analysis indicated, no significant change in starch crystallinity as well, due to modification. This modification enabled the production of starch derivatives without the loss of granularity and crystallinity, but with wide range of functional properties suiting to different end uses.

Isolation and characterization of giant taro (*Alocasia*) starch

The biochemical composition of the tubers of giant taro (*Alocasia macrorrhiza*) was analyzed and the process for the isolation of starch from these tubers has been standardized. The proximate composition and the functional properties of the starch were also determined. The total starch and oxalate content of the tubers were 24.42% and 0.04%, respectively on DWB. Wet milling of the tubers after pre treatment with sodium meta bisulphite could eliminate significant amount of calcium oxalate. The total oxalate content was about 0.01-0.02% in the starch isolated from the treated tuber, whereas it was 0.03% in the non treated tubers. The starch yield was about 24% with a total amylose content of about 13.8-14.2%, which was slightly lesser than that of cassava, potato, taro and tannia starches. The starch had lower paste clarity, enzymatic digestibility (33.1%-33.7%) and paste viscosity (1335 - 1512 cP), with higher pasting temperature (81.3 - 82.5°C) compared to cassava starch.

Activity 3: Design and development of pre and post harvest machineries/storage systems in tuber crops (T. Krishnakumar)

Engineering properties of Chinese potato tubers

Engineering properties of Chinese potato tubers, such as moisture, length, width, thickness, arithmetic mean diameter, geometric mean diameter, roundness and sphericity are important to design and develop a size based farm grader for Chinese potato tubers. Harvested Chinese potato tubers were mixed together and sorted into three categories as small, medium and large based on size (Fig. 127). Fifty samples from each category were chosen to study the

a) Small b) Medium c) Large

Fig. 127. Different commercial grades of Chinese potato tubers

above engineering properties. Chinese potato tubers have a moisture content of 74.95 % on WWB. The geometric mean diameter of the average sized tubers under the small, medium and big categories was determined as 20, 30, and 40 mm respectively. The geometric mean diameter of the tubers was slightly higher than the arithmetic mean diameter. The respective sphericity values are 0.53, 0.59, and 0.66 for small, medium and large tubers. Similarly, the tuber roundness ratios for small, medium and large tubers were 0.42, 0.63 and 0.69 respectively.

Design and development of Chinese potato grader

Grading of Chinese potato tubers to uniform sizes will increase the market value. Chinese potato tubers are now graded manually at the farm level which requires more labour, time and cost. Hence,the study was designed to develop a power operated on farm Chinese potato grader to boost market value and address the concerns identified. A grader for Chinese potato tubers with a capacity of one tonne per hour was developed (Fig. 128). It consists of three laser cut rotating drums with holes of varied diameters that rotate at a speed of 10 rpm, which was optimised based on performance evaluation. The grader is mainly made up of five parts *viz.,* a feeding chute, a grading

Fig. 128. Power operated Chinese potato grader

drum, guiding rollers, a collection chute and a power transmission system. Chinese potato tubers are sorted into three sizes *viz.,* small (less than 20 mm), medium (20.1-30 mm) and large (30.1-40 mm) by the grader. The oversized Chinese potato tubers having more than 40 mm size are collected at the other end of grading drum whereas the other three grades are collected through the cushioned outlets positioned below the grading drum. It is powered by 0.5 HP single phase electric motor and 0.25 HP motor for operating guiding roller place. The grader will reduce the drudgery of human labour in grading the tubers. The mechanical grading of Chinese potato tubers was ten times less expensive than manual grading.

Effect of different packaging materials on long term storage of cassava flour

The effect of the various packaging materials on the shelf life and quality of cassava flour has been investigated. Fresh cassava tubers were processed into cassava flour through peeling, washing, slicing, drying, milling, sifting and packaging. For the study, four packaging materials were chosen *viz.,* aluminium pouches, ethylene vinyl alcohol (EVOH), low density polyethylene (LDPE) and polypropylene (PP) with 40 µm thickness. The main characteristics such as oxygen permeability, water vapour permeability and carbon dioxide permeability of the selected packaging materials were also studied. The prepared cassava flour samples (500 g) with a particle size of 100 µm (150 mesh) were packed in the selected packaging materials and stored at room temperature (28.8°C) for 12 months with poly ethylene tere phthalate (PET) in a jar as control (Fig. 129).

a) Aluminium pouch b) EVOH c) LDPE d) PP e) PET jar

Fig. 129. Cassava flour stored in different packaging materials

The physico chemical analysis of the stored cassava samples, such as moisture, crude fibre, crude fat, crude protein, total sugars, total ash, colour value, water activity and functional properties, such as swelling power, solubility, viscosity and rheological behaviour at monthly intervals is in progress.

Activity 4: Quality changes associated with post harvest storage / processing and development of value added functional foods from cassava and sweet potato (C. Pradeepika)

In the present study, tuber crop flour (sweet potato) and ancient grain flour (finger millets) were used to develop flour composites for nutrient rich breakfast (pancake) mix using a factorial design. The study investigated the effect of different proportions of sweet potato (50, 60, 70%) and ragi flour (30, 40, 50%) on the quality of nutrient rich pancake mix and resultant pancake products. In addition, characterization of physico chemical, nutritional, functional and rheological properties of nutrient rich pancake mix was carried out to understand the interaction effect of sweet potato and ragi flour to develop breakfast mixes (Fig. 130).

Fig. 130. Sweet potato: ragi composite flours based pancake mix and products (left side) and control: wheat based pancake mix and pancake product (right side)

The results showed, significantly higher fibre (1.31% and 0.89%), ash (8.54% and 3.47%) protein (15.37% and 11.87%) and starch (59.61% and 33.27%) on DWB among the pancake mixes and pancake products containing higher proportions of sweet potato and ragi flour compared to treatments with lower proportions of these flours followed by control (wheat based pancake mix). Similarly, micronutrient analysis revealed higher levels of Ca (40.93 and 161.01 mg $100g^{-1}$), Mg (26.75 and 107 mg $100g^{-1}$**)**, Fe (9.79 and 14.45 mg $100g^{-1}$**)**, Mn (0.69 and 5.87 mg $100g^{-1}$), Zn (2.33 and 2.67 mg $100g^{-1}$**)** and Cu (1.06 and 2.45 mg $100g^{-1}$**)** among pancake mixes and pancake products respectively with higher levels of sweet potato and ragi flour. Pancake product developed from higher levels of sweet potato and ragi flour showed significant effect on functional, physical and rheological properties of composite flour based pancake mixes in the present study.

Production of functional pasta from sweet potato-maida-*Moringa* leaf based composite flour

Sweet potato-maida-*Moringa* leaf based composite flour was used for making pasta. The experiments were carried out by mixture D optimal design using response surface methodology. The sweet potato flour varied as 69-75%, maida: 19-25% and *Moringa* leaf: 2-6%. Biochemical and cooking qualities of these products were evaluated.

The cooking time of the noodles was around 6 minutes. Cooking loss varied as 9.0- 14.25% and swelling index from 1.65-2.51. The respective control samples values had cooking time, 6.10 minutes, cooking loss, 10.25% and swelling index, 1.71. Based on the biochemical and cooking characteristics, the optimised conditions for the composite flour were 72.45% sweet potato, 24.92% maida flour and 2.63% *Moringa* leaf powder for producing good quality pasta with minimum cooking loss and good nutritional value.

Production of functional noodles from sweet potato-maida-banana flour

Sweet potato-maida-banana flour based noodles were prepared by fortifying with ferric pyrophosphate

(0.01g per 300g). The experiments were carried out by mixture D optimal design using response surface methodology. Sweet potato flour (60-70%), maida (20-25%) and banana flour (5-15%) were used in the experiments. Biochemical and cooking quality analysis of the products indicated the cooking time of the noodles was around 7 minutes. Cooking loss varied between 8.50-12.75% and swelling index from 1.78-2.70 where as the control samples values were 7.07 minutes, 9.75% and 1.94 respectively. Based on the biochemical and cooking characteristics, the optimised conditions for the composite flour was 66.3% sweet potato;13.69% banana flour and 20.60% maida for producing good quality noodles with minimum cooking loss and good nutritional value (Fig. 131).

Control

Moringa leaf based pasta

Banana flour based sweet potato noodles

Control

Fig. 131. Sweet potato based functional noodles and pasta

External Funded Projects

Techno Incubation Centre (TIC) (M.S. Sajeev)

The ICAR-CTCRI, has evolved a number of value addition technologies suitable for home, farm and industrial uses. The TIC was established at HQ in 2015 (Fig. 132) with the financial support of Small Farmers' Agri-business Consortium (SFAC), Department of Agriculture Development and Farmer's Welfare, GoK to create and promote entrepreneurships to establish small scale enterprises among the rural youth and women. It is financially supported by The main objective is to provide hands on training on the preparation of value added products from tuber crops and to provide incubator facility to prospective entrepreneurs for product development. The Centre has three major processing units *viz.,* flour production unit (FPU),

Fig. 132. Techno Incubation Centre at HQ

snack food manufacturing unit (SMU) and fried chips manufacturing unit (FCMU). Different types of machineries and equipments are available at the centre to suit for the various processes for the development of value added products. This facility can be used by entrepreneurs especially women groups by paying a nominal user fee and make profit from the produce, without much investment. TIC has a well equipped training hall and demonstration unit.

During this year, eight on campus internship training programs on 'Improved processing and value addition technologies of tuber crops' were imparted to 85 engineering students from Tamil Nadu, Kerala and Punjab. In addition, eight off campus trainings were given on 'Value addition and entrepreneurship development in tuber crops' to the stakeholders of Thiruvananthapuram, Kollam and Idukki districts. Moreover, the TIC at HQ organized 24 practical technology demonstration cum trainings on value added products from tuber crops and entrepreneurship development, benefitting 559 farmers/entrepreneurs. The incubation centre was used by 15 entrepreneurs for the production of snack foods. Six MoU's were signed on the technology of fried snack products and three on technology for the production of quick cooking cassava/ EFY tubers.

Establishment of techno incubation centre at the ICAR-CTCRI, RS, Odisha for commercialization of value added products from sweet potato and other tuber crops (M. Nedunchezhian)

The TIC- RS, Odisha (Fig. 133) organized hands on trainings on value added products from tuber crops to eight B.Sc (Ag.) students from SOA University, Bhubaneswar where the students were trained to make various fried snack food products from cassava and sweet potato. Moreover, 17 off campus trainings were organized to train 850 farmers on value addition of tuber crops in ten districts of Odisha.

Fig. 133. Techno Incubation Centre, RS, Odisha

7.5

Extension & Social Sciences

Theme Areas

- Technology transfer
- Impact assessment
- Gender studies
- Smart farming
- Intelligent bioinformatic tools

Achievements

- Conducted forty eight FLDs on improved varieties of tuber crops
- Assessment of consumer preference of biofortified sweet potato pasta
- Mapping empowerment of women involved in Chinese potato cultivation
- Forecasted average market price of sweet potato for 2022
- Developed e Crop based smart farming technology for sweet potato
- Developed Phyre 2, a web based tool for 3D modelling of the proteins involved in carotenoid biosynthesis pathway of cassava

Institute Projects

Sl. No.	Project code | Project title | PI	Co-PIs
VIII.	HORTCTCRISIL 202001601472 |**Developing methodologies and tools for assessment and transfer of tuber crops technologies** |Sheela Immanuel	D. Jaganathan, P. Sethuraman Sivakumar, P. Prakash, V.S. Santhosh Mithra, J. Sreekumar, G. Byju, G. Suja, R. Muthuraj, P. Murugesan A.V.V. Koundinya, H. Kesava Kumar, T. Krishnakumar, M. Nedunchezhiyan, K. Laxminarayana, K. Sunilkumar, Sanket J. More, M. L. Jeeva, Shirly Raichal Anil, S. Sunitha, T. Makeshkumar, M.N. Sheela, K. Susan John, K.M. Senthilkumar, V. Ramesh

External funded projects

Sl. No.	Title | PI | Co-PIs	Funding agency
1	**Development of smart solutions for managing biotic and abiotic stresses in cassava, sweet potato and taro through artificial intelligence** | V. S. Santhosh Mithra | G. Byju, T. Makeshkumar, M. S. Sajeev, E. R. Harish	Department of Science and Technology, Goverment of India
2	**Improving rural agro-system through horticultural crops based smart-farming technologies** | V. S. Santhosh Mithra | G. Byju, J. Sreekumar, D. Jaganathan	State Horticulture Mission, Government of Kerala
3	**Smart cassava farms: Validation and upscaling of AI & an IOT device** | V. S. Santhosh Mithra | G. Byju, J. Sreekumar, D. Jaganathan	Kerala State Planning Board, Government of Kerala
4	**National Agricultural Innovation Fund (NAIF) [Component I: Innovation Fund (IP & TM Unit)]** |P. Sethuraman Sivakumar | Sheela Immanuel, R. Muthuraj, P. Prakash	ICAR- Intellectual Property (IP) and Technology Management (TM) Unit, New Delhi
5	**National Agricultural Innovation Fund (NAIF) [Component II: Incubation Fund (Agri-business Incubator)]** | P. Sethuraman Sivakumar | Sheela Immanuel, Saravanan Raju, R. Muthuraj, A.V.V. Koundinya, P. Prakash, T. Krishnakumar	ICAR- NAIF, New Delhi

Institute Project VIII

Developing methodologies and tools for assessment and transfer of tuber crops technologies

Activity 1: Technological interventions and documentation of farmers' innovations including ITKs in tropical tuber crops (D. Jaganathan)

FLD on improved variety of Chinese potato

Fifteen FLDs on improved variety of Chinese potato *viz.,* Sree Dhara with 50 cents each were established at Pallakkal Pothukudi in Tirunelveli district and Kuthapanjan in Tenkasi district of Tamil Nadu in collaboration with Department of Horticulture, Government of Tamil Nadu (Fig. 134).


Fig. 134. FLDs on Chinese potato var. Sree Dhara at Tirunelveli and Tenkasi

Recommended Package of Practices (PoP) were adopted by the farmers as per the guidance of Institute scientists. Farming practices, socio economic characteristics, pest and disease incidence, growth and yield parameters of the crops were recorded. Technology gap, extension gap and technology index were also worked out to formulate strategies.

Data from seven FLDs in Tirunelveli district revealed that, yield of Sree Dhara (24.43 t ha^{-1}) was higher (15.40 %) than local varieties (21.17 t ha^{-1}). Net income realized from Sree Dhara was ₹ 2.79 lakhs ha^{-1} (B:C ratio: 3.51) in comparison to local varieties (₹ 2.31 lakhs ha^{-1}) (B:C ratio:3.15). Technology gap, extension gap and technology index of Sree Dhara was estimated as 3.57, 3.26 and 12.75 respectively. Similarly, data from eight FLDs in Tenkasi district showed that, yield of Sree Dhara (24.87 t ha^{-1}) was higher (13.41 %) than local varieties (21.93 t ha^{-1}). The net income realized from Sree Dhara was ₹ 3.22 lakhs ha^{-1} (B:C ratio: 3.84) in comparison to local varieties (₹ 2.74 lakhs ha^{-1}) (B:C ratio: 3.49). Technology gap, extension gap and technology index of Sree Dhara at Tenkasi was estimated as 3.13, 2.94 and 11.18 respectively. Farmers opined that, the improved variety is high yielding with good tuber shape and size, good keeping quality, produces more number of tubers per plant, nutrient efficient, drought tolerant, short duration (4-5 months), has high market demand with remunerative price.

Lack of good quality planting materials, incidence of nematodes /pests and diseases, price fluctuation, lack of machineries especially for harvesting and grading, absence of organized marketing system and weather aberrations were the constraints faced by the farmers. The harvesting, grading and packing of the seed tubers were done manually for seed purpose and also for transporting to different markets in Tamil Nadu, Kerala and other states of India for consumption. Harvested tubers were distributed to the interested farmers for establishing demonstrations (25 FLDs) cum seed villages (5 numbers) in Pallakkal Pothukudi and Mannarkovil in Tirunelveli and Kuthapanjan, Rajankhapuram and K. Alangulam in Tenkasi district for meeting the demands of good quality planting materials of Sree Dhara in the next season. Large areas are expected to be covered under 'Sree Dhara' in future.

FLDs on improved varieties of sweet potato

Six FLDs on improved varieties of sweet potato *viz.,* Sree Kanaka and Gouri with 50 cents each were established in Kilimanoor panchayat of Thiruvananthapuram district, Kerala in collaboration with the Department of Agriculture, Government of Kerala (Fig. 135). Recommended package of practices were adopted by the farmers as per the guidance of ICAR-CTCRI scientists. Farming practices, socio economic characteristics, pest and disease incidence, growth and yield parameters of the crops were recorded.

Fig. 135. FLDs on sweet potato varieties at Kilimanoor

FLDs on improved varieties of cassava

Seventeen FLDs on improved hybrid variety of cassava 'Sree Athulya' with one acre each were established in Salem (7 numbers) and Pudukottai (10 numbers) districts of Tamil Nadu in collaboration with the Department of Horticulture (DoH), Government of Tamil Nadu. Ten FLDs on CMD resistant variety of cassava 'Sree Reksha' with 50 cents each were established at Peddapuram mandal of East Godavari district, Andhra Pradesh in collaboration with DoH, Government of Andhra Pradesh.

Recommended package of practices were adopted by the farmers as per the guidance of scientists. Farming practices, socio economic characteristics, pest and disease incidence, growth and yield parameters of the crops were recorded.

Documentation of farmers' innovations and ITKs in tropical tuber crops

Farmers' innovations and ITKs pertaining to varieties, agronomic practices, nutrient management, pest and disease management, mechanization, pre and post harvest processing, value addition, storage of planting materials and tubers were documented from the tuber crops growers of Wayanad, Malappuram, Ernakulam and Thiruvananthapuram districts of Kerala. Assessment attributes of farmers' innovations /ITKs *viz.,* sustainable yield, satisfying farmers needs, easily observable results, high BC ratio, effective alternative to modern practice, reduction in cost of cultivation, easiness in understanding and faster adoption were taken into account for documentation. Some of the farmers' innovations /ITKs documented in Kerala are given below.

- Varieties of cassava: *Ullichuvala, Nadan Chuvappu, Kandhari Padappan, Mankuzhanthan, Vella Thandan, Mixture Vella, Ambakkadan, Mixture Chuvapu, Pathinettu, Kalikalan, Singapore Karupu, Aarumasa Chuvapu, Aarumasa Vella, Ummen, Diwan, Kottarakara Vella, Malabar, Pulladu Kappa, Etha Kappa*
- Varieties of yams: *Mattu Kachil, Neendi Kachil, Parisa Kodan, Neela Kachil, Inchi Kachil, Mukkizhangu, Sugantha Kachil, Thunan Kachil, Payasam Kachil, Mooduvanni, Soorai Kachil, Noor Kizhangu, Ari Kizhangu, Kaduvakkayyan, Karadi Karan*
- Seed treatment with cowdung, ash, biofertilizers, neem oil emulsion
- Nutrient management practices like rotation with pulses, green manuring, application of compost, ash, fermented oil cakes, cowdung slurry, *Panchagavya, Dasagavya, Jeevamrutham.*

- Pest and diseases management using botanicals, ginger-chilli-garlic extract, ash, oil cakes, neem oil, nicotine, tobacco decoction, neem cake and rice husk, boarder crop with *Chrysanthemum* for management of nematodes, placement of cowdung balls for fungal diseases, warm ash for leaf eating insects, border cropping with red gram/lead wort for rat control.
- Pre and post harvest processing machineries, tools, equipments *viz.,* cassava stem cutter, cassava harvester.
- Value addition in tuber crops *viz.,* dehydrated products, snack food products, jam, jelly
- Storage of planting materials by smoking with neem and mango leaves

Rationality of farmers' innovations /ITKs were done based on experts rating with different scores ranging from 4 to 1. Adoption quotient and perceived effectiveness index of farmers' innovations/ITKs in tuber crops are estimated using standard procedures.

Activity 2: Upscaling tuber crops technologies for promoting food and nutritional security (P.Sethuraman Sivakumar)

Sensory and consumer acceptability studies on biofortified sweet potato varieties and products

Consumption of sweet potato

Sweet potato was consumed mostly in boiled forms and also as roti made from its flour. About 95% of the interviewed children consumed sweet potato regularly in their home, based on seasonal availability and 56% of them consumed pasta at least once in three months. The per capita monthly consumption of sweet potato in boiled or in other forms is 0.23 kg.

Sensory acceptability of biofortified sweet potato pasta

To understand the acceptability of biofortified sweet potato pasta among tribal children (age<16) in Anjaw district, Arunachal Pradesh, sensory evaluation using a generalized Bradley-Terry paired preference model was conducted. Under the 'full information' conditions, the children were informed about the health benefits of biofortified sweet potato varieties and pasta variants prior to evaluation. Three variations of pasta *viz.,* commercial variant along with sweet potato pasta prepared from orange and purple fleshed sweet potato were presented to the children in pairs for choosing the best version based on sensory quality. The data were analyzed to estimate Bayesian probabilities of preference for each pasta variant.

Results indicated that, pasta prepared from orange fleshed sweet potato (OFSP) had higher probabilities of preference compared to purple fleshed sweet potato pasta (P=0.612) and white fleshed sweet potato pasta (P=0.576). The white fleshed sweet potato pasta had higher probability of preference (P=0.538) than purple fleshed sweet potato pasta. Over 80% of the children indicated that, OFSP was preferred due to its health benefits and taste (Fig. 136).

Fig 136. Sensory evaluation and consumer assessment of biofortified sweet potato pasta

Nutritional assessment surveys

For conducting nutritional assessment surveys in Tamil Nadu, Kerala and Meghalaya, the protocol for assessing micronutrient malnutrition was developed. Since the malnutrition assessment and consumption studies require ethical clearance for conducting research with human subjects, an Institutional Ethics Committee on Human Research was constituted.

Promoting tuber crops in non traditional areas

To popularize the improved cassava varieties in the non traditional areas, 500 stems of cassava varieties *viz.*, Sree Reksha and Sree Suvarna were distributed to KVK, Bhuj,Gujarat for conducting five FLDs (Fig. 137).

Fig 137. FLD on improved varieties of cassava at Bhuj

Activity 3: Mapping of women empowerment in tuber crops cultivation for engendering research and development (Sheela Immanuel)

A study was conducted to assess the level of empowerment of women involved in Chinese potato cultivation. A sample of 66 men and 66 women farmers from Tenkasi and Tirunelveli districts of Tamil Nadu were selected as respondents using simple random sampling. All these farmers and farm women were interviewed and the data were collected and analysed.

Profile characteristics of the respondents

Majority of the men (81.82%) and women (77.27%) doing Chinese potato cultivation were middle aged. Nearly 40% of the men and around 36% of women had high school education. Both men (98.48%) and women (96.97%) had agriculture as their main occupation. Nuclear family system was dominating (65.15%). In majority of the households, the number of family members was between 4 to 6. In farming, 40% women and 48.48% men had more than 20 years of experience. Majority (87.88%) of the farm women cultivated Chinese potato in marginal farms of less than 2.5 acres. The mean area under cultivation of this crop was 1.54 acres. Majority (51.52%) of them had livestock at their backyards. The aspiration level of both men (74.24%) and women (72.73%) was medium. Medium level of innovativeness was reported by men (83.33%) and women (63.64%).

Participation of women and men in Chinese potato cultivation

The extent of participation of men and women in Chinese potato cultivation was calculated and the respondents were classified into three categories *viz*., low, medium and high using mean and standard deviation (SD). It was observed that, majority of the women respondents (83.33%) and men respondents (71.21%) had medium level of participation. As regards to all activities, from land preparation to harvesting, there was significant differences (1% level) in the level of participation between women and men. Even though the involvement of men was more, women also had participation in all the activities and the mean difference is marginal between them.

Empowerment index

The Women Empowerment Index in Chinese potato (WEICP) consists of five domains *viz*., decision making in production, access to productive resources, control over use of income, community leadership and time allocation. Each domain has sub indicators of empowerment.The mean empowerment index of men was more than women in areas like input in productive decisions (men: 2.89, women: 1.65), autonomy in production (men: 2.68, women: 1.67), ownership of assets (men: 2.82, women: 1.29). Significant differences were also observed in the indicators like group membership, work load and leisure time. Empowerment index in Chinese potato cultivation was estimated as 0.55 for women and 0.80 for men. Men were dominating in all the indicators.

Needs of farm women in Chinese potato cultivation

The analysis of the need of women in Chinese potato cultivation revealed that, their first and foremost requirement was quality planting materials (mean: 2.73) followed by demonstration on improved technologies (2.61), pre and post harvest machineries for drudgery reduction (2.58), training on improved technologies (2.53), and subsidies /inputs (1.98).

Preferences of farm women in Chinese potato cultivation

The results revealed that, the first preference was given for high yielding potential of the crop with a mean value of 2.97 followed by pest and disease resistance (2.71), good keeping quality (2.36), short duration varieties (2.18), suitable cropping systems (1.80) and good cooking quality (1.71).

Opportunities in Chinese potato cultivation

The opportunities in Chinese potato cultivation as reported by farm women were, enhancing yield by adoption of improved technologies (2.53), suitability for different agro climatic and edaphic conditions (2.48), suitability for cropping systems (2.00), linking crop insurance scheme (1.26) and scope for post harvest processing by linking women SHG's and FPO's (1.23).

Major constraints in Chinese potato cultivation

The major constraints as reported by the farm women were price fluctuation (mean: 2.65), non availability of quality planting materials of improved varieties (2.30), pest and disease incidence (2.23), erratic rainfall/weather aberrations (2.06), lack of marketing facilities (1.94), lack of knowledge and access to crop loans and subsidies (1.71).

Activity 4: Impact assessment of technologies of tropical tuber crops (P. Prakash)

Price forecasting of sweet potato was carried out for six selected states in India using time series monthly market price, collected from AGMARKNET price portal from January 2010 to December 2021. The accuracy of the forecasted model was assessed with the help of Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE) and Root Mean Square Error (RMSE).

Average monthly market price of sweet potato in India (2010-2021)

It was observed that, the highest price prevailed in Kerala market (₹ 2079 per quintal) followed by Odisha (₹ 1526 per quintal), Gujarat (₹ 1497 per quintal), Maharashtra (₹ 1444 per quintal), Telangana (₹ 1058 per quintal) and Karnataka (₹ 571 per quintal). Further, price behavior based on the seasonality index showed that, the highest price of sweet potato was observed in Kerala market prevailed during September followed by October and November. The lowest price was observed in Karnataka market during July and December.

Exponential smoothing model

Under exponential smoothing model, Holt winters multiplicative techniques were considered for forecasting the prices of sweet potato for the selected states in India.

Forecast indicated that, the average market price of sweet potato in selected states of India *viz.,* Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana would be in the range of ₹ 788 to ₹ 2854 per quintal during the period January 2022 to December 2022.

Seasonal Autoregressive Integrated Moving Average model (SARIMA)

A seasonal autoregressive integrated moving average model was used for forecasting of sweet potato prices. It was observed that, the SARIMA (1,1,1) (1,1,1), SARIMA (2,1,1) (0,1,1), SARIMA (1,1,1) (0,1,1), SARIMA (0,1,3) (2,0,0), SARIMA (0,1,2) (0,1,1) and SARIMA (2,1,1) (0,1,1) were found suitable for Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana respectively. These were found to be the best fit models. The parameters estimated through an iterative process using a least square technique gave the best model. The coefficients were also found to be statistically significant and hence the selected models were considered best fit and were used for forecasting. Ex-ante forecast prices of sweet potato for the selected markets in India was done for the month of January 2021 to December 2021 using the identified models and they were compared with actual prices of the same period. Further, ex-post forecasts for the period, January to December 2022 was made and the accuracy of the forecasts was tested using the test statistics. It was observed that, the forecasted price of sweet potato in selected markets was very close to the actual value. The accuracy of the models was empirically verified with the help of MAPE, MAE and RMSE statistics. The model was validated

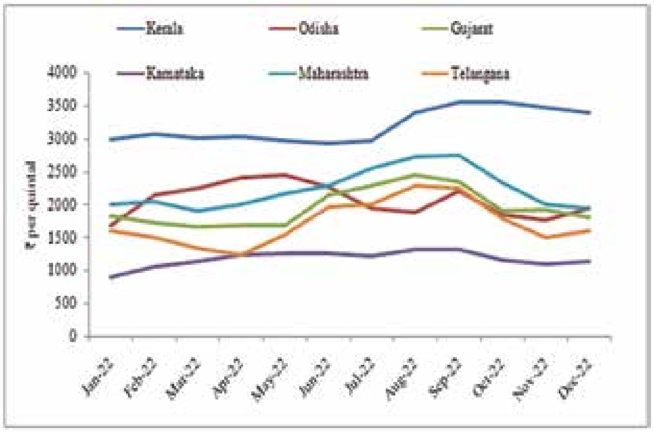


Fig. 138. Forecasted price of sweet potato in selected states of India using SARIMA

for the accuracy and observed that, there were wide variations between upper and lower confidence limits of forecast prices of sweet potato from January 2022 to December 2022. The forecast indicates that, the average market prices of sweet potato in selected states of India *viz.,* Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana would be in the range of ₹ 1178 to ₹ 3187 per quintal during January 2022 to December 2022 (Fig 138).

Time Delay Neural Network (TDNN)

The time delay neural network model was applied for forecasting sweet potato prices in selected states of India. The neural network architecture used consisted of single hidden layer, six input nodes and one output node. This was selected for modelling and forecasting of sweet potato prices. The forecasted average market price of sweet potato in selected states of India *viz.,* Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana, would be in the range of ₹ 684 to ₹ 2757 per quintal during January 2022 to December 2022. The prices would be high in some markets *viz.,* Kerala (₹ 2757 per quintal), Odisha (₹ 2202 per quintal), Maharashtra (₹ 1928 per quintal) and Gujarat (₹ 1898 per quintal) and low in other markets *viz*., Karnataka (₹ 684 per quintal) and Telangana (₹ 1712 per quintal).

Among the different forecasting techniques, TDNN model predicted the accurate future prices of sweet potato in selected states of India as compared to SARIMA and exponential ESM based on the lowest MAPE, MAE and RMSE.

Diffusion of tuber crops technologies and their impact

Data were being collected from 150 farmers practicing cassava and Chinese potato cultivation in Dharmapuri, Salem, Namakkal, Pudukottai, Tenkasi and Tirunelveli districts of Tamil Nadu for assessing the adoption and their impact.

Activity 5: Development of intelligent smart technologies for tropical tuber crops (V.S. Santhosh Mithra)

Field trial to test the efficacy of e Crop based smart farming technology for irrigation and fertilizer application is in progress. Sweet potato (var. Sree Kanaka) was planted in the trial in three replications with the following treatments comprising irrigation and fertilizer application treatments.

T_1- e Crop based smart farming recommendation through drip fertigation

T_2- PoP recommendation of ICAR-CTCRI through drip fertigation

T_3- PoP recommendation of ICAR-CTCRI by manual application

Activity 6: Generation and application of statistical and bioinformatics tools for tropical tuber crops research and development (J. Sreekumar)

In silico analysis of carotenoid biosynthesis pathway in cassava

The apocarotenoids play a vital role in plant growth and development process especially, strigolactones, which can induce rooting and help in the interaction of symbiotic microbes with plants. They also act as colorants, antioxidants, hormones, signalling components, scent/aroma constituents and chromophores. *In silico* approaches are valuable in reducing the complexity of gene networks in plants that help to develop new biotechnological and bioinformatics tactics in crop improvement programmes. An *in silico* comparative genomic analysis of the key enzymes encoding genes involved in apocarotenoid biosynthesis in cassava was carried out using template plants such as A*rabidopsis*, tomato, potato and sweet potato. Forty carotenoid genes were identified and the nucleotide sequences were subjected to various regulatory sequence analyses such as transcription factor prediction, CpG island analysis, microRNA regulatory analysis and promotor sequence analysis. The corresponding protein sequences were subjected to domain/motif analysis and phylogenetic analysis. The expression profile of apocarotenoid genes in cassava were generated and sub cellular localization prediction was done to identify the distribution of the proteins. The results indicated that, the apocarotenoid protein domains were conserved in template plants and cassava. Eighteen transcription factors like MYB, BBR-BPC, bHLH and NAC were associated with the identified carotenoid genes in cassava. The apocarotenoid genes were found to be expressed in all the major parts of the

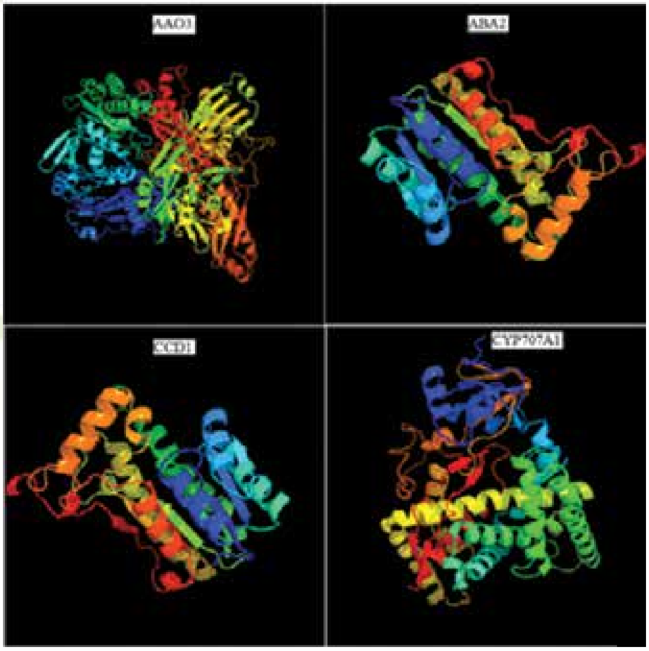


Fig.139. Protein structure of the representative genes involved in the carotenoid biosynthetic pathway

plants. GBrowse option in phytozome database was used for locally identifying and visualizing the carotenoid gene sequences in cassava. Phyre 2, a web based tool for predicting and analysing protein structure and function using advanced remote homology detection methods was used for 3D modelling of the identified genes and are shown in Fig. 139.

The MiRNA regulatory analysis identified three microRNAs, namely miR159a, miR171b and miR396a which were significantly associated with carotenoid biosynthesis in cassava and the pathway was reconstructed by incorporating the above information. A better understanding of the genes and pathway associated with carotenoid biosynthesis in cassava would be helpful in the breeding programme to develop improved carotenoid rich varieties.

Prediction of protein-protein interaction of stress responsive proteins in cassava using machine learning and deep learning techniques

Cassava is a cold sensitive crop, and several changes happen when it is exposed to low temperature that includes alteration in plant metabolism, physiology as well as plant productivity. Many genes in cassava associated with cold tolerance were identified. However, it is poorly known, how cassava can modify its metabolism and growth to adapt to cold stress. Protein-protein interactions (PPIs) control variety of biological phenomena including development, cell to cell interactions and metabolic processes.

At RNA level, a total of 508 transcripts in cassava were identified as early cold induced genes. Of which, 319 sequences had functional descriptions aligned with *Arabidopsis* proteins. *Insilico* methods were applied effectively for identifying the protein-protein interactions. Protein features (1400) were extracted using Protr Package in R. Applied Support Vector Machine (SVM) classification in R and obtained accuracy prediction of about 71%. In comparison with SVM, Random Forest (RV) is fast. Hence, used the python language and obtained a model in 63 minutes.

As the score was not in binary format, the prediction accuracy was lesser. Random Forest Model (RFM) was developed for cassava intra species PPIs.

D-Script deep learning technique was performed in python environment. To train the model protein sequences, protein pairs with interaction score, training and validation data set was given as input data, which were obtained using STRING database. The testing of the model was performed with the stress resistant (cold) protein sequences.

External Funded Projects

Development of smart solutions for managing biotic and abiotic stresses in cassava, sweet potato and taro through artificial intelligence (V.S. Santhosh Mithra)

For the development of Artificial Intelligence (AI) solutions for various stresses in cassava, sweet potato and taro, large amount of data was collected for the analysis including the aerial leaf images of these crops at different growth stages. For this purpose, drone camera with 4K resolution was used. Both images and videos were recorded with the help of drone. Images were extracted from the videos using the wondershare filmora software.

Cassava

Data on cassava leaf images were collected from Chenkal, Thiruvananthapuram, Kerala. Aerial images and videos were recorded from different cassava fields (Fig. 140) of 1, 2, 3, 4, 5 months age using drone camera. Five sets of images for each variety (about 1000 images per set) were collected. Initial observation on pest and diseases were also recorded. Major disease recorded in all fields was CMD caused by ICMV. PDI value ranged from 30-50% in these fields. All plants irrespective of age were found infected with CMD with symptoms as mottling and twisted leaflets. Soil samples were also collected from these fields for nutrient analysis.


Fig. 140. Image of cassava field taken using drone camera

Sweet potato

Different fields of sweet potato were selected at Olabari, Bagamunda, Kumuri, Tentulipuda, Laimunda villages of Odisha. Data were collected from sweet potato fields at different stages of growth *viz.,* 15, 30, 45, 60 and 75 DAP. Aerial images and videos were recorded from sweet potato fields using drone camera.

Taro

Different fields of taro were selected at Botalana, Pubusahi, Ramasili, Ranapur, Govindpur, Sanpur, Souri, Megha, Jhajia, Gudupad, Mahulakhoh and Maidapur villages of Odisha. Data collected at different stages of crop growth of taro *viz.,* 15 days, 1, 2, 3, 4 and 5 MAP included six different data sets. Aerial images (Fig 141.) and videos were recorded using drone camera.

Fig. 141. Data collection using drone camera in taro field

Major disease observed was taro leaf blight with symptoms as small, dark brown flecks or light brown spots on the upper leaf surface. These spots enlarge rapidly, becoming circular, zonate and purplish brown to brown in color.

Soil analysis

Soil analysis was carried out to estimate the status of soil moisture, pH, organic carbon, N, P, K, Ca, Mg, S, Mn, B, Cu, Zn, Fe in the soil samples collected from the fields from where the aerial images were taken.

Improving rural agro-system through horticultural crops based smart farming technologies (V.S. Santhosh Mithra)

Field visit, survey and soil analysis

Five panchayats namely Anad, Aruvikkara, Karakulam, Panavoor and Vembayam of Nedumangad block were selected for conducting the study in addition to ICAR-CTCRI-HQ. The Agricultural Officers of these panchayats selected suitable farmers for cultivating banana, cassava, sweet potato and elephant foot yam as per the methodology proposed in the project. Soil samples of individual fields were collected and tested for soil moisture, pH, electrical conductivity, organic carbon and other major nutrients like N,P and K.

Fabrication and installation of e Crop device

Eight e Crop units *viz*., three at ICAR-CTCRI-HQ and five were installed in Anad, Aruvikkara, Karakulam, Panavoor and Vembayam panchayats of Thiruvananthapuram district (Fig. 142).

Fig. 142. e Crop units installed at ICAR-CTCRI-HQ and a Panchayat in Thiruvananthapuram

Mobile application for smart farming

Mobile application named 'Krishi Krithya' app was used for smart farming (Fig. 143). The app works with individual registration of farmers. Every farmer after successful registration creates an account in the application by creating personal user ID and password. Application is connected with e Crop unit and the farmers will be able to get information about their cultivated crops and obtain daily as well as weekly advisories including the amount of irrigation water and amount of fertilizers to be applied in the field using this application. The basic information such as date of planting, crop name, location, latitude, longitude, altitude, variety and soil type of the crops can be viewed.

Fig. 143. Views of mobile app 'Krishi Krithya'

Smart cassava farms: Validation and upscaling of AI & an IOT device (V.S. Santhosh Mithra)

This project is being implemented at two panchayats *viz*., Koottilangadi and Wandoor in Malappuram district. One progressive farmer from each panchayat was selected for the study by the concerned Agriculture Officer.

Selection of farmer's field and soil profiling

Well drained, levelled, fertile fields were selected for the conduct of the experiment. Soil samples were collected from the fields and tested for moisture, pH, electrical conductivity and major soil nutrients.

Fabrication and installation of IoT devices

Fig. 144. e Crop units installed at Malappuram district

Two units of e Crop, the IoT device developed by ICAR-CTCRI was installed in two panchayats of Malappuram district *viz.*, Wandoor and Koottilangadi (Fig. 144).

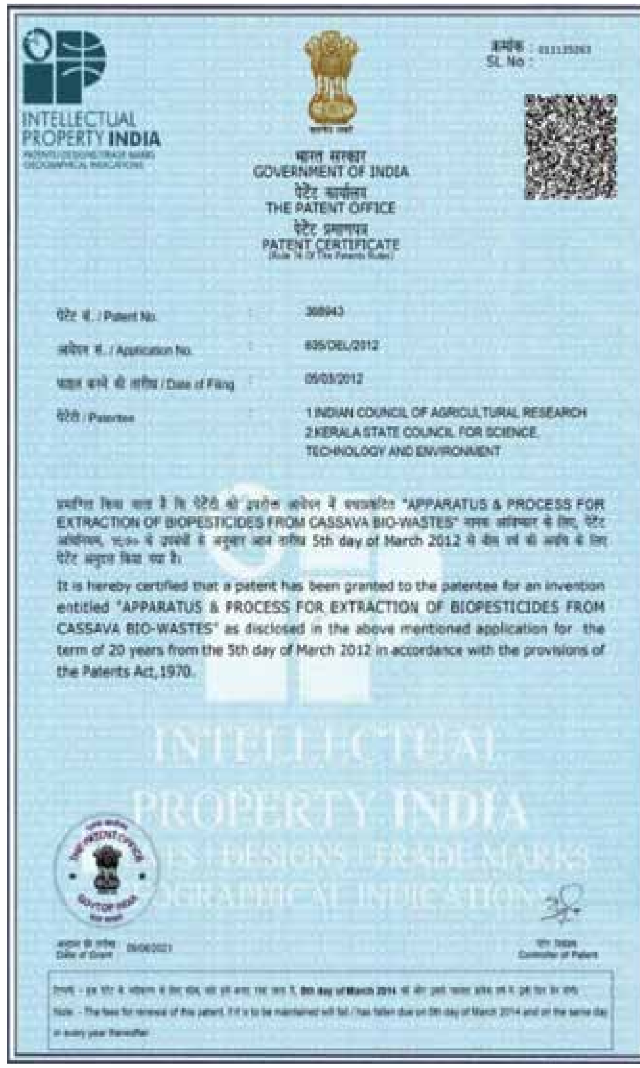
Development of mobile app to manage smart farming

Mobile app namely 'Krishi Krithya' was developed for managing smart farming. The app is developed for android operating system and the crops included are cassava, sweet potato and elephant foot yam. The mobile application is uploaded in Google play store and is available at https://play.google.com/store/apps/details?id=org.ctcri.krishikrithya.

National Agricultural Innovation Fund (NAIF): Component I: IP & TM Unit (P. Sethuraman Sivakumar)

Technology patented/commercialized/licensed

A patent for the technology 'Apparatus and Process for Extraction of Biopesticides from Cassava Bio-Wastes' developed by ICAR-CTCRI under a project sponsored by the Kerala State Council for Science, Technology and Environment (KSCSTE) was granted for a term of 20 years from the 5th day of March 2012 in accordance with the provisions of the Patents Act, 1970. The patent number is 368943 (Fig. 145).



INTELLECTUAL PROPERTY INDIA

भारत सरकार
GOVERNMENT OF INDIA
पेटेंट कार्यालय
THE PATENT OFFICE
पेटेंट प्रमाणपत्र
PATENT CERTIFICATE

Patent No. : 368943
Application No. : 635/DEL/2012
Date of Filing : 05/03/2012
Patentee : 1 INDIAN COUNCIL OF AGRICULTURAL RESEARCH 2 KERALA STATE COUNCIL FOR SCIENCE TECHNOLOGY AND ENVIRONMENT

It is hereby certified that a patent has been granted to the patentee for an invention entitled "APPARATUS & PROCESS FOR EXTRACTION OF BIOPESTICIDES FROM CASSAVA BIO-WASTES" as disclosed in the above mentioned application for the term of 20 years from the 5th day of March 2012 in accordance with the provisions of the Patents Act,1970.

Fig. 145. Patent document

Fig. 146. Apparatus for extraction of biopesticides

The present invention relates to an apparatus (Fig. 146) for extracting toxic principles from cassava plant biowastes and also relates to a process for carrying out such extraction of the toxic principles from cassava biowastes. The biopesticides extracted from cassava leaves are very effective for controlling borer pests like red palm weevil (*Rhynchophorus ferrugineus* Oliver) in coconut and pseudostem weevil (*Odoiporous longicollis* Oliver) in banana.

Technology commercialized through licensing

The details of technologies commercialised through Institute Technology Management Unit (ITMU) and the revenue generated are indicated (Table 1. & Fig. 147).

Technology undertaken for contract research

Development of pasta and cookies from Sprotone added with tuber starches as binding agents with M/S, Moza Organic Private Limited, Ernakulam, Kochi, Kerala signed on 17 November for a licence fee of ₹ 176646 only.

Table 1. Details of technologies commercialized during 2021

Sl. No.	Name of the technology	Licensed firms	Date	Revenue generated (₹)
1	Fried snacks from cassava	M/S Southern Hills Industries Pvt. Ltd, Kannur, Kerala	2 February	25000
		Vazhoor Swasraya Karshika Vikasana Samithi, Pullickal Kavala, Ernakulam, Kerala	21 March	25000
		Sri. Kiran, L.R., Pandits Colony, Kowdiar, Thiruvananthapuram, Kerala	23 July	25000
		M/S Nirpans Tasty Roots, Plamoottikada, Thiruvananthapuram, Kerala	11 August	25000
		Ms. Manjula, 2T Products, Nedumangad, Thiruvananthapuram, Kerala	17 November	25000
2	Quick cooking dehydrated tuber	M/S Edens Agro products, Kottayam, Kerala	23 July	25000
		M/S Moza Organic Private Limited, Aroma Gardens, SRM Road, Ernakulam, Kerala	18 October	25000
		M/S Arakuzha Agro Producers Co-operative Society, Muvattupuzha, Ernakulam, Kerala	17 November	25000
3	e Crop	M/S AR Magna Labz 26/91 Mangattu, Cheravally, Kayamkulam, Kerala	4 August	50000
		M/S Semilon Technologies (Pvt.) Ltd., Thiruvananthapuram	18 March	50000
4	Wax coating of cassava tubers	M/S Foodco Delicacies India (P) Ltd., Cherthala, Alappuzha, Kerala	23 July	25000

a b c

Fig. 147. Technology licensing for (a) e Crop technology; (b) wax coating technology; (c) Fried snacks from cassava

National Agricultural Innovation Fund (NAIF): Component II: Agribusiness Incubator (ABI) (P. Sethuraman Sivakumar)

Technology Development/Promotion/ Entrepreneurship through Agri Business Incubator

The ABI was established both at HQ and RS as a part of the National Agricultural Innovation Fund (NAIF) (Component II) during 2019 (Fig. 148). The major activities undertaken through the incubation centres are technology development, tuber crops technology promotion among stakeholders, enabling grass root level entrepreneurship and stakeholders interface meetings.

Fig. 148. ABI at ICAR-CTCRI-HQ

Technology development through incubation

M/S Oditribe Innovations Private Limited, Bhubaneswar, Odisha, has enrolled in the ICAR-CTCRI-RS, ABI Centre under RKVY, TIC at RS, Odisha for the development of food products from tuber crops such as arrowroot laddu and sweet potato soft drink under the mentorship of Dr. M. Nedunchezhiyan and Dr. M.S. Sajeev.

Tuber crops technology promotion

An online workshop on 'How to start a tuber crops based food processing business?' was organised by TIC and ABI at HQ along with SFAC, DoAD & FW, GoK on 8 June to introduce the healthy foods developed from tuber crops as 'healthy alternatives'. Dr. Sudha Mysore, CEO, Agrinnovate India, inaugurated the programme in the presence of Dr. M.N. Sheela, Director (A), Dr. G. Padmaja, Emeritus Scientist, Dr. M.S. Sajeev and Dr. Sheela Immanuel. Various tuber crops technologies and their products were introduced. Quality standards of tuber crops for industrial production, government schemes to promote start ups and MSMEs were discussed. Over 150 participants from 21 states took part.

Fig. 149. View of the webinar

Enabling grassroot entrepreneurship

An online planning workshop on 'Strategies for extending technology business incubation support to Farmer Producer Organizations (FPOs)' was organized by ICAR-CTCRI-HQ (ABI) on 22 December (Fig. 149). The purpose of the workshop was to design strategies for ABI's to mentor the FPOs in running successful agri-business. The workshop was inaugurated by Dr. Adimulam Bhavani Shankar, General Manager, Farm Sector Development Department (FSDD), NABARD. A total of 219 stakeholders participated in the meeting.

Stakeholders interface meeting

A virtual stakeholders meet-cum-planning workshop on 'Diversifying cassava value chains for promoting cassava starch industries' was organized by ICAR-CTCRI-HQ on 22 November with an objective to develop strategies for promoting innovations in industrial starch and sago industries to strengthen cassava value chains in India. The meeting was inaugurated by Dr. T. Mohapatra, Secretary, DARE & DG, ICAR and dignitaries namely, Dr. A.K. Singh, DDG (HS.), ICAR, Dr. T. Janakiram, VC, Dr. Y.S.R. Horticultural University, Andhra Pradesh, Dr. L. Pugalendhi, Dean (Hort.), Horticultural College and Research Institute, TNAU and Dr. V.K. Pandey, ADG (HS-I), ICAR took part in the meeting. A total of 293 stakeholders from six states participated.

Entrepreneurship development programme for students

The ICAR-CTCRI-HQ-ABI in collaboration with KAU (CoA,Vellayani), Thiruvananthapuram organized an online entrepreneurship development programme for students of agriculture and allied sciences during 23-25 November. Ten theory classes cum discussion on ecosystem based entrepreneurship development were offered for the trainees during the different sessions and was attended by 150 students.

08.0 All India Co-ordinated Research Project on Tuber Crops (AICRP-TC)

The AICRP-TC, is the largest national network of tropical root and tuber crops in 18 states and one union territory. Presently, the AICRP-TC is having 21 centres, affiliated to 12 State Agricultural Universities, three ICAR Institutions and two Central Agricultural Universities (Fig. 150).

Fig. 150. AICRP Centres on tuber crops

The major outcomes of the centre during this year is as given below:

Varieties recommended for release

Cassava

Accession No. 8S 501-2 with the special trait of CMD resistance was recommended from ICAR-CTCRI, HQ for central release for Kerala, Tamil Nadu and Andhra Pradesh for industrial use.

Greater yam

1. Accession, Hati Aloo (TGy 14-9) with excellent cooking quality was recommended from Assam Agricultural University (AAU), Jorhat for central release for Assam, Chhattisgarh, Andhra Pradesh and Rajasthan.
2. Accession, IK-DIO-04-54 (TGy 14-3) with excellent cooking quality was recommended from IGKV, Jagdalpur for central release for Maharashtra, Rajasthan, Manipur, Kerala and Assam.
3. Accession, Da H9-196 with white flesh colour and good cooking quality was recommended from ICAR-CTCRI-HQ for release for Kerala.
4. Accession, TGy 14-11 with light creamy flesh and medium cooking quality was recommended from HRS, Dr. YSRHU, Kovvur for Andhra Pradesh (Fig. 151).

Hati Aloo IK-DIO-04-54 TGy 14-11

Fig. 151. Yam varieties recommended for release

Salient achievements

- Weed management in taro through mulching with plastic ground cover mats resulted in 95-98% weed control efficiency and maximum cormel yield was recorded at Thiruvananthapuram, Ranchi and Rajendranagar

Technologies recommended

- Integrated Farming System (IFS) models involving improved varieties of tuber crops, vegetables, cereals, pulses, fruit crops, piggery, fish culture, livestock and poultry were recommended for more units in north eastern states and tribal areas.
- Management of sucking pests of taro *viz*., aphids and white fly by insecticidal treatments with imidacloprid 17.8 SL (0.5 ml l^{-1}) or thiamethoxam 25WG (0.5 g l^{-1}) was recommended for Assam, Tripura, Bihar and Telangana
- Management of taro leaf blight disease incidence using mancozeb + metalaxyl M 0.1% or copper hydroxide 0.2% was recommended for West Bengal, Assam, Jharkand, Maharashtra, Chattisgarh, Himachal Pradesh, Telengana, Tamil Nadu and Andaman and Nicobar Islands.

Annual Group Meeting

The 21^{st} Annual Group Meeting of the AICRP-TC was held online at ICAR-CTCRI-HQ during 27-28 May (Fig. 152). Dr. A.K. Singh, DDG (HS) inaugurated the programme. Dr. V. Pandey, ADG (HS-1), Dr. V. Ravi, Director (A) and Project Coordinator (i/c), AICRP-TC, scientists from 21 AICRP centres, HQ and RS, Odisha attended. Dr. Arya, K., Professor and Head, Department of Plant Breeding, KAU, Dr. James George, Former Project Coordinator, AICRP TC, Dr. Santhosh J. Eapen, Principal Scientist and Head, Division of Crop Protection, ICAR-IISR, Calicut and Dr. A.K. Sherif, Former Professor and Head (Agricultural Extension), KAU were the external experts. The two day deliberations reviewed the ongoing AICRP projects. In the plenary session held on 28 May, one new cassava variety (for central) and four greater yam varieties (2 for state and 2 for central) were recommended for release. The AICRP centre at RS, Odisha was selected as the best AICRP centre during 2020-21 based on its performance.

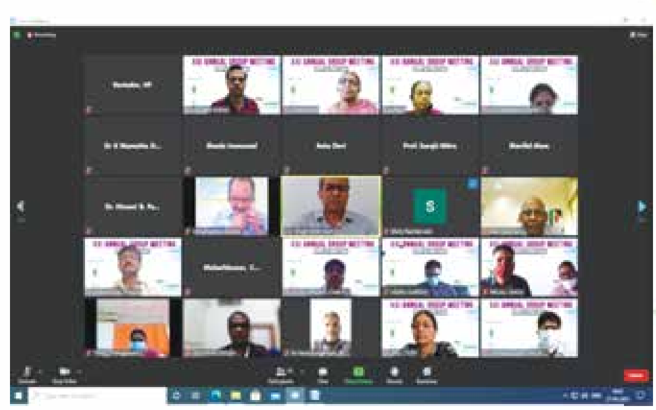


Fig. 152. Glimpses of 21^{st} AGM

09.0 Centrally Sponsored Schemes

Schemes	Title	Nodal Officer|PI	Co-PI's
Scheduled Castes Sub Plan (SCSP)	Empowerment of farmers through tuber crops based technological interventions	**Sheela Immanuel| D. Jaganathan**	G. Byju, K. Susan John, S. Sunitha, K. Sunilkumar, V. Ramesh, R. Muthuraj, M. S. Sajeev, T. Krishnakumar, K. M. Senthilkumar, A.V.V. Koundinya, B. G. Sangeetha, E.R. Harish, P. Prakash, C. Pradeepika
North Eastern Hill (NEH) Region Programme	Scaling up of biofortified tuber crops through 'Rainbow Diet Approach' in the North Eastern Hill Region	**Sheela Immanuel| P. Sethuraman Sivakumar**	M. Nedunchezhiyan, K. Laxminarayana, V. B. S. Chauhan, M. S. Sajeev, P. Murugesan, H. Kesava Kumar, T. Krishnakumar, P. Prakash
Tribal Sub Plan (TSP)	Livelihood improvement of tribal farmers through tuber crops technologies	**Sheela Immanuel| M. Nedunchezhiyan**	K. Laxminarayana, Kalidas Pati, V.B.S. Chauhan, K. Hanume Gowda, V.V. Bansode, R. Arutselvan

Scheduled Castes Sub Plan (SCSP)

Empowerment of farmers through tuber crops based technological interventions

Technologies of tropical tuber crops *viz.,* improved varieties, nutrient use efficient varieties, site specific nutrient management, integrated nutrient management including customized fertilizers, pest and disease management, post harvest processing and value addition were disseminated through frontline extension programmes *viz.,* on farm demonstrations, trainings, farm advisory visits, field days, exhibitions and through different media *viz.,* print media (technical folders, leaflets, pamphlets), mass and social media. The scheme was implemented in Kerala, Tamil Nadu and Andhra Pradesh for the benefit of small and marginal SC farmers.

On farm demonstrations (2020-21)

Inputs *viz.,* chemical fertilizers (6 tonnes), micronutrient formulations (micronol) for tuber crops (100 litres) and farm implements/tools (Chinese potato grader: 1, cassava chipping machines : 8, cassava slicers: 200, knapsack sprayers: 55, spade: 45, pick axe: 45) were distributed to 55 SC farmers as a part of on farm demonstrations in Ernakulam and Thiruvananthapuram districts, Kerala and Tenkasi and Tirunelveli districts, Tamil Nadu (Fig 153).

Fig. 153. Distribution of inputs

Frontline demonstrations (2021-22)

A total of 185 demonstrations on improved varieties and production technologies of tuber crops *viz.,* cassava, sweet potato, elephant foot yam, greater yam and Chinese potato were conducted during 2021 in 92.5 acres in the major tuber crops growing districts of Kerala and Tamil Nadu (Table 2).

Planting materials of improved varieties of tuber crops *viz.,* cassava: 36000 stems, sweet potato : 60000 vine cuttings, Chinese potato: 3.7 lakh vine cuttings, elephant foot yam: 11.75 tonnes and greater yam 3.0 tonnes (Fig. 154) were supplied to the farmers for establishing demonstration plots. Inputs *viz.,* chemical fertilizers : 27.27 tonnes, micronol for tuber crops : 2500 litres, vermicompost : 2 tonnes, micronutrient mixture: 2 tonnes, biofertilizers (PGPR I) : 2 tonnes, biocontrol agents (PGPR II): 2 tonnes, AMF : 1.6 tonnes and farm implements / tools (Chinese potato grader:1, cassava slicers: 8, power sprayers:185, spade:185, pick axe:185, crow bar: 185 and radio: 185) were distributed to 185 SC farmers (Fig. 155).

Fig. 154. Distribution of planting materials of cassava

Fig. 155. Distribution of planting materials of cassava and micronol for cassava at Alappuzha

Outreach programmes

A total of 34 outreach programmes *viz.,* trainings, seminars cum exhibition and stakeholders interface were conducted in addition to field days, group discussions and farm advisory visits. These programmes were conducted in Thiruvananthapuram, Alappuzha, Pathanamthitta, Ernakulam and Malappuram districts of Kerala, Salem, Pudukottai, Karur, Tenkasi and Tirunelveli districts of Tamil Nadu and East Godavari district of Andhra Pradesh for the benefit of 2437 farmers (Table 3, Fig. 156). Publications

Table 2. Details of technological interventions

Sl .No.	Name of the technologies	Number of FLDs	Location
A.	**Kerala**		
1	Improved varieties and site-specific nutrient management (SSNM) in cassava	15	Karode and Parassala, Thiruvananthapuram
		10	Puliyoor, Alappuzha
		10	Mezhuveli, Pathanamthitta
2	Improved varieties and SSNM in elephant foot yam	10	Pallichal, Thiruvananthapuram
		10	Mezhuveli, Pathanamthitta
3	Improved varieties and SSNM in greater yam	5	Mezhuveli, Pathanamthitta
4	Improved varieties and integrated nutrient management in tuber crops	25	Kizhuvilam, Thiruvananthapuram

5	Best agronomic practices in cassava and elephant foot yam	16	Perumkadavila, Thiruvananthapuram
6	Improved varieties of sweet potato	6	Kilimanoor, Thiruvananthapuram
B.	**Tamil Nadu**		
7	Improved varieties of cassava	7	Gangavalli and Thalaivasal, Salem
		7	Kolli hills, Namakkal
		10	Kandarvakottai, Pudukottai
		12	Shenkottai, Tenkasi
8	Improved varieties and integrated nutrient management in cassava	10	Mayanur, Karur
		2	Kalrayan hills, Salem
9	Improved variety and technologies of Chinese potato	15	Kuthapanjan, Rajankhapuram, T. Alangulam, Tenkasi
10	Improved variety and technologies of Chinese potato	10	Pallakal Pothukudi and Mannarkovil, Tirunelveli
11	Improved varieties of elephant foot yam	5	Pattakuruchi, Tenkasi
	Total	**185**	


Fig. 156. Glimpses of the outreach programmes

on technologies of tropical tuber crops and training kits were given. Wider press coverage on improved varieties and technologies of tuber crops was given in leading English, Malayalam, Tamil and Telugu newspapers for creating awareness among the farmers and other stakeholders.

Table 3. Outreach programmes in Kerala, Tamil Nadu and Andhra Pradesh

Sl. No.	Topic of the programme	Date	Venue	Number of farmers
A. Training Programmes				
1.	Improved technologies of tuber crops for enhancing farm income	27 January	Pallakal Pothukudi, Tirunelveli	75
2.		28 January	Kizhuvilam, Thiruvananthapuram	35
3.		29 January	Keelapuliyoor, Tenkasi	80
4.		10 February	Nediyiruppu, Malappuram	87
5.		12 February	Vadakkekara, Ernakulam	94
6.		18 February	Goodamalai, Salem	80
7.		19 February	Veeradipatti, Pudukottai	90
8.	Value addition in tuber crops	25 February	Chengannur, Alappuzha	20
9.		26 February	Goodamalai, Salem	15
10.		03 March	Vattiyoorkavu, Thiruvananthapuram	15
11.		06 March	Aranmula, Pathanamthitta	20
12.	Scientific technologies of tuber crops for enhancing farm income	10 March	Peddapuram, East Godavari	110
13.		29 July	Vadakkekara and Thiruvankulam, Ernakulam	45
14.		30 July	Kilimanoor, Thiruvananthapuram	15
15.		13 August	Chenkal, Thiruvananthapuram	25
16.		25 August	Kuthapanjan, Tenkasi	32
17.		25 August	Pallakal Pothukudi, Tirunelveli	28
18.	Post harvest processing & value addition	15 September	ICAR-CTCRI-HQ	20
		28 September	Kollimalai, Namakkal	60
19.	Agro techniques in tuber crops cultivation, value addition and enterpreneurship development in tuber crops	29 September	Goodamalai, Salem	105
20.		12 October	ICAR-CTCRI-HQ	25
21.		24 November	Peddapuram, East Godavari	105
22.		27 November	Karode, Thiruvananthapuram	116
23.		21 December	Mekkarai, Tenkasi	120
24.		23 December	Rajankhapuram, Tenkasi	115
25.		24 December	Mannarkovil, Tirunelveli	105
B. Seminar cum exhibition				
1.	Improved technologies and value addition in tuber crops	04 March	Puliyur, Alappuzha	250
2.		16 October	Mezhuveli, Pathanamthitta	80
3.		22 October	Parassala, Thiruvananthapuram	84
4.		28 December	Perumkadavila, Thiruvananthapuram	116

C. Stakeholders Interface				
1.	Scientific cultivation of tropical tuber crops	24 August	Kanakapillaivalasi, Tenkasi, Tamil Nadu	60
2.		24 August	Keelapuliyoor, Tenkasi, Tamil Nadu	50
3.		24 August	Kuthapanjan, Alankulam Taluk, Tenkasi district of Tamil Nadu	80
4.		25 August	Pallkal Pothukudi, Ambasamudram, Tirunelveli, Tamil Nadu	75
5.		30 September	Veeradipatti, Gantharvakottai, Pudukottai, Tamil Nadu	70
6.	Soil and soil health	04 December	ICAR-CTCRI-HQ	25
7.	Improved technologies of cassava	22 December	Mayanur, Karur, Tamil Nadu	15

North Eastern Hill (NEH) Region Programme

Scaling up of biofortified tuber crops through 'Rainbow Diet Approach' in the North Eastern Hill region

Model for strengthening grass root level seed systems for tuber crops

A model for developing 'seed villages' to strengthen grassroot level seed systems was designed and implemented in Tripura and Arunachal Pradesh (Fig. 157).

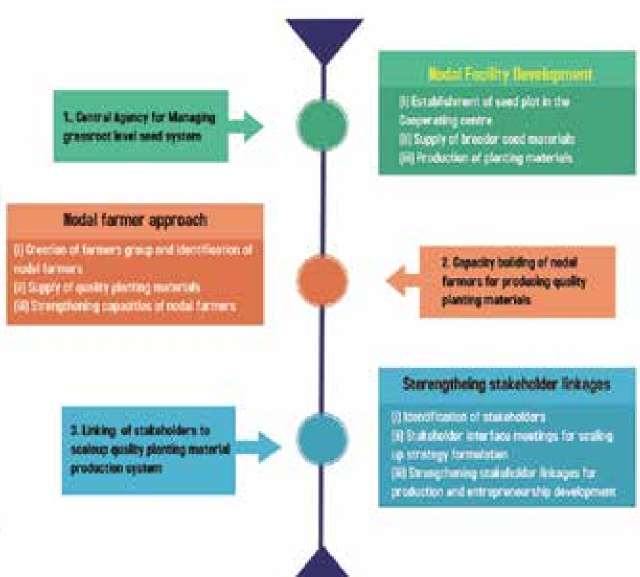


Fig. 157. Grassroot seed system development model for tuber crops

A central seed production plot was established at the collaborating institutions *viz.,* Central Agricultural University, Tripura and KVK, Anjaw, Arunachal Pradesh as a Multi Technology Testing Centre (MTTC) and a Vocational Training Centre (VTC) in the first stage.

In the second stage, the farmers groups were formed in each designated seed villages to manage the production of quality planting materials (QPM) of tuber crops. At the beginning, tuber crops planting materials were supplied to the selected seed villages (Table 4).

After the supply of QPM, the farmers' groups were trained on the 'Protocols of quality planting material production'. In Arunachal Pradesh, two groups comprising 130 farmers were trained through online programme and 70 farmers during the campaign event in Khupa village. In Tripura, 100 beneficiary farmers of Takarjala village, 70 farmers of Ratanpur, 70 farmers of Tilakpara village and 50 farmers of Jampuijala village were trained on QPM production by ICAR-CTCRI (Table 5, Fig. 158).

Combating micronutrient malnutrition through biofortified varieties

Under phase 2 of the 'Rainbow Diet Campaign', two nutritional awareness programmes were conducted among school children (6-13 years) in Arunachal Pradesh and adolescents (10-19 years) in Tripura. Considering the changes in food habits of children and adolescents, biofortified sweet potato pasta was popularised through 'Pasta tasting' sessions. Under this approach, three variants of sweet potato pasta were introduced and their health benefits were explained. Later these variants were cooked

Table 4. Supply of QPM for seed villages in NEH region

State	Name of seed villages	Quantity of planting materials supplied		
		Crop	Variety	Quantity (kg|No.s)
Arunachal Pradesh	Anjaw district Tafraliang Bijliang	Sweet potato	Bidhan, Jyoti, Gouri	Tubers (kg): 3332
		Greater yam	Orissa elite	Tubers (kg): 1000
		Elephant foot yam	Gajendra	Tubers (kg): 1485
		Taro	Muktakeshi	Tubers (kg): 1250
		Cassava	Sree Jaya, Sree Vijaya	Stems (No.s): 1100
Tripura	Sepahijala district Ratanpur Takarjala	Sweet potato	Bhu Sona, Bhu Krishna Bhu Sona, Bhu Krishna	Vines (No.s): 11000 Tubers (kg): 1160 Tubers (kg): 1080
		Greater yam	Orissa elite	Tubers (kg) 1675
		Elephant foot yam	Gajendra	Tubers (kg): 2000
		Taro	Muktakeshi	Tubers (kg): 1600
		Cassava	Sree Jaya, Sree Vijaya	Stems (No.s): 2000

Table 5. Trainings | campaign conducted under NEH programme of ICAR-CTCRI

Particulars of trainings |Campaign	Date	Number of beneficiaries and state
Production of quality planting materials of tuber crops	01 March	70 farmers from Ratanpur, Sepahijala district, Tripura
Production of quality planting materials of tropical tuber crops for NEH region	04 June	40 farmers/ officers/ students from NEH region
Production and value addition in tropical tuber crops	7-9 July	100 farmers from Sepahijala and West Tripura districts, Tripura
'Rainbow Diet Campaign' on creating sustainable entrepreneurship through seed villages of tuber crops & nutritional awareness	27 February	100 farmers from Sepahijala district, Tripura
'Rainbow Diet Campaign' for students	2 March	400 students of ICFAT University, Tripura
'Rainbow Diet Campaign' on creating sustainable entrepreneurship through seed villages of tuber crops & nutritional awareness	5 March	113 stakeholders from Anjaw district, Arunachal Pradesh

Fig. 158. Capacity building of farmers on QPM production

Fig. 159. Demonstration of sweet potato pasta in Tripura

'on-site' and provided for tasting and their immediate reactions were recorded (Fig. 159).

Maximising farmers income through varietal intervention

Ten FLDs of improved taro variety, Mutakeshi was conducted in five villages in Anjaw district, Arunachal Pradesh (Fig. 160).

Fig. 160. FLD of taro in Anjaw, Arunachal Pradesh

Data collected after harvest indicated that, this variety has significantly increased the income of the farmers as 55.35% in Tafraliang village to 408% in Walla village compared to the baseline period of 2020. The average increase in the income was 217.44% compared to the baseline in 2020 while taro alone had contributed to 167.84% increase in income.

Tribal Sub Plan (TSP)

Livelihood improvement of tribal farmers through tuber crops technologies

A total of 523 tribal households were adopted from Chakapada, Phiringia, Thumidibandha, Kotagarh, Muniguda, Bissam Cuttack, Semiliguda and Pottangi Blocks in Odisha. Planting materials of sweet potato (225000 vine cuttings), greater yam (11800 kg), elephant foot yam (4500 kg), *Colocasia* (700 kg), yam bean (100 kg), cassava (6000 stems), maize seed (20 kg), red gram (10 kg), vegetable seed kits (600 numbers) were distributed to the tribal farmers. Vegetable kits contained *Amaranthus*, Okra, chilli, cowpea, french bean, tomato, palak and *Dolichos* seeds. Regular monitoring was carried out to address the problems faced by the tribal farmers.

For capacity building of the tribal farmers on tuber crops cultivation and value addition, eight on farm training programmes were organized. A 'Tuber crops day' was celebrated on 22 March at Mohana, Gajapati district of Odisha. More than 300 tribal farmers attended (Fig. 161). In tribal farmer's field, the average yield of tuber crops were as follows: sweet potato: 14.2 t ha^{-1}, yam bean: 20.5 t ha^{-1}, taro : 13.5 t ha^{-1}, elephant foot yam : 25 t ha^{-1}, maize: 3250 kg ha^{-1}, ragi : 1090 kg ha^{-1} and greater yam : 26.2 t ha^{-1}. Each tribal household produced sufficient tubers, rice, ragi, maize and other crops for household consumption and surplus for selling.

Fig. 161. Activities under TSP

10.0 Development Programmes

10.1 Mera Gaon Mera Gaurav (MGMG)

The *Mera Gaon Mera Gaurav* is a national initiative/program launched by Hon'ble Prime Minister on 25 July 2015, wherein agricultural scientists from all over the country have to adopt one village each and offer technological support to the farmers. This program is implemented both at HQ and RS of ICAR-CTCRI. A total of 44 villages were adopted by 44 scientists as 10 teams in Thiruvananthapuram, Kerala and different districts of Odisha.

Frequent visits were made to these villages and more than 10 awareness programmes and trainings were organized on tuber crops production and processing technologies. At HQ, demonstrations on improved varieties of cassava, sweet potato, arrowroot and Chinese potato were conducted in the farmer's fields. Soil samples were taken from these farmer's plots and soil health cards were issued on World Soil Day. The farmers of these villages were provided with recent agro advisory brochures in local language. Several meetings were organized, tuber crop leaflets and other literature were distributed to the farmers, mobile based agro advisories were given on improved varieties, crop production technologies, emerging pests and diseases, value addition, and marketing. Linkages were established with the Krishi Bhavans of the grama panchayats of Pothencode, Kaniyapuram, Andoorkonam, Kazhakuttam, Karichara, Vellara and Sreekariyam (Fig. 162).

At RS, Odisha, the scientists along with the technical staff identified farmers and distributed quality planting materials of sweet potato (var. Gouri, Bhu Sona & Bhu Krishna: 2000 vines), Chinese potato (var. Sree Dhara: 500 cuttings), arrowroot tubers (local variety: 75 kg), cassava stem cuttings, taro cormels and 30 vegetable seed kits (containing okra, tomato, palak, A*maranthus*, chilli, french bean, *Dolichos* bean and cowpea). Around 100 farmers from MGMG villages, Cuttack district, Odisha participated in the Kisan Diwas organized on 23 December (Fig. 163).

Fig. 162. Ditribution of planting materials at Pothencode and Karichara

Around 120 farmers from the selected MGMG villages of both states attended the National Swachhata Campaign on 'Waste to Wealth' and live telecast of 'Natural Farming' addressed by Hon'ble Prime Minister.

Apart from tuber crops, farmer's problems in vegetables and plantation crops, were also resolved with the technical support of officials from state departments, KVK's, Agricultural University and other extension departments. In general, there was lack of awareness among farmers about the biofortified and nutrient rich varieties and value addition in tuber crops. Linkages were created with Pubusahi grampanchayat, Khurda block, Khurda district and Madhuban grampanchayat, Cuttack district, Odisha. In addition, farmers were given timely advisories especially on agrotechniques of tuber crops.

Fig. 163. Awareness classes on tuber crops technologies at RS, Odisha

10.2 Soil Health Card Programme

Soil health cards (SHC) (Fig. 164) were issued to farmers of the villages of Pothencode, Kazhakuttam and Andoorkonam during the World Soil Day organized at HQ on 4 December. The farmers under SCSP of the Perunkadavila and Kunnathukal panchayats of Perunkadavila block were also issued with soil health cards in a function held on 28 December (Fig. 165).

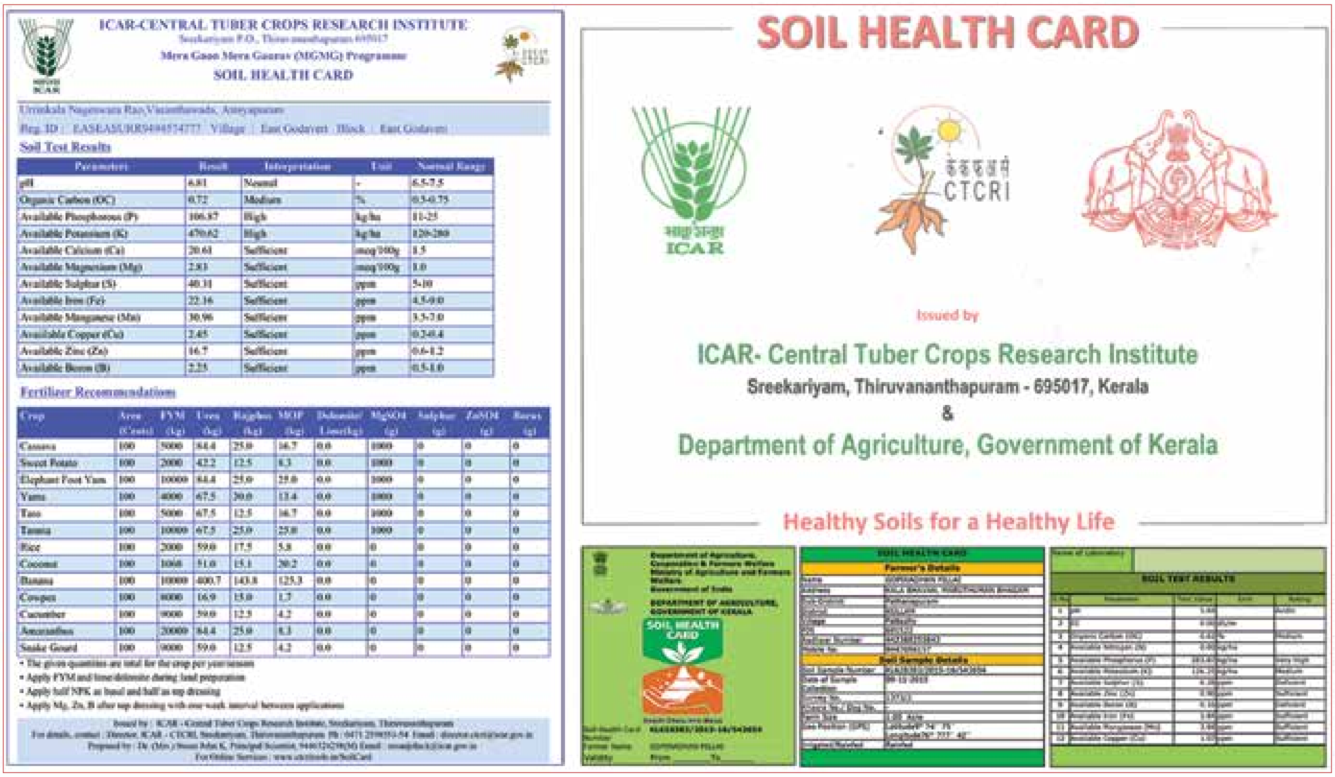


Fig. 164. SHCs issued to farmers

Fig. 165. Issue of SHC to MGMG farmers

10.3 Swachh Bharat Abhiyan

Fig. 166. Glimpses of the cleaning drive at HQ & RS premises

The diversified activities envisaged under the Swachh Bharat Mission were implemented at HQ and RS. Cleanliness programmes were regularly conducted at the Institute premises, adjacent public places and nearby villages. Staff members were apprised for maintaining neatness in their respective work places *viz*., sitting place, laboratories, canteen and farm (Fig. 166).

Swachhta Pakhwada

Under Swachhta Pakhwada, swachhta pledge (Fig. 167) was administered by the Director (A) along with all staff. Dr. M. N. Sheela, Director (A), in her address highlighted the importance of observing Swachhta Pakhwada. The

Fig. 167. Swachhta pledge as part of Swachhta Pakhwada

Swachhta awareness banner was displayed at the main entrance at HQ and RS and other prominent public places. Cleanliness drive was conducted to remove plastic wastes from the Institute premises and adjacent places on day-to-day basis by the staff members. A cleaning campaign was organized at a tourist spot near the Instititue HQ at Akkulam under this programme (Fig. 168). The RS

Fig. 168. Glimpses of the Swachhta Pakhwada conducted at Akkulam boat club

also had spread the message of cleanliness and actively participated in cleaning schools and villages.

Special National Swachhta Campaign on 'Waste to Wealth'

As a part of the Special Swachh Bharat Campaign, an awareness programme on 'Waste to Wealth' was organized for 50 farmers of Chenkal and neighbouring villages of Thiruvananthapuram. Dr. M.N. Sheela, Director (A) briefed about the theme of the programme. Two lectures on the composting of farm waste and family net vessel composting were delivered by Dr. K. Susan John. A short video on the vermicomposting given by ICAR-IISS was screened for the farmers. Literature on 'Waste to Wealth' was also distributed to farmers.

A contingent of 75 members from the Institute visited the Primary Health Centre, Pangappara and initiated the cleaning of the premises (Fig. 169). Plastic, medical and degradable wastes were segregated separately and kept for safe disposal. The weeds in the health centre premises were removed. The staff from the Primary Health Centre also joined the programme (Fig. 170).

Fig. 169. Initiating cleaning of Institute premises

Fig. 170. National swachhta campaign at Pangappara Health Centre

At RS, Odisha, the Special Swachhta Campaign on 'Waste to Wealth', was organized at Madhuban village, Cuttack district, Odisha on 9 November. Dr. K. Laxminarayana, Dr. Kalidas Pati and Dr. R. Arutselvan, scientists explained the importance of public participation in maintaining the cleanliness, sanitation and hygiene. Sixty farm women attended (Fig. 171).

Fig. 171. Glimpses of the programme at RS, Odisha

11.0 Technologies Generated & Transferred

Technologies Developed

- Drought tolerant sweet potato lines
- *In vitro* plant regeneration protocol for taro early line 'Telia' and Chinese potato (var. Sree Dhara)
- Optimization of *in vitro* pollen germination medium for greater yam to test the pollen viability of male parents
- Non trailing white yam variety, SD-15 with high yield (44.72 t ha^{-1})
- Power operated Chinese potato grader of one tonne capacity
- Laboratory scale process to produce
  a. Cassava starch-graft-soybean oil maleate with hydrophobic properties and film forming properties
  b. Cross-linked cassava starch with STPP/STMP
  c. Thermoplastic starch sheets from cassava starch-rice husk | paddy straw based flour
  d. Pancake from sweet potato tuber and millet based composite flour

Technologies transferred

- Tuber crops technologies *viz.,* modern agro techniques, value added products, biofortified sweet potato varieties were transferred to the farmers of Odisha, Kerala, Tamil Nadu and Andra Pradesh
- Improved tuber crop varieties and vegetable varieties were popularized in tribal blocks of Odisha
- Customized fertilizer for cassava in Thiruvananthapuram district
- Customized fertilizer and foliar micronutrient formulation for Chinese potato in Tenkasi and Tirunelveli districts
- Biopesticides *viz., Nanma* and *Shreya* in the management of major pest of cassava in Coimbatore, Namakkal, Salem and Kanyakumari districts of Tamil Nadu and Thrissur district of Kerala
- Soil fertility management practices in the control of mealy bugs in cassava at Thirupathisaram, Tamil Nadu

Technologies included | added in the PoP of KAU (2021)

- Organic package of practices for cassava
- Secondary and micronutrient management for sweet potato
- Management of tuber cracking due to Boron (B) deficiency in sweet potato
- Customized fertilizer (CF) formulations for elephant foot yam, greater yam and cassava under intercropping in coconut
- Organic management of
  a. Collar rot in EFY
  b. Corm rot in EFY
  c. Leaf blight in taro

12.0 Human Resource Development (HRD)

Human Resource Development (HRD) Cell

The HRD cell was established at ICAR-CTCRI as per the guidelines. It is staff centric and it is providing training to the employees of the Institute as per their need. The staff members are participating in the trainings organised by ICAR Institutes and other organizations. The capacity building opportunity is provided to all the categories of staff. The Annual Training Plan (ATP) is prepared in the beginning of the financial year after assessing the training needs of the individual staff.

12.1 Training

Trainings attended by staff

During this year, 25 scientists, four technical staff, four administrative and accounts staff as well as two skilled support staff attended various training programmes. The details are as follows (Table 6):

Table 6. Training (Online) attended by staff of ICAR-CTCRI

Name of Staff	Topic	Organizers	Period
Scientists			
Drs. R. Arutselvan, V.V. Bansode, G. Byju, V.B.S. Chauhan, Kalidas Pati, H. Kesava Kumar, A.V.V Koundinya, K. Laxminarayana, T. Makeshkumar, R. Muthuraj, M. Nedunchezhiyan, V. Ramesh, V. Ravi, B.G. Sangeetha, Sanket J. More, V.S. Santhosh Mithra, R. Saravanan, K.M. Senthilkumar, Shirly Raichal Anil, G. Suja, K. Sunilkumar, S. Sunitha, J. Suresh Kumar, K. Susan John, S.S. Veena, Vivek Hegde, C. Visalakshi Chandra	Root architecture imaging and analysis for tropical tuber crops	ICAR-CTCRI, Thiruvananthapuram; Louisiana State University, Louisiana, U.S.A.	20-22 January
Dr. K.I. Asha, Dr. M.N. Sheela, Dr. C. Visalakshi Chandra, Dr. Vivek Hegde	DUS testing	PPV& FRA, Government of India	1 July
Dr. D. Jaganathan	Indigenous Knowledge Systems (IKS) and rural/tribal development	National Institute of Rural Development, Hyderabad	22-26 March
Dr. A. N. Jyothi Dr. C. Pradeepika	Biofortification: A key to nutritional security	MANAGE, Hyderabad; Harvest Plus	12-14 July
Dr. H. Kesava Kumar	Pest and disease management through biocontrol methods	Kerala Agricultural University	28 June-24 July

Dr. N. Krishna Radhika	Hands-on laboratory course on CRISPR-Cas gene editing	SGT University, Gurgaon; Alliance of Bioversity International; CIAT Asia-India, New Delhi;ICAR-NRRI, Cuttack; ICAR-NIPB, New Delhi; DBT-NABI, Mohali	23-27 March
	Biosecurity and biosafety: Policies, diagnostics, phytosanitary treatments and issues	ICAR-NBPGR, New Delhi	15-24 September
Dr. T. Krishnakumar	Response surface methodology	ICAR-NAARM, Hyderabad	24-26 August
	Post harvest handling, processing technology and value chain management	National Institute of Food Technology Entrepreneurship & Management, Haryana	07 December
Dr. P. Prakash	Time series data analysis	ICAR-NAARM, Hyderabad	04-09 January
	Impact assessment of agricultural technologies	ICAR-NAARM, Hyderabad	18-22 December
Dr. Sanket J. More	Design thinking for research project formulation and implementation	ICAR-NAARM, Hyderabad	24-28 August
Dr. K.M. Senthilkumar	Enhancing research skills and refinement of technology by a scientist	ICAR-IIHR, Bengaluru	18-20 January
	SNP mining, GWAS and genomic selection	ICAR-IASRI, New Delhi	16-21 December
Dr. K.M. Senthilkumar Dr. Vivek Hegde	Application of bioinformatics in agricultural research and education	ICAR-NAARM, Hyderabad	20-24 September
Dr. Sheela Immanuel	Leadership development for women scientists	ICAR-NAARM, Hyderabad	8-10 March
Dr. Shirly Raichal Anil	Management Development Program (MDP) on biodiversity and environmental laws for agricultural researchers	ICAR-NAARM, Hyderabad	7-9 June
	Generic online training in cyber security	Ministry of Electronics and Information Technology, New Delhi	29 July
Dr. Shirly Raichal Anil Dr. S.S. Veena	Emotional intelligence at workplace for scientists/ technologists	Centre for Organization Development, Hyderabad; DST, Government of India.	20-24 September

Dr. P. S. Sivakumar	JCR and certification program	Clarivate Web of Science	15-17 June
	RTB toolbox: Building a better seed future together	CIP, Lima, Peru	26-29 July
	Venture capital and private equity for SMEs	Indian Academy of Venture Capital, Mumbai	31 July - 4 September
	Nutrition sensitive agriculture	MANAGE, Hyderabad	15-17 October
Dr. S.S. Veena	On farm production of bio-control agents and microbial biopesticides	NIPHM, Hyderabad	13- 17 September
Dr. C. Visalakshi Chandra Dr. K.M. Senthilkumar	Transcriptomic data analysis	ICAR-IASRI, New Delhi	28-30 September
Technical Staff			
Smt. B.S. Deepa	Capacity building workshop for agricultural LIS professionals	PJTSAU, Hyderabad; ICAR-NAHEP	22 - 27 November
	Koha library management system	Kerala Library Association, Thiruvananthapuram	12 - 18 June
Dr. B.S. Prakash Krishnan Dr. L.S. Rajeswari Shri. B. Satheesan	Root architecture imaging and analysis for tropical tuber crops	ICAR-CTCRI,Thiruvananthapuram; Louisiana State University, Louisiana, U.S.A.	20-22 January
Administrative Staff			
Shri. O.C. Ayyappan	Establishment matters of L.D.C & U.D.C.	ICAR-IISR, Lucknow	15-20 November
Smt. C. Chandra Bindu Smt. B. Presanna	Accrual accounting	ICAR-NRRI, Cuttack	21-26 November 26-30 July
Shri. C. Chandru	Asset management	ICAR-IARI, New Delhi	6-8 October

Trainings | Seminars conducted

The details are as follows (Table 7):

Table 7. Details of trainings | seminars conducted by ICAR-CTCRI-HQ and RS

Particulars of training|seminar	Date |Venue	Organizers	Number of participants
Value chain-oriented extension approaches for maximizing profitability of tuber crops	22-26 February | ICAR-CTCRI	ICAR-CTCRI; MANAGE, Hyderabad	45
Soil fertility and nutrient management in tuber crops	18 March| Nanniyode Krishi Bhavan	RKVY, ICAR-CTCRI; DoAD& FW, GoK	75
Organic farming for self sufficiency in the homesteads of Kerala and distribution of organic inputs and agricultural implements	12 August | ICAR-CTCRI-HQ	AINP-OF, ICAR-CTCRI	1200

Scaling up of cassava technologies in the industrial cassava region of Tamil Nadu	18 August |ICAR-CTCRI	ICAR-CTCRI; KVK, TANUVAS, Kalakurichi	35
Agro techniques and value addition	27 August| Bhubaneswar	ICAR-CTCRI-RS, Odisha	55
Good agricultural practices for tuber crops with special emphazis to seed material multiplication	22-23 September| Melukav; Poonjar South; Thalanad panchayats, Kottayam	RKVY, ICAR-CTCRI; DoAD& FW, GoK	150
Agro techniques of tuber crops	22 September| KVK, Idukki	RKVY, ICAR-CTCRI; DoAD& FW, GoK	110
Improved production technologies and value addition in tropical tuber crops	20-22 October| ICAR-CTCRI	ICAR-CTCRI; Department of Horticulture, Tamil Nadu	25
Soil health management for sustainable crop production	11 November| Bhubaneswar	ICAR-CTCRI-RS, Odisha	50
Improved production and processing technologies of tuber crops	20 November |Adoor, Pathanamthitta	AINP-OF, ICAR-CTCRI	150
Value addition and entrepreneurship development in tuber crops	8-9 November | KVK, Kollam	Krishi Vigyan Kendra, Kollam	76
	29 November | Adimali, Idukki	VFPCK, Idukki district	102
	18 December | Thiruvananthapuram	Kerala Agri Food Pro 2021, Dept of Industries and Commerce (DIC), Kerala	110
Value added products from tuber crops for microfood processing enterprises	30 December| Idukki	DIC, Idukki district	120
Incubation support and processing machineries for entrepreneurship development in tuber crops	30 December | Idukki	DIC, Idukki district	65

12.2 Capacity building

Participation of Scientists in Conferences, Meetings, Workshops, Seminars, Symposia and Webinars

The details are as follows (Table 8):

Table 8. Details of participation of scientists

Name	Programme	Organizers| Date
Dr. A. Asha Devi Dr. C. Visalakshi Chandra	Nutritional security: Challenges and opportunities on gender sensitive agriculture	ICAR-CIWA, Odisha | 25 March
Dr. A. Asha Devi Dr. K.I. Asha Dr. V. B. S. Chauhan Dr. N. Krishna Radhika Dr. C. Visalakshi Chandra	Genomics and breeding innovations in agriculture	ICRISAT, Hyderabad | 6 July

Dr. A. Asha Devi Dr. V. B. S. Chauhan Dr. N. Krishna Radhika	Genome editing tools and its applications for targeted plant breeding	APAARI, KBCH, BCIL | 21 July
Dr. A. Asha Devi Dr. K.I. Asha Dr. J. Sreekumar	Predictive modelling and AI for biodiversity under computational biology and bioinformatics	ICAR-NIPGR, New Delhi | 22 June
Dr. K.I. Asha	Planning and management of CWR and RET species exploration and germplasm collection	BSI and ICAR-NBPGR | 5 July
	SB centenary talk series 4: Omics approaches for deeper understanding of key traits and crop improvement	Central University, Karnataka | 9 July
	Walking through the Western ghats	Fathima Matha National College, Kollam | 20 July
	Talent search for manning agriculture TREE (Teaching, Research and Extension Education)	Ministry of Agriculture, Govt. of India | 11 November
	A critical look at Global Hunger Index	ICAR-IASRI | 11 November
	Protection of plant varieties, the key to improved agricultural commerce and growth	ICAR-NAHEP | 1 December
Dr. K.I. Asha Dr. K.M. Senthilkumar	ICAR-CIAT Work plan meeting	ICAR-CTCRI and CIAT | 13 September
Dr. K.I. Asha Dr. G. Suja	An evening with world food prize laureates - Discussion on global food and nutrition security to meet the SDGs during and after covid 19 pandemic	ICAR | 16 October
Dr. V. B. S. Chauhan Dr. N. Krishna Radhika	Vegetable research and innovations for nutrition, entrepreneurship and environment	ISVS; ICAR-IIVR U.P. | 14-16 December
Dr. V. B. S. Chauhan	Advancing genome edited plants from lab to land	APAAR; KBCH; BCIL | 4 August
	Enabling policies for genome editing in agriculture	APAARI, KBCH; BCIL | 18 August
	XV Agricultural Science Congress (ASC), ASC expo	NAAS, New Delhi; BHU, Varanasi | 13-16 November
Dr. D. Jaganathan	Next generation horticulture	TNAU, Tamil Nadu | 16-19 September

Dr. D. Jaganathan Dr. M.N. Sheela Dr. P. Sethuraman Sivakumar	Review and sensitization workshop of ZTMUs | ITMUs | PMEs under NAIF	ICAR, New Delhi | 6 October
Dr. C. A. Jayaprakas	Advances in biological suppression of pests	ICAR- CPCRI | 22 September
	Plant science and research	IRIS scientific group, Spain | 2 November
Dr. M. L. Jeeva	New paradigms in biological control of insect pests and diseases	ICAR - IISR | 16 August
	Post harvest disease management and value addition of horticultural crops	ICAR- IARI | 18-20 August
Dr. A. N. Jyothi	Photochemistry-Impacts and applications and Prof. (Dr.) A. Hisham endowment award ceremony-2021	Kerala Science Academy | 27-28 September
Dr. Kalidas Pati	Scrutiny of project proposals on ginger processing	Directorate of Horticulture, Odisha | 3 September
	Crop wise strategies for increase in area and productivity of vegetables in Odisha	Directorate of Horticulture, Odisha | 16 November
	Opening of expression of interest on organic farming (EOI) under MIDH	Directorate of Horticulture, Odisha | 16 November
Dr. H. Kesava Kumar	Nematodes, a continuing bottleneck in crop production: Available technologies and recent advances	MPUAT, Rajasthan | 6 April
	Importance of Acarology in agriculture: The role of mite taxonomy	BCKV, West Bengal | 29 July
	Nematode- A hidden enemy of crops	Bayer Crop Science | 2 September
	The facets of innovation and development of plant Nematology	Nematological Society of India, New Delhi | 29-30 October
Dr. T. Krishnakumar	Roots and tuber crops chain	KALRO; Self Help Africa; Root and Tuber Crops Unit; Ministry of Agriculture | 27-29 July
	Nano biotechnology for transforming food processing sector: Our actions are our future	National Institute of Food Technology Entrepreneurship and Management, Haryana | 15 October
	Agricultural research through knowledge discovery	EBSCO Information Services, USA | 23 February
Dr. K. Laxminarayana	Scrutinization and evaluation of project proposals under RKVY	RKVY, Govt. of India | 19 -21 May
	ICAR Institutes-SAUs-State interface meet	OUAT; ICAR-NRII, Orissa | 22 September

Dr. P. Murugesan	Oil Palm : A right choice towards self sufficiency in edible oil production	ICAR- IIOPR, Pedavegi | 6 September
	Digitization of data for oil palm breeding and annual general body meeting	International Society for Oil Palm Breeders, Malaysian Palm Oil Board, Malaysia | 17 October
	Agro biodiversity conservation and use for climate resilience and livelihood improvement of small holder farmers	ICAR-VPCAS, Almora | 23 December
Dr. R. Muthuraj	Seed quality enhancement	Indo-German & TNAU collaborative programme | 23-25 May
Dr. N. Nedunchezhiyan	Plant science in post genomics era (International)	Agri vision 2021, Evation business solutions (P) Ltd. | 14-16 March
Dr. P. Prakash	Strategies for promotion of biofortified crops in India	MANAGE, Hyderabad | 18 May
Dr. P. Prakash Dr. P. Sethuraman Sivakumar	Review on Agri-Business Incubation (ABI) centres of Horticulture Division	IPTM- ICAR, New Delhi | 27-28 July
Dr. V. Ramesh	Scientific advisory committee meeting	KVK Thirupathisaram, TN | 25 March
	Modelling soil physical processes for improving resource use efficiency in agriculture	Indian Society of Agro Physics | 08 December
Dr. Sanket J. More	Phisiological interventions for climate smart agriculture	ICAR-SBI; ISSP; SSRD | 11-12 March
Dr. K. M. Senthilkumar	Genomes of animals and plants (GAP)	Dovetail Genomics, LLC, Singapore | 12-14 January
	10th Interactive session for IBSCs registered on IBKP portal	RCGM Secretariat, Department of Biotechnology | 28 January
	4th International Symposium on genome editing	Texas A & M University | 28 October
	Use of molecular techniqs in uderstanding plant defense against insect herbivory	
Dr. Sheela Immanuel	RINK technology conclave celebrated on the National Technology Day	Kerala Start-up Mission partner with TiE Kerala | 11 May
Dr. M.N. Sheela	Global Conference on green development of seed industries	FAO | 4–5 November

Dr. P. S. Sivakumar	Agri-start ups in India: Opportunities, challenges and way forward	NAAS, New Delhi | 1 November
	Vigyan Utsav–R & D infrastructure in Kerala	KSCSTE, Kerala | 11 November
	Livelihoods India summit 2021	ACCESS Development Services, New Delhi | 16-17 December
Dr. J. Sreekumar	Exchange of post PVP control measures	PPV& FRA, New Delhi | 8 April
Dr. G. Suja	Pre-conference session on Kerala agriculture- The need to raise productivity and agriculture in the international conference on Kerala looks ahead	Kerala State Planning Board, GoK | 27 January & 2 February
	Coconut based high density multi species cropping systems (HDMSCS)	ICAR-CPCRI, Kasargod | 30 January
	Alternate cropping system for climate change and resource conservation	ICAR-IIFSR, U.P. | 29 September - 1 October
	Crop rotation for soil health management and improved productivity	Department of Agriculture & Farmers Welfare, Tamil Nadu | 2 October
	16th Annual group meeting of AINP-OF	ICAR-IIFSR, U.P. | 3-4 December
Dr. G. Suja Dr. S. Sunitha Dr. J. Suresh Kumar	Fifth International Agronomy Congress on Agri innovations to combat food and nutrition challenges	PJTSAU, Telangana | 23-24 November
Dr. G. Suja Dr. K. Susan John Dr. S.S. Veena Dr. M.L. Jeeva	State level Package of Practices workshop	KAU | 2 December
Dr. K. Sunilkumar	Formalization of seed material supply chain of tuber crops in Kerala	ICAR-CTCRI, DoAD & FW, GoK | 17 March
	Bio fortification to address hidden hunger and nutritional security- Present status and way forward	NAAS, New Delhi | 26 March
	State level project screening committee of RKVY	DoAD & FW, GoK | 24 June
	Price fixation of tuber crop planting materials produced by decentralized multipliers	DoAD & FW, GoK | 20 September

Dr. Susan John K.	Micronutrient fertilizers for food and nutrition security	CII; IZA, New Delhi | 5 March
	Agri and food: Pre event in support of the UN food systems Summit 2021-Actions towards strengthening food systems in India	CII;IZA, New Delhi | 13-14 September
	Zinc fertilizer and its raw materials for food and nutrition security	CII ; IZA, New Delhi | 15 September
	85th Annual convention of the Indian Society of Soil Science	Indian Society of Soil Science | 16-19 November
Dr. S. S. Veena	Recent molecular approaches for plant disease diagnosis	S V Agricultural College, Tirupathi, Andhra Pradesh | 5 January
	Advances in Phytopathology	YSR Horticultural University | 6-7 January
	Robust plant protection strategies for sustainable agriculture	ICAR- NRRI, Cuttack | 19-20 January
	Unravelling the enigma in etiology and management of bud rot of oil palm	ICAR- IIOPR | 16 February
	Agriculture Knowledge Centre	Office of ADA, Attingal | 10 March
	Plant health and food security: Challenges and opportunities	ICAR-IARI, New Delhi | 25 -27 March
	Farmer- Scientist interface	KVK, Kumarakom | 05 June
	Fifth YR Sarma memorial lecture	IISR, Calicut | 15 June
	Coleman lecture 2021, VIII annual lecture	UAS, GKVK, Bangalore | 16 June
	Recent advances in sustainable integrated disease management in plantation crops	ICAR- IIOPR | 6-8 July
	IPS Platinum jubilee lecture series	IPS, New Delhi | 13, 21, 27 October, 25, 27 November
	Novel approaches for simplified detection of plant viruses and virus like pathogens	Plant Protection Association of India | 22 October
	Farm diagnostics of diseases in ornamental crops	ICAR- DFR, Pune | 30 November
	Global perspectives in crop protection for food security	Centre for Plant Protection Studies, TNAU | 8-10 December
Dr. C. Visalakshi Chandra	Awareness programme on germpalsm registration of horticultural crops	ICAR-IIHR | 1 October
All Scientists	Cassava viruses:Global status and strategies for disease control and prevention	ICAR-CTCRI, Thiruvananthapuram | 10 August

12.3 Education

Education programmes

The details are as follows (Table 9):

Table 9. Details of the different education programmes undertaken by ICAR-CTCRI

Mentors| Number of students		Division| Section, ICAR-CTCRI | Student discipline | University
Ph.D (Regular) In progress : 20		
Dr. Asha, K.I.	1	Crop Improvement | Botany | University of Kerala
Dr. Shirly Raichal Anil	1	
Dr. G. Byju	2	Crop Production | Environmental Science | University of Kerala
Dr. G. Suja	1	
Dr. K. Susan John	2	
Dr. C.A. Jayaprakas	5	Crop Protection| Biotechnology, Zoology| University of Kerala
Dr. M.L. Jeeva	3	
Dr. T. Makeshkumar	4	
Dr. A.N. Jyothi	1	Crop Utilization| Chemistry | University of Kerala
Ph.D (Internship)		
Dr. T. Makeshkumar	1	Crop Protection| Entomology | TNAU
M.Sc.| M. Tech.(Project work)| M.Sc. Integrated : 62		
Dr. V.B.S. Chauhan	1	Crop Improvement| Calicut University, MG University, Kerala; OUAT, Odisha; University of Kerala; CUSAT, Kerala; KAU, Kerala
Dr. Kalidas Pati	1	
Dr. A.V.V.Koundinya	3	
Dr. N. Krishna Radhika	1	
Dr. C. Mohan	2	
Dr. P. Murugesan	4	
Dr. K.M. Senthilkumar	3	
Dr. M.N. Sheela	2	

Dr. Shirly Raichal Anil	2	
Dr. Visalakshi Chandra	1	
Dr. G. Byju	3	Crop Production| MG University, Kerala; University of Kerala; Odisha Universty of Agriculture and Technology
Dr. Laxminarayana	2	
Dr. Sanket J More	2	
Dr. G. Suja	2	
Dr. J. Suresh Kumar	2	
Dr. K. Susan John	2	
Dr. E.R. Harish	1	Crop Protection| Periyar University, Tamil Nadu; Calicut University, Kerala; MG University, Kerala
Dr. C.A. Jayaprakas	5	
Dr. B.G. Sangeetha	4	
Dr. S.S. Veena	6	
Dr. A.N. Jyothi	3	Crop Utilization| University of Kerala ; FTRI, Konni, Kerala; MG University, Kerala; Calicut University, Kerala; Anna University, Tamil Nadu
Dr. T. Krishnakumar	2	
Dr. C. Pradeepika	2	
Dr. M.S. Sajeev	4	
Dr. J. Sreekumar	2	Extension and Social Sciences| Bharathiar University, Tamil Nadu

Student Internship (Under graduation): 99

Division| Number of students		Course| University
Crop Improvement	14	B.Sc. (Biotechnology, Botany) | Amritha School of Biotechnology, University of Kerala
Crop Production	10	B.Sc. (Agri.) | Dr. BSKKV, Dapoli, Maharashtra
Crop Utilization	68	B.E., B. Tech. (Agricultural Engineering, Food Technology) | University of Kerala; MG University; CUSAT; Kerala Technical University; TNAU; Chandigarh University; KAU
Extension and Social Sciences	7	B.Sc. (Agri.), B.Sc. (Hort.)| Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, U.P.

Professional Student Internship:14		
Extension and Social Sciences (Mentor: Dr. P. Prakash)	1	M.A (Social Entrepreneurship) |Madras School of Social Research, Tamil Nadu
Crop Utilisation (Mentor: Dr. T. Krishnakumar)	13	Online professional attachment training on Post harvest processing and value addition in food crops | TNAU
Rural Horticulture Work Experience Programme (RHWEP) : 03		
Extension and Social Sciences (Mentors: Dr. V. Ramesh, Dr. H. Kesava Kumar)	3	Improved technologies of tropical tuber crops | Dr. YSRHU, College of Horticulture, Andhra Pradesh | 2 August to 15 December

Ph.D Degree Awarded

Dr. Remya Ramesh

Environmental Science | University of Kerala

Thesis: GIS based site specific and environment friendly fertilization programmes for yams

Supervising Teacher: Dr. G. Byju

Dr. V.R. Vishnu

Chemistry | University of Kerala

Thesis: Studies on chemical structure and structure-activity relationship of anthocyanins in purple sweet potato and greater yam

Supervising Teacher: Dr. A.N. Jyothi

13.0 Azadi Ka Amrit Mahotsav Programmes

The Azadi Ka Amrit Mahotsav (AKAM) is an initiative of the Government of India to celebrate and commemorate 75 years of independence and the glorious history of its people, culture and achievements. In connection with AKAM, ICAR-CTCRI both HQ and RS organized a series of webinars, celebrated important national and international days | week and conducted iconic events.

13.1 Webinars

The details of webinars conducted are given Table 10:

Table 10. Details of webinars conducted

Theme	Chief guest | Speaker	Number of participants	Date
Scientific cultivation of cassava	Dr. K. Susan John	242	10 June
Quality planting material production in cassava	Dr. K. Sunilkumar	155	14 June
Quality planting material production in cassava (in Tamil)	Dr. R. Muthuraj	160	21 June
Production technology of elephant foot yam	Dr. S. Sunitha	70	28 June
Cassava based microfood processing enterprises	Chief guest: Mr. Rajeev G, General Manager, District Industries Centre (DIC), Thiruvananthapuram Dr. M.S. Sajeev	110	15 July
93 ICAR foundation day: Agro biodiversity for food security	Chief guest: Dr. C. George Thomas, Chairman, Kerala State Biodiversity Board	122	16 July
Tuber crops based microfood processing enterprises	Chief guest: Mr. Biju Kurian, General Manager, DIC, Kollam, Dr. M. S. Sajeev	115	19 July
58 Foundation Day celebrations of ICAR-CTCRI : Climate change adaptation approaches for sustainable water management	Chief guest: Shri. P. Prasad, Hon'ble Agriculture Minister, GoK; Prof. K. P. Sudheer, Executive Vice President, Kerala State Council for Science, Technology and Environment (KSCSTE), Kerala	145	23 July
Production technology of tuber crops (in Marathi)	Chief guest: Dr. S.D. Sawant, VC; Dr. P. Haladankar, Director of Research; Dr. Sanjay Bhave, Director of Extension; BSKKV, Dapoli, Dr. Sanket J. More	130	27 July
Cassava viruses: Global status and strategies for disease control and prevention (International)	Chief guest: Dr. T. Mohapatra, Secretary, DARE and DG, ICAR; Patron: Dr. A.K. Singh, DDG (HS), ICAR; Guest of Honour: Dr. V. Pandey, ADG (HS-I), ICAR; Dr. Sunil Chandra Dubey, ADG (Plant Protection & Bio safety); Dr. Stephan Winter, Head, Plant Virus Division, DSMZ, Germany, Dr. M. N. Sheela; Dr. T. Makeshkumar	290	12 August

Organic farming for self sufficiency in the homesteads of Kerala	Dr. S. Bhaskar, ADG (AAFCC); Dr. N. Ravisankar, National PI, AINP-OF	76	12 August
The tribal way of sustainable living: Lessons from Tuhet farms of Nicobar islands	Dr. Joseph John K., Principal Scientist, ICAR- NBPGR- RS Thrissur, Kerala	72	17 August
Tuber crops for food and nutrition	Dr. A.N. Jyothi	90	26 August
Cropping system involving tuber crops	Dr. G. Suja	53	3 September
Eat right eat smart	Dr. Suma Divakar, Department of Community Science, KAU	71	7 September
Nutri-cereals and their role on human health: Curtain Raiser of International Year of Millets 2023	Dr. Seeja Thomachan, Department of Community Science, KAU	200	17 September
Agri-incubation for sustainable entrepreneurship	Dr. M. S. Sajeev	85	8 October
Mahila Kisan Diwas: Improved technologies of tropical tuber crops	Dr. Susan John, K, Dr. Shirly Raichal Anil, Dr. C.A Jayaprakas, Dr. M. S. Sajeev	45	12 October
Mahila Kisan Diwas celebration, RS, Odisha	Dr. M. Nedunchezhiyan, Dr. Kalidas Pati, Dr. V.B.S. Chauhan, Dr. R. Arutselvan	50	15 October
Entrepreneurship development in tuber crops for value added products	Dr. M.S. Sajeev, Dr. S. Shanavas	56	18 October
Horizontal gene transfer among plant pathogens	Dr. V.G. Malathi, Former Principal Scientist, ICAR-IARI	70	25 October
Biofortification strategies in tropical tuber crops	Dr. Shirly Raichal Anil	52	29 October
Agriculture and environment: The citizen face-interacting with school children	Dr. Archana Raghavan Sathya, KAU	92	5 November
Pest and diseases of aroids and their management	Dr. S. S. Veena, Dr. E.R. Harish	32	18 November
Post harvest processing and value addition in cassava	Chief guest: Dr S. Ram Mohan, Deputy Director of Horticulture, East Godavari district, Andhra Pradesh	51	18 November
Diversifying cassava value chains for promoting cassava starch industries in India	Chief guest: Dr. T. Mohapatra, DG, ICAR & Secretary, DARE; Dr. A.K. Singh (DDG, HS); Dr. V. Pandey (ADG) (HS-1); Dr. M.S. Sajeev; Dr. A.N. Jyothi; Dr. G. Padmaja	120	22 November
National Agricultural Education day for school students	Dr. Gopakumar S, Director of Education, KAU	160	3 December
Extending technology business incubation support to farmer producer organizations	Chief guest: Dr. A.B. Sankar, GM, NABARD; Dr. K.S. Mahesh, Director, NABKISAN Ltd.; R. Saravanan Raj, Director, MANAGE	95	22 December
Post harvest management and value addition in cassava	Dr. T. Krishnakumar	130	29 December

13.2 Celebrations of important national and international days | week

National Science Day

The National Science Day (NSD) was celebrated on 26 February. Prof. Dr. G. M. Nair, President, Kerala Academy of Sciences and Advisor, Kerala Biotechnology Commission was the chief guest and he delivered a talk on the NSD theme 'Future of STI: Impacts on Education, Skills and Work'. It was attended by the scientists, staff and students of the Institute.

International Women's Day

The International Women's Day was celebrated on 8 March on the theme 'Women Leadership in Agriculture: Entrepreneurship, Equity and Empowerment'. The programme commenced with a march of all staff with placards displaying the theme, led by Dr. V. Ravi, Director (A). A separate facility was inaugurated for women cell along with an upgraded sick room.

Dr. M. L. Jeeva, Chairperson, Women cell, welcomed the audience during the meeting conducted as a part of the event. The Director (A) in his presidential address, talked about the important role of women in different spheres of society. A special talk was delivered by Dr. K. Vasuki, IAS, Director, DoAD & FW, GoK. The Chief Guest honoured women entrepreneurs of Kerala for popularising the tropical tuber crops technologies and its value addition. Six scientists and 3 students of ICAR-CTCRI were also honoured. Mrs. Sujatha Kumari, CTO delivered vote of thanks. A total of 180 participants attended (Fig. 172).

Fig. 172. View of the celebration

World Water Day

The Institute observed World Water Day on 22 March. Dr. C. George Thomas, Chairman, Kerala State Biodiversity Board was the chief guest and he delivered a talk on the theme: 'Valuing Water'. Dr. V. Ravi, Director (A) made the presidential address. Scientists, staff and students of the Institute and beneficiary farmers of SCSP programme under AINP-OF participated. Three progressive farmers were felicitated. Dr. S. Sunitha welcomed the gathering and Dr. Sanket J. More proposed vote of thanks (Fig. 173).

Fig. 173. View of the world water day celebration

International Yoga Day

The Seventh International Yoga Day (IYD) was celebrated on 5 June by arranging live yoga lessons on 'Equip yourself for the Covid-19 era' by Isha foundation and conducting competitions. To commemorate the 7th IYD, seven yoga asana challenge was organized to popularise yoga among staff members (Fig. 174).

Fig. 174. Webinar on International Yoga Day

ICAR Foundation Day

In connection with the celebration of India @ 75 Azadi Ka Amrit Mahotsav, a tree planting campaign was organized on 16 July on the occasion of the 93rd Foundation day of ICAR. The programme was named as *'HAR MED PAR PED'*. The planting was lead by Dr. M. N. Sheela, Director (A). Fruit trees and other plants were planted in the main campus (Fig. 175).

Fig. 175. View of the tree planting at HQ campus

ICAR-CTCRI Foundation Day

The ICAR- CTCRI celebrated its 58th Foundation Day on 23 July. Shri. P. Prasad, Hon'ble Minister, DoAD & FW, GoK, inaugurated the function (Fig. 176) which

Fig. 176. Inaugural address by the Hon'ble Agriculture Minister

was presided by Dr. M.N. Sheela, Director (A). In his inaugural address, the Hon'ble Minister reiterated the need to utilize the agricultural produce through value addition, need of enhanced storability and storage facility and the necessity to link the farmers with national and international markets. The MoU's for the commercialization of the Institute technologies were handed over to the licensees by the Hon'ble Minister. Awards for the best employees of ICAR-CTCRI as well as for the farmers were also distributed. Six farmers from different parts of the country were felicitated (Fig. 177) through online and he released eight publications. Dr. A.K. Singh, DDG (HS), ICAR delivered the keynote address. Dr. V.Pandey ADG (HS-1), ICAR, and Smt. Bindu S.R., Ward Councillor, offered special address. Prof. K. P. Sudheer, Executive Vice President, KSCSTE and Ex Officio Secretary, DST (GoK) delivered the foundation day lecture on 'Climate change adaptation approaches for sustainable water management'. About 150 people participated. Dr. Sheela Immanuel, welcomed the gathering. Dr. G. Byju proposed vote of thanks.

Fig. 177. Felicitation of farmers by the Hon'ble Minister

Gandhi Jayanthi

Gandhi Jayanthi was celebrated on 2 October at the Institute. The staff of the Institute assembled and paid floral tribute to the 'Father of the Nation'. Dr. M.N. Sheela Director (A) spoke on the occasion (Fig. 178).

Fig. 178. Celebration of Gandhi Jayanthi at HQ

Mahila Kisan Diwas

The Mahila Kisan Diwas was celebrated on 12 October at the Institute HQ. The inaugural programme was held under the Chairmanship of Dr. M.N Sheela, Director (A). Dr. K. Susan John, welcomed the gathering. A training programme was conducted for 45 farmers of Kizhuvilam and Ulloor panchayats of Thiruvananthapuram district. Dr. Sheela Immanuel gave introductory remarks, followed by keynote address by Dr. G. Byju. Dr. D. Jaganathan, Senior Scientist proposed vote of thanks. Planting materials of released varieties of cassava and sweet potato were distributed to these farmers. Four technical sessions on improved varieties of tuber crops, converting kitchen and farm waste to composts (Special National Swachhta Campaign), application of bio pesticides in crops and value added products from tuber crops were conducted. The participants were provided with training kits containing extension folders of the Institute technologies (Fig. 179).

Fig. 179. Celebration of Mahila Kisan Diwas at HQ

World Food Day

As a part of the World Food Day celebration of the Institute, a training on improved technologies and value addition in tuber crops was conducted at Elavumthitta, Mezhuveli, Pathanamthitta district, Kerala on 16 October. Shri. Chittayam Gopakumar, Hon'ble Deputy Speaker, Kerala Legislative Assembly inaugurated the training and exhibition and delivered the inaugural address. He emphasized the importance of tuber crops for food and nutritional security in the context of climate change. Dr. M. N. Sheela, Director (A), delivered special address. Smt. Pinky Sreedhar, President, Mezhuveli gramapanchayat, Shri. K. C. Rajagopalan, Former MLA, Aranmula, Smt. Anila Cheriyan, Vice President, Mezhuveli gramapanchayat, Shri. V. Vinod, Ward Member, Elavumthitta and Shri. Ramdeen, SAO, ICAR-CTCRI offered felicitations. Dr. G. Byju, welcomed the audience and Dr. D. Jaganathan, proposed vote of thanks. Technical sessions, scientists-farmers interface and exhibition of tuber crops were organized (Fig. 180).

Fig. 180. Inaugural address by Shri. Chittayam Gopakumar, Hon'ble Deputy Speaker, Kerala Legislative Assembly

At RS, Odisha, Dr. M. Nedunchezhiyan, Dr. Kalidas Pati, Dr. V.B.S. Chauhan and Dr. R. Arutselvan delivered lectures on agro techniques, nutrition and value addition in tuber crops. Around 50 farmers participated.

Vigilance Awareness Week

The Vigilance Awareness Week was observed from 26 October to 1 November with the theme 'Independent India @ 75: Self Reliance and Integrity'. The celebrations began by taking Integrity Pledge on 26 October under the leadership of Dr. M. N. Sheela, Director (A) and all the staff took part in the e-Pledge at Central Vigilance Commission website.

A vigilance awareness lecture was organized on 01 November at the Institute. Dr. M. N. Sheela, Director (A) in her welcome speech highlighted the importance of observing vigilance awareness week. Smt. R. Sreelekha, IPS, former DGP, GoK delivered the awareness lecture and shared her experience. Dr. J. Sreekumar, Chief Vigilance Officer, proposed vote of thanks (Fig. 181).

Fig. 181. Glimpses of the function

Constitution Day

The Constitution Day celebration by the Hon'ble President of India at the Central Hall of Parliament was live streamed at the Millennium hall of the Institute on 26 November. The staff, officials and students attended the event, addressed by Hon'ble Vice- President, Hon'ble Prime Minister, Hon'ble Speaker and other dignitaries and read the Preamble of our Constitution along with the Hon'ble President of India. As part of the celebration, Dr. M. L. Jeeva, Head (A), delivered an awareness lecture on the 'Constitution of India'. A total of 152 participants attended (Fig. 182).

The Constitution Day celebration was also organized at RS, Odisha. Dr. M. Nedunchezhiyan, Scientist (i/c),

Fig. 182. Reading the Preamble of Indian Constitution at HQ

Fig. 183. Reading the Preamble of Indian Constitution at RS

narrated the importance of our Constitution and was attended by all staff of the station (Fig. 183).

Tuber Crops Day

The ICAR- CTCRI and Indian Society for Root Crops (ISRC) jointly organized the 'Tuber Crops Day' on 17 November. Dr. M.S. Sajeev, welcomed the gathering. Dr. Jiju P. Alex, Member, Kerala State Planning Board in his inaugural address, pointed out the important role played by tuber crops in food security during the covid time. The chief guest, Smt. C.A. Latha, IAS, Secretary, DoAD & FW and Public Relations, GoK, in her address, appreciated the Institute for developing various technologies and its commercialization among different stakeholders. The meeting was presided by Dr. M.N. Sheela, Director (A) & Secretary, ISRC. Padmasree Smt. Lakshmikutty Amma and Shri. Reji Joseph, the recipient of Plant Genome Saviour Famer Award were honoured. The MoU's for the commercialization of technologies were handed over to the licensees. Special address was made by the awardees and Dr. V. Ramesh, proposed vote of thanks. A total of 155 participants attended (Fig. 184).

Fig. 184. Glimpse of the program

Communal Harmony Campaign Week & Flag Day

The Communal Harmony Campaign Week was observed during 19 - 25 November and Flag Day on 25 November to spread the message of communal harmony and national integration. Banners were displayed to create awareness about the importance of communal harmony among the public. Few competitions were conducted and prizes were distributed. Around 142 participants attended (Fig. 185). The staff and students of the Institute were distributed with communal harmony flags to support the campaign.

Fig. 185. View of the participants

National Agricultural Education Day

The ICAR-CTCRI in association with Mathrubhumi, Student Empowerment for Environmental Development (SEED), Kerala celebrated the Agricultural Education Day on 3 December. Dr. Sheela Immanuel, delivered the welcome address. Dr. M. N. Sheela, Director (A) in her presidential address, highlighted the importance of tuber crops technologies and the scope for students to become agri-preneurs. The chief guest, Dr. S. Gopakumar, Director of Education, KAU, delivered a talk on the topic 'Opportunities of higher education in agriculture'. Smt. Anjali Rajan, Unit Manager, Mathrubhuni, Smt. Nisha, Federal Bank and Shri. Pallipuram Jayakumar Nair, SEED Co-ordinator, Govt. U.P.S, Edavilakom offered felicitations. Dr. P. Prakash, co-ordinated the session and Dr. J. Sreekumar, proposed vote of thanks.

World Soil Day

The World Soil Day (WSD) was celebrated at ICAR-CTCRI-HQ on 4 December. Dr. M.N Sheela, Director (A) in her presidential address stressed the significance of soil in the prosperity of the family, society and the

Fig. 186. World soil day celebration at ICAR-CTCRI-HQ and RS, Odisha

nation as well. The WSD pledge was administered both in Malayalam and English. Dr. G. Byju made the special address. Director distributed soil health cards to MGMG farmers. Dr. A. K Sreelatha, Head, Rice Research Station, Vytilla, KAU and Mr. Haroon I., Agricultural Officer, Krishi Bhavan, Kizhuvilam, DoAD & FW, GoK made felicitation address. Dr. K. Susan John, Nodal Officer of the Soil Health Card (SHC) Programme welcomed the audience and Dr. V. Ramesh, Co-ordinator proposed vote of thanks. Dr. Sreelatha, gave the theme lecture on ‘Halt soil salinization, boost soil productivity’. A class on ‘*Mannarivu’* was given to the farmers by Dr. K. Susan John. The meeting was attended by 20 high school students, staff of the Govt. High School, Sreekariyam, farmers from Kizhuvilam and Pothencode panchayats.

At RS, Odisha, Shri. B. B. Das, Technical Officer welcomed the gathering and 40 farmers and farm women attended the programme. Introductory remark was made by Dr. K. Laxminarayana. Dr. M. Nedunchezhiyan, stressed the need to enhance the soil quality in an integrated manner for sustaining the crop productivity in degraded lands. Dr. Basudev Behera, former Professor & Head (Agronomy Division), OUAT in his guest lecture narrated the importance of eco-friendly agricultural practices for enhancing the soil fertility and to boost the crop productivity. Shri. Keshab Paikaray, Senior Technician proposed vote of thanks (Fig. 186).

Kisan Diwas

The Institute celebrated the Kisan Diwas (National Farmer’s day) on 23 December. Dr. M. N. Sheela, Director (A), presided the meeting. Shri. Kadakampally Surendran, Hon’ble MLA, Kazhakuttam Legistative Assembly, inaugurated the function. In his inaugural address, he said that, farmers are an integral part of the society and they are to be included in all the development programmes. Three tuber crops farmers were honoured (Fig. 187). Dr. Sheela Immanuel welcomed the gathering and Dr. G. Byju proposed vote of thanks. Insect proof net house,

Fig. 187. Honouring of tuber crop farmers by Hon’ble MLA

a facility for rapid multiplication of quality tuber crops planting materials was inaugurated by the Hon’ble MLA. He took part in the National Swachhta campaign held at the Institute. About 100 farmers attended the function.

At RS, Odisha more than 100 farmers from MGMG villages attended. Dr. M. Nedunchezhiyan welcomed the gathering and was followed by the address by the chief guest, Mrs. Sumina Pradhan, Sarpanch, Barang Block, Cuttack District. Technical sessions on tuber crops were conducted. Planting materials were distributed to the farmers (Fig. 188).

Fig. 188. Distribution of planting materials

13.3 Iconic Events

International Workshop on Root Architecture Imaging and Analysis for Tropical Tuber Crops (RAIATTC 2021)

The workshop was jointly organized by ICAR-CTCRI, Thiruvananthapuram, Kerala and Louisiana State University, Louisiana, U.S.A during 20-22 January through virtual mode. Dr. A. Villordon, Louisiana State University, Louisiana, U.S.A; Dr. Luis Duque, Penn State University, U.S.A.; Dr. Larry York, Noble Research Institute, U.S.A.; Dr. Patompong Saengwilai, Root Lab, Thailand; Dr. Michael Gomez Selvaraj, Alliance Bioversity International-CIAT, Colombia and Dr. Michael O. Adu, The University of Cape Coast, Ghana delivered the lectures. Thirty five scientists of the Institute and technical officers along with 5 professors from SAU's attended. Dr. Sanket J. More and Dr. J. Suresh Kumar co-ordinated the workshop and Dr. G. Byju and Dr. G. Suja were the mentors (Fig. 189).

Fig. 189. Glimpses of the workshop

Mass Awareness Campaign on Organic Farming: Kerala

The programme was jointly organized by AINP-OF Centre, ICAR-CTCRI, Thiruvananthapuram, Kerala and ICAR-IIFSR, Modipuram, U.P on 24 May in virtual mode. More than 1000 people attended the live program including farmers, students, scientists, and other stakeholders. Dr. N. Ravisankar, Principal Scientist & National PI, AINP-OF, Modipuram, gave the introductory remarks. Dr. G. Suja, PI, AINP-OF welcomed the participants. Dr. Peyush Punia, Director (i/c), ICAR-IIFSR, Modipuram, offered the felicitation address and Dr. V. Ravi, Director (A), delivered the special remarks. The Chief Guest, Dr. S. Bhaskar, ADG (AAFCC), ICAR, narrated the scope and potential of Kerala for scientific organic production

Fig. 190. View of the online meeting

of high value crops for export promotion. Dr. G. Suja; Dr. Jacob John, Dr. A. Sajeena, IFSRS, KAU; Dr. P. Subramanian, ICAR-CPCRI; and Shri. G.S. Ajithkumar, Life Concepts, Thiruvananthapuram, dealt the different sessions. Dr. G. Byju, proposed vote of thanks (Fig. 190).

H.H. Sree Visakham Thirunal Endowment Lecture

The lecture was organised on 25 May through virtual platform. The lecture is organised every year to commemorate and honour His Highness Sree Visakham Thirunal Rama Varma, who was instrumental in the development of tapioca cultivation in Travancore which helped the state to survive a massive famine. Keeping this in view, the ISRC has instituted an endowment lecture every year since 2010. The gathering was welcomed by Dr. M. N. Sheela, Secretary, ISRC followed by the presidential address by Dr. V. Ravi, Director (A). The guest of honour, Prince Adithya Varma from the Royal family of Travancore delivered the felicitation. Dr. Madhu Subramanian, Director of Research, KAU delivered the endowment lecture on 'Whither to Indian Agriculture? : A Research Perspective'. It was attended by 100 participants including dignitaries, staff and students. Dr. C. Visalakshi Chandra, Joint Secretary, ISRC proposed vote of thanks (Fig. 191).

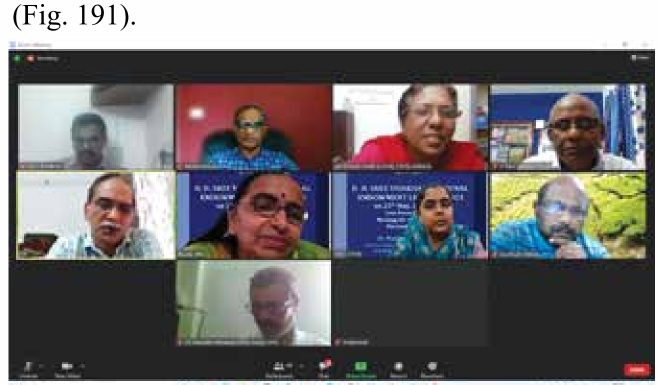


Fig. 191. View of the webinar

International Webinar on Cassava Viruses: Global Status and Strategies for Disease Control and Prevention

The international webinar was organised by ICAR-CTCRI, on 12 August to understand the status of the progress of CMD research globally. Dr. M.N. Sheela, Director (A) welcomed the audience. The webinar was inaugurated by Dr. Trilochan Mohapatra, Secretary, DARE & DG, ICAR who in his presidential address, stressed the need to design, define and implement strategies to prevent crop losses from viral diseases and stabilise production. Dr. A.K. Singh, DDG (HS), ICAR, in his inaugural speech, emphasised the importance of viral diseases and their impact on cassava in the wake of the changing climate. Dr. V. Pandey, ADG (HS-I), ICAR, Dr. Sunil Chandra Dubey ADG (Plant Protection & Biosafety) and Dr. Stephan Winter, Head, Plant Virus Division, DSMZ, Germany offered felicitations. The inaugural session ended with the vote of thanks by Dr. T. Makeshkumar, organising secretary. Ten presentations were made by experts from various national and international organisations on various aspects of cassava viruses and management and 290 participants from 35 countries attended (Fig. 192).

Fig. 192. View of the online program

Organic Farming for Self Sufficiency in the Homesteads of Kerala and Distribution of Organic Inputs and Agricultural Implements

The training was organized in hybrid mode at ICAR-CTCRI under AINP-OF (SCSP) on 12 August. It was inaugurated by Ms. Arya Rajendran S., Respected Mayor, Thiruvananthapuram Corporation. In her inaugural address, she stressed the need for promotion of tuber crops cultivation, in the urban home gardens and to create awareness on its importance as a health food. She

Fig. 193. Ms. Arya Rajendran S., Respected Mayor as chief guest

distributed organic inputs and agricultural implements to the beneficiary farmers. Dr. S. Bhaskar, ADG (AAFCC), Dr. M.N. Sheela, Director (A), ICAR-CTCRI, Dr. N. Ravisankar, National PI, AINP-OF, Ms. Bindu S.R., Cheruvaikal Ward Councillor, Dr. G. Suja, PI (AINP-OF) and Dr. G. Byju, Head (A) spoke on the occasion. Lectures on organic farming and integrated farming system were delivered by Dr. Jacob John, Professor and Head, Dr. A. Sajeena, Assistant Professor, IFSRS, KAU and Dr. G. Suja (Fig. 193).

Curtain Raiser of International Year of Millets 2023

A campaign on ‘Nutri garden and tree plantation’ was organized on 17 September. A web telecast of the national programme was arranged for the staff, farmers, girl students and other stakeholders. All the participants were provided with locally available millet based food and food products to create awareness about the benefit of millets. A tree planting campaign was organised which was inaugurated by Mrs. S.R. Bindu, the Cheruvikkal ward councillor by planting a mango sapling (Fig. 194). Around 3000 cuttings of tuber crop planting materials

Fig. 194. Tree planting at HQ

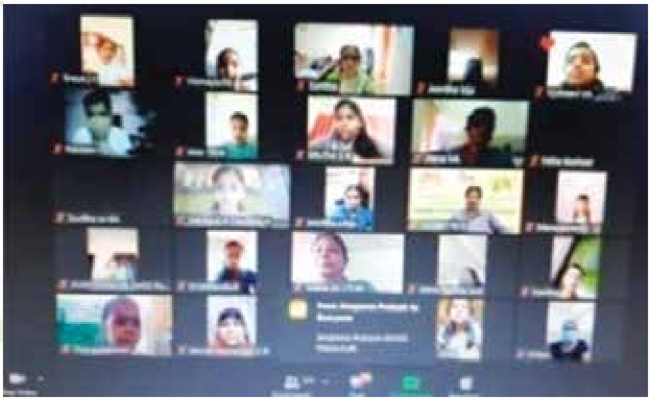


Fig. 195. View of the webinar at HQ

were distributed. An online webinar was organised for the adolescent girls to make awareness about the health benefits of millets. Dr. Sheela Immanuel, welcomed the gathering. Dr. M.N. Sheela, Director (A) briefed about the importance of millets in our daily life. A talk on 'Nutri-cereals and their role on human health' was delivered by Dr. Seeja Thomachan, KAU (Fig. 195). Nearly 200 girl students, teachers and other stakeholders participated. Dr. K.M. Senthilkumar proposed vote of thanks.

At RS, Odisha, the programme was conducted with Mr. B. Gangadhar, former Assistant Director of Agriculture, Telangana as the chief guest and Mr. Sushil Kumar Mohapatra, Science faculty, Syed Mumtaz Ali High School, Bhubaneswar as the Guest of Honour. The students of the school were distributed with value added millet products (Fig. 196, 197).

Fig. 196. Tree planting at RS, Odisha

Fig. 197. Distribution of millet products at RS, Odisha

Mass Campaign for Large Scale Use of Climate Resilient Technologies and Methods

A scientist-farmer interface on climate resilient varieties, technologies and practices of tropical tuber crops was organized on 28 September at HQ and RS. At HQ, the interface was inaugurated by Dr. A. K. Sherief, former CEO, VFPCK, GoK & former Professor, KAU. He emphasised the need for innovative technologies and practices to manage climate change related issues in farming and allied sectors. Dr. M. N. Sheela, Director (A), in her presidential address highlighted the importance of tropical tuber crops in the era of climate change. Dr. Sheela Immanuel, in her special address emphasised the importance of scientists-farmers interface. Dr. D. Jaganathan, welcomed the gathering and Dr. H. Kesava Kumar, proposed vote of thanks.

The live telecast of the Hon'ble Prime Minister's programme was arranged for the staff and farmers through videoconferencing in which the Hon'ble PM dedicated 35 crop varieties and the National Institute for Biotic Stress Management, Raipur, Chhattisgarh to the nation. The Hon'ble Prime Minister interacted with the farmers across the country (Fig. 198).

Fig. 198. Audience viewing the live telecast

The technical sessions on 'Climate resilient varieties of tropical tuber crops' by Dr. Shirly Raichal Anil and on 'Improved technologies and practices of tropical tuber crops' by Dr. K. Susan John, were held, followed by discussions on tuber crops. Around 110 people attended.

Programme on Natural Farming

An one day training on natural farming practices in tropical tuber crops was organized on 16 December. Dr. M. N. Sheela, Director (A), delivered welcome address. Dr. G. Suja, described the significance of natural farming in the present agricultural scenario and Ms. S.J. Harishma,

Fig. 199. Audience viewing the live telecast at HQ

Fig. 200. Live telecast of the speech of Hon'ble Prime Minister at RS, Odisha

handled classes on natural farming practices in tuber crops followed by live streaming addressed by Hon'ble Prime Minister. There was detailed interactions and was attended by 285 participants (Fig. 199).

At RS, Odisha, during the programme, introductory remark was made by Dr. K. Laxminarayana and he narrated the importance of natural and organic farming. Dr. M. Nedunchezhiyan, Head (i/c) stressed the need to enhance the soil quality by application of organic resources. The live telecast of the programme addressed by the Hon'ble Prime Minister and other dignitaries were viewed by the farmers (Fig. 200). Planting materials of orange fleshed sweet potato vines and tubers of *Colocasia* were distributed.

Interaction of DG with ICAR Scientists

An interactive session of all the scientists of ICAR with Secretary, DARE & DG, ICAR was held on 4 January. Discussions were held on emerging research needs in agriculture and allied fields and to explore its possibilities for implementation for the benefit of farmers and other stakeholders. It was attended by all the scientists of the Institute. A meeting was also convened by DG for juniour level scientists on 8 December and it was attended by all the concerned scientists of the Institute. The DG emphasized the scientists to explore key research areas keeping in view of the challenges ahead.

14.0 Outreach Programmes

14.1 Exhibitions

The ICAR-CTCRI arranged exhibitions for the benefit of different stakeholders. The exhibitions were conducted as a part of the seminar cum trainings on ‘Improved technologies of tuber crops for increasing farm income’. Following are the details of the exhibitions conducted (Fig. 201).

Kerala

ICAR-KVK, Thavanoor, Malappuram	: 9 February
Kondotty, Malappuram	: 10 February
Vadakkekara panchayat, Ernakulam	: 12 February
Puliyoor panchayat, Alappuzha	: 4 March
Elavumthitta, Pathanamthitta	: 16 October
Parassala, Thiruvananthapuram	: 22 October
Perumkadavila, Thiruvananthapuram	: 28 December
Adoor, Pathanamthitta	: 20 November
VAIGA 2021, Thrissur	: 10-14 February

Andhra Pradesh

Peddapuram, East Godavari district	: 10 March, 24 November

Tamil Nadu

P. Pothukudi, Tirunelveli	: 27 January
Keelapuliyur, Tenkasi	: 29 January
Thalaivasal, Salem	: 18 February
Kandarvakottai, Pudukottai	: 19 February

Odisha

Agri Vision 2021, Bhubaneswar	: 14-16 March
XV Agricultural Science Congress, BHU, Varanasi	: 13-16 November.

Fig. 201. Exhibitions organized by ICAR-CTCRI, HQ & RS

14.2 Exposure Visit

The Institute HQ and RS were visited by 575 farmers, 96 students and 23 officials from all over the nation (Fig. 202) for getting information on the different activities of the Institute as well as for training primarily on varieties, production, protection, processing and enterpreneurship development of tropical tuber crops (Fig. 203).

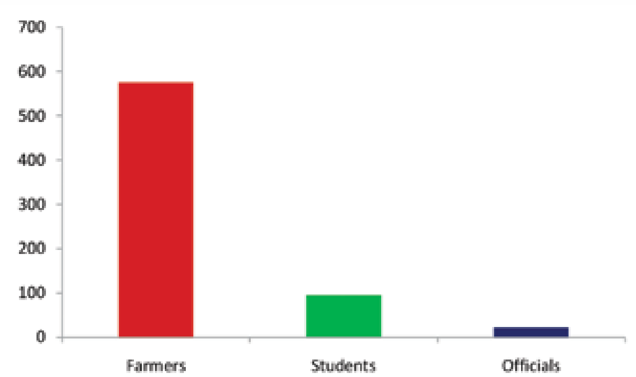


Fig. 202. Exposure visit of different stakeholders at ICAR-CTCRI (HQ & RS)

Fig. 203. Glimpses of the visit of farmers and handling classes at ICAR-CTCRI

14.3 Resource Persons in Training Programmes

Scientists of the Institute had served as resource persons for handling more than 125 classes on different aspects of tuber crops *viz*., varieties, production, protection, processing, value addition, entrepreneurship development organized by the Institute as well as by different organizations *viz*., State Agricultural Departments, KVK's, NGO's, VFPCK, SAU's, DIC's both on campus and off campus.

14.4 Tuber Crops Popularisation

Sweet potato popularization through Madhuragramam

Bhu Krishna, Sree Varun, Gowri and Sree Arun varieties of sweet potato were supplied to farm families and Kudumbasree groups of Vadakkekara panchayat, Ernakulam and was harvested on 11 February 2021. Mrs. Reshmi Anilkumar, President, Vadakkekara panchayat inaugurated the harvest festival. Dr. G. Byju, Dr. D. Jaganathan, Sri. V.R. Sasankan and Sri. D.T. Rejin participated and was attended by sixty two beneficiaries (Fig. 204).

Fig. 204. Harvest festival at Madhuragramam

Establishment of tuber crops museum at educational institutions

Christ Nagar School, Kowdiar & Attingal, Thiruvananthapuram district

To create awareness among school children on nutrition garden, sweet potato and Chinese potato varieties were supplied and a planting festival was conducted on 17 August at Christ Nagar Central School, Kowdiar and 04 October 2021 at Attingal. Fr. Bino Pattrkalam, Principal, Christ Nagar Central School and Mrs. S. Preena, faculty, coordinated the establishment of the tuber crops museum at Christ Nagar School, Kowdiar. Fr. Xavier Ampatt, Principal, Christ Nagar Central School, Attingal and other faculties and students participated in the establishment of a tuber crops museum at their campus. Dr. G. Byju and Sri. D.T. Rejin explained the agro techniques (Fig. 205).

Fig. 205. Planting festival at Christ Nagar school, Attingal, Thiruvananthapuram

14.5 Agro Advisories

The farm advisory visits undertaken by ICAR-CTCRI scientists are mainly on diagnosing and giving recommendations for diseases like mealy bugs in cassava, collar rot of elephant foot yam, tuber and stem rot in cassava and nematode infestation in Chinese potato in Kerala and Tamil Nadu. Moreover, diagnosis of nutritional disorders and their correction too were advocated. In addition to this, need based mobile advisories on agro techniques including soil, nutrient, water and weed management were given. Field problems on tuber crops as well as general tuber crops problems were attended on regular basis. During this year, speical emphazis was given for around 50 field problems mainly in Kerala, Tamil Nadu, Andhra Pradesh and Odisha (Fig. 206). Mobile advisories to the tune of more than 300 was given for the queries asked by farmers both independently and on team basis after proper multidisciplinary team discussion. The technical leaflets, pamphlets and folders prepared in different languages too were used for providing remedies for the field problems faced by the farmers.


Fig. 206. Farm advisory visit at Salem, Tamil Nadu

14.6 Analytical Services

Major services rendered for research, academics & industries

The ICAR- CTCRI with its full fledged and well equipped laboratory facility has been extending analytical and equipment usage services for students, industry and other R&D organizations. The analytical services on payment basis includes soil chemical properties, plant nutrient contents, biochemical parameters of tubers/ corms of all tuber crops. In addition, the equipment usage facility is extended for instruments *viz.,* ELISA reader, Gel documentation, Thermal cycler, Nanodrop, Real time PCR, Atomic absorption spectrophotometer, N analyser (Digestion+ Distillation), Portable leaf area meter, Automated soil CO_2 flux system (Model LI-COR 8100 A), Genetic analyzer, NIR and Inverted microscope.

15.0 Official Language Implementation Committee (OLIC)

The OLIC conducted meeting on every quarter (23 March, 30 June, 30 September and 23 December) under the chairmanship of the Institute Director (A) through online and offline modes. Various points related to OLIC were discussed and the decisions taken were implemented.

- Purchasing of Hindi magazines/ books etc. is in process by the Library committee.
- Necessary entries are made in the service records of awardees of various Hindi competitions by the Establishment section

Hindi Fornight Celebrations

Valedictory function of the Hindi Fortnight Celebrations 2020 cum inauguration of Hindi Fortnight Celebration 2021 was conducted on 14 September. Incentive Scheme Award 2021 was bagged by Shri. Padmakumar, M., for maximum work carried out in Hindi.

The Hindi Fortnight was celebrated during 14-28 September 2021 at RS, Odisha. Various competitions were held for the staff and awareness was created to use Hindi language for official works (Fig. 207).

Fig. 207. Hindi fortnight celebrations

All quarterly performance reports were regularly sent to the Council for compliances.

राजभाषा कार्यान्वयन समिति (रा.भा.का.स.)

रा.भा.का.स. ने प्रत्येक तिमाही (23 मार्च, 30 जून, 30 सितंबर और 23 दिसंबर) को संस्थान निदेशक (ए) की अध्यक्षता में ऑनलाइन और ऑफलाइन मोड के माध्यम से बैठक कि आयोजना की। रा.भा.का.स. से संबंधित विभिन्न बिंदुओं पर चर्चा की गई और लिए गए निर्णयों को लागू किया गया।

- पुस्तकालय समिति द्वारा हिन्दी पत्रिकाओं/पुस्तकों आदि की खरीद की प्रक्रिया चल रही है।
- स्थापना अनुभाग द्वारा विभिन्न हिंदी प्रतियोगिताओं के पुरस्कार विजेताओं के सेवा अभिलेखों में आवश्यक प्रविष्टियां की जाती हैं

हिंदी पखवाड़ा समारोह 2020 का समापन समारोह हिंदी पखवाड़ा समारोह 2021 का उद्घाटन 14 सितंबर 2021 को आयोजित किया गया था। सहायक निदेशक (हिंदी) के पद को भरने के प्रयास जारी हैं। प्रोत्साहन योजना पुरस्कार 2021 को हिंदी में किए गए अधिकतम कार्य के लिए श्री पद्मकुमार एम द्वारा प्राप्त किया गया था। उन्हें हिंदी में आधिकारिक कार्य करने के लिए TOLIC से भी पुरस्कार मिला। सभी त्रैमासिक प्रगति रिपोर्ट उनके अनुपालन के लिए परिषद को भेजी गई थी।

क्षेत्रीय स्टेशन, उड़ीसा में 14-28 सितंबर के दौरान हिंदी पखवाड़ा मनाया गया। कर्मचारियों के लिए विभिन्न प्रतियोगिताएं आयोजित की गईं और आधिकारिक कार्यों के लिए हिंदी भाषा के उपयोग के लिए जागरूकता पैदा की गई।

16.0 R & D Facilitating Units | Committees

Farm

The ICAR-CTCRI-HQ campus is spread in five blocks with an area of 112 acres. The Institute building is in Block I and the research experiments are laid out in Block I, II and III and the planting material production is in other blocks. The thrust during this year was to bring more experimental fields under irrigation, farm mechanization and cost reduction of farm operations, repair and maintenance of farm vehicles/implements, expanding more area under cultivation especially for planting material production. During this year, the allocation of farm resources were made online. Initiated sale of portray raised minisett planting material of tuber crops (yams and cassava).

Procurement of mini tractor (John Deere 28 HP), rotavator blades (42 numbers), 5000 L tractor drawn water tank, construction of storage shed for keeping farm produce, farm implements, land development in block III and IV and barbed fencing were undertaken during this year.

The RS, Odisha farm has an area of 49.8 acres with six blocks. Approximately 8.45 acres of land is utilized for research purpose and 24.23 acres for the production of quality planting materials (Fig. 208).

Fig. 208. View of the ICAR-CTCRI-HQ & RS farm offices

A total revenue of ₹ 35 lakhs was generated through sale of planting materials and farm produce during this year.

Library

The Library is providing excellent information support services to the research and training activities of the Institute (Fig. 209). Two Ph.D theses, five M.Sc. theses, three B.Sc. theses and one ICAR-publication

Fig. 209. View of the ICAR-CTCRI-HQ Library

(Hand book of Agricultural Extension, 2020) were added in the accession register of the library. A total of 15450 catalogue data migrated from Alice for windows library management software to Koha. In addition, the following services are also made available to the users of the library.

Circulation of books

A total of 90 books were issued to the users on loan.

CeRA

A total of 137 users utilized various CeRA services like full text/abstracts views, inter library loan (ILL) request and table of contents browsing with total hits of 3630.

Ready-reference service

More than 345 users availed the facility of reference services by using reference documents.

Reading and reference facilities to the research scholars

Services were extended to graduate, post graduate students, Ph.D and PDF scholars from Colleges and Universities, who undertake their research works under the guidance of the Institute scientists. They were given necessary guidance in the use of reference resources, jgateplus.com

Photocopying

Photocopying service was provided to the Institute staff and other library users on official/payment basis. During this period, 5746 copies were provided against indents.

Agriculture Knowledge Management Unit (AKMU)

The AKMU was established in an area of 1400 sq.ft. with 17 work stations with centralized facilities for printing and scanning (Fig. 210). It also houses a centralized server room and a power room with centralized generator facility. The ICAR-CTCRI- AKMU is one of the nodal point of National Knowledge Network of India (NKN) for effective sharing of scientific resources. A high speed 100 mbps fiber optic connectivity each for LAN and another 100 mbps fibre optic connectivity from BSNL to supplement/ backup is established. The ICAR- CTCRI home page can be accessed at http://www.ctcri.org

Fig. 210. View of the AKMU of ICAR-CTCRI-HQ

Museum

The Institute museum depicts the different research activities as well as the display of the different value added products from tuber crops. The museum is regularly visited by students and farmers which help them to gain first hand information on the recent research and developments of the Institute (Fig. 211).

Fig. 211. Students visiting the museum at ICAR-CTCRI-HQ

Priority setting, Monitoring and Evaluation (PME) Cell

Priority setting, Monitoring and Evaluation efforts are essential in the management of agricultural research and development. The PME Cell at ICAR- CTCRI is functional since 2000. The main activities are to coordinate and synthesize the recommendations of QRT, RAC, IRC, vision documents of the Institute and ICAR, to recommend research priorities of the Institution for short listing priority researchable problems across mandate crop(s)/Divisions/programmes at Institution level (priority setting), maintenance of scientific/technical files including research project files, consultancy/NAIP project files, annual monitoring and evaluation of the on going research projects, capacity building of research managers through training programmes, updation of database for projects, publications, preparation of scientific documents and reporting to SMD / Council.

Science Forum

Five science forum meetings were conducted. Dr. C. Pradeepika, presented the deputation report of her Ph.D work entitled 'Functional bioactive compounds from sweet potato tubers for human health benefits' done at North Dakota State University, Fargo, North Dakota state, USA on 18 January followed by a presentation on ICAR guidelines for promoting the brand 'ICAR' by Dr. P. Sethuraman Sivakumar. On 29 January, Mr. A. Madhu, ACTO, conducted an interactive session on 'Getting acquainted with e-office'. Ms. Reshma Maria Joseph, Ph.D student delivered a talk on 'Rhythm of life-plant circadian clock' on 24 November. In addition, the scientist-technical meet is conducted every month, which provides a platform for interaction of the staff of the Institute with Director.

Institute Research Council

The 47th Annual Institute Research Council (IRC) was held from 4-6 May 2021 through online mode under the Chairmanship of Dr. V. Ravi, Director (A). All the scientists from HQ and RS attended. Dr. C. Mohan, member secretary, IRC welcomed the chairman and members of IRC. In his inaugural address, Dr. V. Ravi congratulated all the scientists for their scientific contributions. Dr. C. Mohan, presented the Action Taken Report (ATR) of the 46th IRC proceedings. Dr. G. Suja, member secretary, RAC-VIII, presented the RAC recommendations. The Heads of Divisions|Sections presented the overall achievements. The achievements of eight Institute projects and the activities completed in the previous year (2020-2021) were presented by the respective activity leaders, which included 42 activities under five Divisions/Sections. The meeting concluded with the plenary session on the third day in which Dr. V. Pandey ADG (HS-1) suggested to have inter institutional collaborations for advanced research and for developing value added products (Fig. 212).

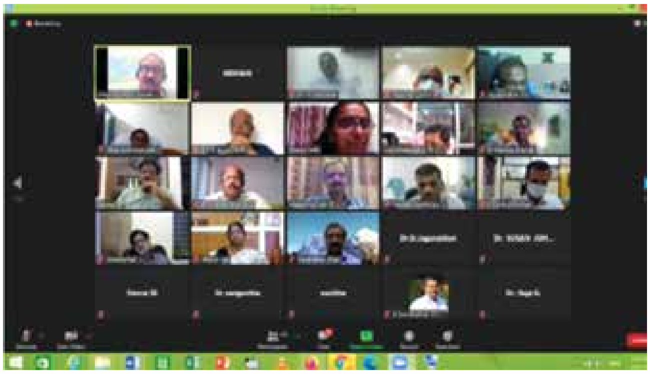


Fig. 212. View of the 47th IRC meeting

Dr. V. Ravi, Director (A) and Chairman, 47th IRC, thanked the DDG and ADG for their constant support and guidance for the Institute activities. The meeting ended with vote of thanks by Dr. C. Mohan.

Research Advisory Committee (RAC)

The IX RAC of the Institute was constituted with effect from 11 July 2021 with the following experts.

Chairman: Dr. N.K. Krishna Kumar, Former DDG (Hort. Sciences)

Members
Dr. S.K. Pandey, Former Director, ICAR-CPRI, Shimla
Dr. K. Umamaheswaran, Former Professor, KAU
Dr. Sanjaya Kumar Dash, Dean, College of Agricultural Engineering & Technology, OUAT, Bhubaneswar
Dr. P. M. Govindakrishnan, Former PC, ICAR-CPRI, Shimla
Dr. H. Philip, Former Director (Extension), TNAU
Dr. Vikramditya Pandey, ADG (HS-I), ICAR
Dr. M.N. Sheela, Director (Acting), ICAR-CTCRI
Member Secretary : Dr. P. Murugesan, Principal Scientist, ICAR-CTCRI

Institute Management Committee (IMC)

The present IMC was constituted with effect from 28 August 2018 with Director as Chairman, external members and SAO as the member secretary. The Committee meets at regular intervals and discusses the research achievements of the Institute as well as the significant management aspects related to research, administration and finance.

Institute NABL Accreditation Committee

The National Accreditation Board for Testing and Calibration of Laboratories (NABL) is a constituent board of the Quality Council of India. The Institute has constituted the Institute NABL Accreditation Committee for implementation of NABL accreditation. The registration of the Institute with NABL and accreditation is under way.

17.0 Awards & Recognitions

17.1 Awards

Krishi Vigyan Award 2020

Dr. V. S. Santhosh Mithra received the Krishi Vigyan Award 2020, Government of Kerala during 2021 for the smart farming initiatives in tuber crops (Fig. 213).

Fig. 213. Dr. V.S. Santhosh Mithra, receiving award from the Hon'ble Agriculture Minister, GoK

Lifetime Achievement Award

Dr. M. Nedunchezhiyan**,** received Dr. Sabuj Sahoo Memorial Lifetime Achievement Award during the International conference on 'Plant Science in Post Genomics Era', 14-16 March 2021 at Institute of Life Sciences, Bhubaneswar, Odisha, organized by Agrivision 2021 and Evation Business Solutions (P) Ltd., Odisha.

Best Oral Presentation Award

Drs. S.S. Veena, M. L. Jeeva and A. Asha Devi received the second best award for the paper titled 'Eco-conscious approaches to manage fungal diseases of aroids' in the National e-Conference on 'Plant Health and Food Security: Challenges and Opportunities', 25-27 March, ICAR-IARI, New Delhi

Best Poster Presentation Awards

- Dr. A.V.V. Koundinya received the award for the research paper titled 'Phenotypic and genotypic screening of cassava genotypes for drought tolerance' in the International Horticulture Conference (Next Gen Hort 2021), 16 -19 September, TNAU, Coimbatore.
- Drs. P. Murugesan, M. N. Sheela, R. Arulmoorthy, P. R. Ranaganayaki and Dr. V. Pandey received the award for the research paper titled 'Standardization of breeder seed quality of yam bean (*Pachyrhizus erosus*): An underutilized tuber yielding legume' in the 9th Indian Horticulture Congress, 18-21 November, Chandra Shekar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh.

Best AICRP- TC Centre Award

The ICAR-CTCRI, RS, Odisha (Scientists involved: Drs. M. Nedunchezhiyan and Kalidas Pati) received the Best Centre Award-2021 among the 21 AICRP- TC centres all over India.

Best Research Award

Dr. Vijaya Bahadur Singh Chauhan received the award instituted by Science Father, International Research Awards on New Science Inventions (NESIN 2021) on 3 November.

17.2 Recognitions

Dr. A. Asha Devi

Major advisor: One B.Sc.-M.Sc. (Integrated Biotechnology) student, KAU
Expert panel member: Evaluation of research papers and posters, 33rd Kerala Science Congress
External expert: M.Sc.(Genetics and Plant Breeding, CSS 3) examination, University of Kerala
Resource person: World Food Day celebrations, Lecole Chempaka, Kallayam, Thiruvananthapuram
External examiner: M.Sc.; B.Sc.-M.Sc. (Integrated Biotechnology) examination, KAU

Dr. K.I. Asha

Major advisor: One B.Sc.-M.Sc. (Integrated Biotechnology) student, KAU
Member: Advisory board, one B.Sc.-M.Sc. (Integrated Biotechnology) student, KAU
Subject expert: Evaluation of contest presentations in International conference on 'New Horizons in Plant Sciences'
Expert panel member: Evaluation of technical papers, 33rd Kerala Science Congress
Evaluator: Young Innovators Programme, Kerala Development and Innovation Strategic Council (KDISC)

Dr. G. Byju

Mentor: International Workshop on 'Root architecture imaging and analysis for tropical tuber crops'
Member: 39th Zonal Research & Extension Advisory Council, RARS, KAU
Reviewer: Agricultural Systems; International Journal of Plant Production; Crop and Pasture Science; Data in Brief; Environmental Challenges; Heliyon; Archives in Agronomy and Soil Science; Journal of Environmental Biology
Member: Advisory Committee, one Ph.D student, KAU
External examiner: Four Ph.D.students, KAU; one M.Sc.(Ag.) student, UAS
Mentor: One woman scientist, WOS-A Scheme, DST, Govt. of India

Dr. V.B.S. Chauhan

Invited expert: Orientation lecture, staff of NGO, PRADAN, Jharkhand

Dr. E. R. Harish

Executive committee member: Association for Advancement of Entomology
Reviewer: Springer Nature

Dr. D. Jaganathan

Member: State Level Farmers' Award Committee 2021, Govt. of Kerala
Expert: Scientific Advisory Committee, KVK's, Kottayam, Thiruvananthapuram, Ernakulam
External examiner: Qualifying viva voce, 3 Ph.D. students, KAU
Resource person: PGDAEM, MANAGE
Reviewer: Journal of Agricultural Economics and Rural Development; Journal of Global Agriculture and Ecology; Journal of Economics and Development

Dr. C. A. Jayaprakas

Invited speaker: Kerala Agriculture University Senior Scientist Association; Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram; Department of Zoology, NSS College, Nilamel; Department of Zoology, University of Calicut; Indian Association of Life Skills Education, Mahatma Gandhi University, Kottayam; National Institute of Food Technology, Entrepreneurship and Management, Thanjavur; Indian Society of Analytical Scientists

Dr. M.L. Jeeva

Invited speaker: ICAR-NCIPM, New Delhi

External examiner: One Ph.D; two MSc. students, KAU

Evaluator: Young Innovators Programme, KDISC

Dr. A. N. Jyothi

Evaluator: Young Innovators Programme, KDISC

Member: Technical committee, State Pesticide Testing Laboratory, Department of Agriculture, Govt. of Kerala

Subject expert: Pre-submission seminar of one Ph.D. student, Department of Chemistry, University of Kerala

Chairman and external examiner: Board of Adjudicators, one Ph.D. student, University of Calicut

Member: Advisory committee, two Ph.D. students, KAU; one Ph.D. student, SRMIST, Tamil Nadu

Dr. Kalidas Pati

Expert member: Task force on 'Production and productivity of vegetables in Odisha'.

Dr. H. Kesava Kumar

Member: Advisory committee, one M.Sc. (Ag.) student, KAU

External examiner: One M.Sc. (Ag.) student, TNAU

Member: Working group, Open Access India 2021

Dr. A.V.V. Koundinya

Invited speaker: Webinar on seed production of vegetable crops, College of Horticulture and Forestry, CAU, Arunachal Pradesh

Dr. T. Krishnakumar

Member: Technical committee, Bureau of Indian Standards (BIS), New Delhi

Question paper setter: TNAU; TANUVAS; APJ Abdul Kalam Technical University, Thiruvananthapuram

Subject expert: National Horticulture Fair 2021, ICAR-IIHR

External examiner: One Ph.D student, Periyar University; one M.Tech student, TNAU

Reviewer: Journal of Root Crops; Current Journal of Applied Science &Technology

Dr. N. Krishna Radhika

Member: Advisory board, two B. Sc.-M.Sc .(Integrated Biotechnology) students, KAU

Dr. K. Laxminarayana

Member: Technical committee, evaluation of project proposals of RKVY

External examiner: One Ph.D. student, PJTSAU, Hyderabad

Reviewer: Communications in Soil Science and Plant Analysis; Pedosphere; Archives of Agronomy and Soil Science

Dr. P. Murugesan

Technical member: Accreditation and rating of nursery, NHB

Co-chairman and invited speaker: Horticulture, plantation crops and grassland ecosystems, International Symposium on Coastal Agriculture

Member: DPC, CAS (Scientists), ICAR-IISR, Kozhikode

Expert: Orientation lecture, staff of NGO, PRADAN, Jharkhand

Dr. C. Pradeepika

Convenor: Kerala Agro Food Pro 2021, Department of Industries and Commerce (DIC), GoK

Dr. P. Prakash

Invited speaker: Online national certificate course, CAAST-CSAWM, MPKV, Maharashtra

Reviewer: Indian Journal of Economics and Development; 31st International Conference of Agricultural Economists

Recipient: Financial grants ($275) for participation in the International Conference of Agricultural Economists

Dr. V. Ramesh

External examiner: One Ph.D student, KAU; one M.Sc student, TNAU

Dr. M. S. Sajeev

Member: Expert sub group (Agriculture and Cooperation), Formulation of 14th Five year plan, GoK

Expert member: Appraisal committee, PMFME scheme, GoI

Master trainer: One District One Product (ODOP), PMFME Scheme, GoI

Expert member: District level committee, ODOP, DIC, Kollam

Moderator: Kerala Bureau of Industrial Promotion seminar, DIC, GoK

Member: Advisory committee, one M.Sc. (Food Processing) student, KAU

Member: Board of studies, B. Tech. (Food Engineering), KCAET, KAU

Examiner: M. Tech./Ph. D. student, TNAU; UAS Raichur; IIT Kharagpur; KAU; IIFPT, Thanjavur

Expert: SRF/Project fellow selection committee, CSIR-NIIST

Dr. B.G. Sangeetha

Member: Advisory committee, one M.Sc. Student, KAU

Dr. Sanket J. More

Member: Peer review board, Multilogic in Science

Reviewer: International Journal of Applied Life Sciences; Colombian Journal of Horticultural Sciences; International Journal of Plant and Soil Sciences; Asian Journal of Plant and Soil Sciences; Journal of Horticulture and Forestry

Dr. V. S. Santhosh Mithra

Expert: Career Advancement Scheme (CAS) of teachers, KAU

Member: Advisory committee, one Ph.D., two M.Sc. students, KAU

Invited Speaker: Regional Seminar, Indian Society of Agricultural Economics, KAU; International Potato Conference; Seminar on smart farming, KAU

Dr. K.M. Senthilkumar

Reviewer: Frontiers in Plant Science; Plant Molecular Biology Reporter; Molecular Genetics and Genomics

Invited Speaker: National seminar on ‘Integrative Biology’, University of Kerala

Dr. P. Sethuraman Sivakumar

Invited Speaker: Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar; MANAGE, Hyderabad; Zonal Workshop, KVK ATARI, Bengaluru; ICAR-CIWA, Bhubaneswar; NAARM, Hyderabad; Chloropy Technologies Pvt. Ltd., Hyderabad; RATTC, Thiruvananthapuram

Evaluator: Young Innovators Program, KDISC

Resource person: PGDAEM, MANAGE

Expert member: Review of research proposals, 11 M.Sc., 5 Ph.D. (Agricultural Extension), 4 M.Sc., 2 Ph.D. (Home Science Extension), PJTSAU, Hyderabad

External examiner: Three M.Sc. (Ag.) students, KAU

Advisory board member: Nature Science

Reviewer: Computers for Human Behavior; Journal of Agricultural Education and Extension

Dr. Sheela Immanuel

External examiner: Two Ph.D., two M.F.Sc. students, ICAR-CIFE, Mumbai

Resource person: PGDAEM-MANAGE

Reviewer: Journal of Marine Biological Association; Indian Journal of Fisheries, Fishery Technology

Evaluator: Young Innovators Programme, KDISC

Dr. M.N. Sheela

External examiner: One Ph.D. student, OUAT; one M.Sc. student, KAU; one B.Sc-M.Sc. (Integrated Biotechnology) student, KAU; one M.Sc.(Hort.), CAU, Manipur

Member: Expert Sub Group, Formulation of 14th Five year plan, GoK

External expert: Review of R & D, Division of Crop Improvement, Rubber Board, Kottayam, Kerala

Chairman: Assessment committee, promotion of technical personnel, ICAR-CPCRI, Kasargod

Reviewer: Annals of Agricultural Science; BMC; Philippine Journal of Science

Member: Institute Management Committees, ICAR-CPRI; ICAR-IIHR; ICAR-Directorate of Cashew Research

Principal investigator: ICAR-CIAT- Bioversity International Collaborative Work plan

Dr. Shirly Raichal Anil

Invited speaker and guest: Inauguration, Science club (2020-2021), Department of Botany, All Saints College, Thiruvananthapuram, Vanamahotsav celebrations, Chinmaya Vidyalaya, Kollam

Reviewer: Genetic Resources and Crop Evolution; The Nucleus; Indian Journal of Plant Genetic Resources

Invited judge: Poster presentations, International Seminar on New Horizons in Plant Sciences, Department of Botany, University of Kerala

External examiner: M.Sc. (Genetics and Plant Breeding, CSS 2 & CSS 4) examination, Department of Botany, University of Kerala

Dr. J. Sreekumar

Invited speaker: 7th International Conference on Statistics for 21st Century, Department of Statistics, University of Kerala

Member: Editorial board, Journal of Tropical Agriculture, KAU

Member: State Level Farmers Award Committee 2021, GoK

External examiner: Two Ph.D. students, ICAR-IARI

Member: Advisory Committee, two M.Sc. students, KAU

Dr. G. Suja

Subject expert: Annual Action Plan Meeting, KVKs

External examiner: Eight Ph.D. students; 4 M.Sc. students, Dept of Agronomy, KAU

Evaluator: Young Innovators Program, KDISC

Reviewer: Rubber Science; Journal of Tropical Agriculture; Journal of Root Crops

Expert: National Horticulture Fair, ICAR-IIHR, Bengaluru

Dr. S. Sunitha

Member: Advisory committee, one Ph.D student, Department of Agronomy, KAU

External examiner: Three Ph.D. students; five M.Sc. students, Department of Agronomy, KAU

External expert: Defense seminar, one Ph.D. student, KAU.

Dr. K. Sunilkumar

External Examiner: Eight M. Sc. Students, KAU; two Ph. D. students, YSRHU, A.P.

Reviewer: *In vitro* Cellular and Developmental Biology-Plant; International Journal of Plant and Soil Sciences; Indian Journal of Agricultural Research; Asian Journal of Agricultural and Horticultural Research

Member: State Farmers Award Committee 2021, DoAD & FW, GoK

Dr. J. Suresh Kumar

Reviewer: Journal of Agriculture and Food Research; International Journal of Plant and Soil Sciences

Dr. K. Susan John

Reviewer: Journal of Root Crops

Guest speaker: International Webinar, International Potash Institute on International Women's day

External examiner: Nine M.Sc. students, KAU; two Ph.D. students, TNAU; PJTSAU, Hyderabad

Evaluator: Young Innovators Program, KDISC

Technical Expert: Central Soil Analytical Laboratory, Department of Soil Survey and Soil Conservation, GoK

Member: School Management Committee, Bharatiya Vidhya Bhavan, Thiruvananthapuram

Expert: Scientific Advisory Committee, KVK, Kollam

Co-chair person: Technical session, VAIGA 2021

Invited speaker: DST sponsored training on INM & nutrient budgeting, ICAR- IISWCRC, Ootty, Tamil Nadu

Expert member: Panel discussion on INM', ICAR-IISWCRC, Ootty, Tamil Nadu

Dr. S. S. Veena

Invited speaker: International e-Conference, ICAR - IARI

Convenor: Advances in Plant Disease Diagnostics

Advisory committee member: National symposium, Indian Phytopathological Society South Zone, ICAR-CPCRI

Panelist: Brainstorming session at ICAR- IIOPR and International webinar, ICAR- IIOPR

Member: Advisory committee, one Ph.D. student, KAU

External examiner: One M.Sc. student, KAU

Member: Editorial board, Journal of Agricultural Research Advances

Reviewer: Scientific Reports; Archives of Microbiology; Journal of Tropical Agriculture; Indian Phytopathology; Scientific Review; Journal of Horticultural Sciences; Journal of Pharmaceutical Research International

Member: Agriculture Knowledge Centre, Attingal Block, Kerala

Evaluator: Young Innovators Programme, KDISC

External expert: Selection of field assistant, IISR, Calicut

Success Story in the Compendium of COP26

A success story titled *'Nalla Bhakshana Prasthanam'* (The Safe Food Project) ('Suja, G., Harishma, S.J. and Shyam Sasi. 2021. A holistic approach to sustainable agriculture in India-The use of IOFS models-*Nalla Bakshana Prasthanam* (Safe Food Project), Kerala. *In:* Compendium of Country Case Studies: Accelerating Transition to Sustainable Agriculture) was included in the Compendium of country case studies released at COP26 of UNCC at Glasgow, UK on 6 November). This was based on the geo-referenced survey of organic clusters done under AINP-OF, Thiruvananthapuram centre in 2018 (Fig. 214).

Fig. 214. Compendium of country case studies: COP 26

18.0 Publications

Research Papers

Abraham, L., Kamala, S., Sreekumar, J. and Makeshkumar, T. 2021. Optimization of parameters to improve transformation efficiency of elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). *Biotech.,* **11**(6):1-8. (NAAS Score: 8.41).

Anju, P.S., Susan John, K., Bhadraray, S., Jeena Mathew, Sunitha, S. and Veena, S.S. 2020. Optimum nutrient requirement of elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) under coconut gardens. *J. Root Crops,* **46**(1): 18-24.

Aswathy B Nair, Veena, S. S., Sheela, M. N., Karthikeyan, S. G., Sreelatha, L. and Vishnu.V. R. 2019. Microbial diversity in rhizosphere soils of tropical tuber crops: utilization for pathogen suppression and growth promotion. *J. Root Crops*, **45**(1): 53-63.

Beena, R., Kirubakaran, S., Nithya, N., Manickavelu, A., Rameshwar, P.S., Abida, P.S., Sreekumar, J., Jaslam, P.M., Rejeth,R., Jayalekshmy, V.G., Roy, S., Manju, R.V., Viji, M.M. and Siddique, K.H.M. 2021. Association mapping of drought tolerance and agronomic traits in rice (*Oryza sativa* L.) landraces. *BMC Plant Biol.,* **21**:484. https://doi.org/10.1186/s12870-021-03272-3. (NAAS Score: 10.22)

Bhagya, H.P., Mathur, R.K., Ravichandran, G., Ramajayam, D., Kalyan Baby, B., Anitha, P., Murugesan, P., Sunilkumar, K., Somasundaran, G. and Rahana, S.N. 2021. Identification and selection of elite oil palm Elaeisguineensis Jacq.) genotypes for utilization in a breeding programme. *J. Plantation Crops*, **49**(3): 162-167. (NAAS Score: 4.66)

Chintha, P., Sarkar, D., Pecota, K., Dogramaci, M. and Shetty, K.2021. Improving phenolic bioactive-linked functional qualities of sweet potatoes using beneficial lactic acid bacteria-based biotransformation strategy. *Horticulturae*, **7**(10): 367. (NAAS Score: 8.33).

Chithra, S., Susan John, K., Sreekumar, J. and Manikantan Nair, M. 2020. Mineralization of thippi (cassava starch factory solid residue) compost under incubation. *J. Root Crops*, **46**(1): 33-40.

Choudhury, S., Mansi, Muthusamy, S.K., Padaria, J.C. and Dalal, M. 2021. Genome wide identification of Ran GTPase family genes from wheat (*T. aestivum*) and their expression profile during developmental stages and abiotic stress conditions. *Funct. Integr. Genomics,* **21**(2): 239-250. (NAAS Score: 9.41).

Fathima, J.A., Sreelekha, R., Shiny, R., Veena, S.S. and Byju, G. 2020. Effect of site specific nutrient management of white yam on soil quality. *Int. J. Curr. Microbiol. Appl.Sci.,* **9**(12): 3424-3431. (NAAS Score: 5.38).

Geetika, S., Muthusamy, S. K., Sharma, P., Singh, G.P. and Sharma, P. 2021. Identification and development of novel salt responsive candidate gene based SSRs (cg-SSRs) and *MIR* gene based SSRs (mir-SSRs) in bread wheat (*Triticum aestivum*). *Sci. Rep.,* **11** (1): 1-15. (NAAS Score: 10.38).

Giri, N.A., Sakhale, B.K. and Krishnakumar, T. 2021. Nutrient composition, bioactive components, functional, thermal and pasting properties of sweet potato flour incorporated protein enriched and low glycemic composite flour. *J. Food Process Preserv.*, e16244. (NAAS Score: 8.36).

Gourilekshmi, S.S., Jyothi, A.N. and Sreekumar, J. 2021. Effect of cultivar difference and root growth stage on the thermal, rheological, and *in vitro* digestibility properties of cassava starch. Starch/Stärke, **73**(3-4): 2000157. (NAAS Score: 8.74).

Jeena Mathew, Abdul Haris, A., Ravi Bhat, V., Krishna Kumar, K., Muralidharan, K., Susan John, K. and Surendran, V. 2021. A comparative assessment of nutrient partitioning in healthy and root (wilt) disease affected coconut palms grown in an Entisol of humid tropical Kerala. *Trees* **35**: 621-635. https://doi.org/10.1007/s00468-020-02064-w. (NAAS Score: 8.53).

Jeevarathinam, G., Pandiselvam, R., Pandiarajan, T., Preetha, P., Krishnakumar, T., Balakrishnan, M. and Amirtham, D. 2021. Design, development, and drying kinetics of infrared assisted hot air dryer for turmeric slices. *J. Food Process Eng.*, e13876 (NAAS Score: 8.36).

Joseph, T., Sreejith, S., Joseph, X., Sangeetha, V.P., Prajitha, N., Vandana, U., Jayaprakas, C. A. and Mohanan, P.V. 2021. Effect of cyanide ions (CN^-) extracted from cassava (*Manihot esculenta* Crantz) on alveolar epithelial cells (A549 cells). *Toxicol.,* **464**: 153019. (NAAS Score: 10.10).

Kavitha, H.N., Pramod Kumar, Anbukkani, P., Burman, R.R. and Prakash, P. 2021. Income support schemes evaluation of PM KISAN *vis-à-vis* state government schemes, *Econ. Polit. Wkly.*, **56 (**34): 13-17. (NAAS Score: 5.22).

Koundinya, A.V.V., Ajeesh, B.R., Hegde, V., Sheela, M.N., Mohan, C. and Asha, K.I. 2021. Genetic parameters, stability and selection of cassava genotypes between rainy and water stress conditions using AMMI, WAAS, BLUP and MTSI. *Sci. Hortic.,* **281**: 109949. (NAAS Score: 8.77).

Krishnakumar, T., Sajeev, M.S., Pradeepika, C., Namrata, A.G., More Sanket J., Jeevarathinam, G. and Muthusamy, V. 2021. Physical and mechanical properties of cassava (*Manihot esculenta* Crantz) cultivars: Implications for the design of mechanical peeling machines. *J. Food Process Eng.*, e13923 https://doi.org/10.1111/jfpe.13923. (NAAS Score: 8.36).

Laxminarayana, K. 2021. Effect of lime, inorganic and organic sources on soil quality, yield and proximate composition of elephant foot yam - black gram system in Alfisols. *Commun. Soil Sci. Plant Anal.,* **52**(6): 635-650. https://doi.org/10.1080/00103624.2020.1862162. (NAAS: 6.77).

Lekshmanan, D.K., Raji, P., Santhosh Mithra, V.S., Sunitha, S., James George, Velmurugan, M.P., Ashok, Mhasker, N.V., Desai, K.D., Shiny, R. and Byju, G. 2021.Yield estimation of cassava using SIMCAS model over the major cassava growing regions in India. *Agriculture Res.,* https://doi.org/10.1007/s40003-021-00557-9. (NAAS Score: 5.95).

Leno, N., Sudharmaidevi, C.R., Byju, G., Manorama Thampatti, K.C., Priya, U.K., Geethu Jacob and Pratheesh, P.G. 2021. Thermochemical digestate fertilizer from solid waste: characterization, labile carbon dynamics, dehydrogenase activity, water holding capacity and biomass allocation in *Musa* sp. (AAA). *Waste Management,* **123**:1-14. https://doi.org/10.1016/j.wasman.2021.01.002. (NAAS Score: 11.45).

Madhavi Baiju., Sreelekha, S., Shiny, R., Veena, S. S. and Byju, G. 2020. Site specific nutrient management of cassava improves soil quality. *Int. J. Curr. Microbiol. Appl. Sci.,* **9**(12): 416 - 424. (NAAS rating: 5.38).

Madhumita Das, Brahmanand, P.S. and Laxminarayana, K. 2021. Performance and efficiency services for the removal of hexavalent chromium from water by common macrophytes. *Int. J. Phytoremediation,* **23**(10): 1095-1103. https://doi.org/10.1080/15226514,2021.1878104. (NAAS Score: 8.53).

Mahanta, S., Prusty, M., Sivakumar, P.S., Mishra, D., Sahu, R.P., Goswami, C., Chawla, S., Goswami, L., Elangovan, S., Panda, S.K. (2021). Novel *Levilactobacillus brevis* based formulation for controlling cell proliferation, cell migration and gut dysbiosis. *LWT – Food Sci. Technol.*, **154**: 112818. (NAAS Score: 10.01).

Manaswini, M., Laxminarayana, K. and Nedunchezhiyan, M. 2021. Influence of weed management practices on soil microbial activities and corm yield of elephant foot yam (*Amorphophallus paeoniifolius*) in Alfisols of coastal Odisha. *J. Indian Soc. Coastal Agric. Res.,* **39**(1): 66-77. (NAAS Score: 5.17).

Murugesan, P., Ramajayam, D., Preethi, P., Bhagya, H.P., Ravichandran, G., Anitha, P., Somasundaram, G., Mathur, R.K., Damodaran, V. and Pandey, V. 2021. Identification and evaluation of bunch components of Nigerian source oil palms (*Elaeis guineensis* Jacq.) from Hut Bay, Little Andaman Island, India. *J. Environ. Biol.,* **42**: 678-686. (NAAS Score: 6.78).

Murugesan, P., Somasundaram, G. and Vikramaditya Pandey. 2021. Evaluation of seedlings of oil palm germplasm from Sierra Leone and Senegal in India. *Indian J. Hort.*, **78**(1): 61-66. (NAAS Score: 6.16).

Nagar, C.K., Dash, S.K., Rayaguru, K., Pal, U.S. and Nedunchezhiyan, M. 2021. Isolation, characterization, modification and uses of taro starch: A review. *Int. J. Biol. Macromol.,* **192**: 574–589.https://doi.org/10.1016/j.ijbiomac.2021.10.041. (NAAS Score: 11.16).

Nedunchezhiyan, M., Byju, G. and Jata, S.K. 2021. Drip fertigation for greater yam (*Dioscorea alata*) and maize (*Zea mays*) intercropping. *Indian J. Agric. Sci.,* **91**(9): 1302-1306. (NAAS Score: 6.21).

Nedunchezhiyan, M., Suresh Kumar, J. and Biswanath Sahoo. 2021. Effect of weed control on growth, dry matter production and partitioning in elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). *Curr. Hort.,* **9**(1): 40-44. (NAAS Score: 4.53).

Pati, K., Behera, S., Ray, D.K.,Behera, P.R., Sarkar, A., Chauhan, V.B.S., Bansode, V.V. and Nedunchezhiyan, M. 2021. Element profiling of thirty genotypes of yam bean in eastern India by using proton induced X-ray emission (PIXE). *J. Food Compos. Anal.,* **102:** 104006. https://doi.org/10.1016/j.jfca.2021.104006. (NAAS Score: 9.72).

Prakash, P., Pramod Kumar, Niranjan, S., Jaganathan, D., Prabhat Kishore and Sheela Immanuel. 2021. Economic feasibility of protected cultivation of rose under polyhouse and its supply chain in Maharashtra. *J. Community Mobilization Sustain. Dev.*, **16**(03): 939-946. (NAAS Score: 5.67).

Pramod, K., Kar, A., Singh, D.R., Anbukkani, P., Gowda, A., Reddy, K.V., Badal, P.S., Kamble, A.L., Kamalvanshi, V., Jha, G.K., Nain M.S., Prakash, P., Alataway, A., Dewidar, A. and Elansary, H.O. 2021. Protected cultivation of horticultural crops in Uttarakhand: An economic analysis, *Agron.,* **11**(692):1-24. (NAAS Score: 9.41).

Raji, P. and Byju, G. 2021. Assessing the influence of climate model biases in predicting yield and irrigation requirement of cassava. *Model. Earth Syst. Environ.*, **7**: 307-315. https://doi.org/10.1007/s40808-020-01038-8.

Raji, P., Govindan Kutty and Byju, G. 2021. Sensitivity analysis of WOFOST for yield estimation of cassava over the major growing areas of India. *J. Agrometeorol.,* **23**(4): 375-380. (NAAS Score: 6.47).

Raji, P., Santhosh Mithra, V.S., Sunitha, S., James George, Nedunchezhian, M., Mamatha, K., Ashok, P., Alam, S., Saud, B.K., Tarafdar, J., Mitra, S., Deo, C., Velmurugan, M., Suja, G., Ravi, V. and Byju, G. 2021. Impact of climate change on the yield of tropical root and tuber crops *vs.* rice and potato in India. *Food Secur.,* **14**: 495-508. https://doi.org/10.1007/s12571-021-01226-z. (NAAS Score: 8.10).

Raji, P., Shiny, R. and Byju, G. 2021. Impact of climate change on the potential geographical suitability of cassava and sweet potato *vs.* rice and potato in India. *Theor. Appl. Climatol.,* **146**: 941-960. https://doi.org/10.1007/s00704-021-03763-1. (NAAS Score: 8.88).

Raji, P., Shiny, R., Govindan Kutty, Dua, V.K., Sunitha, S., Santhosh Mithra, V.S. and Byju, G. 2021. Testing of cassava (*Manihot esculenta* Crantz) varieties for climate resilience under Kerala (India) conditions. *Agric. Res.,* **11**:24-31. https://doi.org/10.1007/s40003-021-00547-x. (NAAS Score: 5.95).

Raji, P., Sunitha, S., Santhosh Mithra, V.S. and Byju, G. 2021. Modelling the yield, water requirement, and water productivity of major tropical tuber crops using FAO-Aqua Crop-a study over the main growing areas of India. *J. Trop. Agr*., **59**(2): 155-161. (NAAS Score: 4.85).

Ravisankar, N., Ansari, M.A., Panwar, A.S., Aulakh, C.S., Sharma, S.K., Suganthy, M., Suja, G. and Jaganathan, D. 2021. Organic farming research in India: Potential technologies and way forward. *Indian J. Agron.*, **66**: S142-S162. (NAAS Score: 5.55).

Seena Radhakrishnan, A. R., Suja, G. and Sreekumar, J. 2021. How sustainable is organic management in cassava? Evidences from yield, soil quality, energetics and economics in the humid tropics of south India. *Sci. Hortic.,* **293**: 110723. https://doi.org/10.1016/j.scienta.2021.110723. (NAAS Score: 8.77).

Sharma, P., Mehta, G., Muthusamy, S. K., Singh, S. K. and Singh, G. P. 2021. Development and validation of heat responsive candidate gene and miRNA gene based SSR markers to analysis genetic diversity in wheat for heat tolerance breeding. *Mol. Biol. Rep.*, **48**(1): 381-393. (NAAS Score: 8.32).

Sheela Immanuel, Jaganathan, D., Koundinya, A.V.V., Prakash, P., Sivakumar, P. S., Kesava Kumar, H. and Muthuraj, R**.** 2021. Mapping of livelihood capitals for technological interventions in elephant foot yam and banana cultivation in Andhra Pradesh. *Int. J. Curr. Microbiol. Appl. Sci.,* **9**(8): 3686-3696. (NAAS Score: 5.38).

Shiny, R. and Byju, G. 2021. Kinetics of soil carbon mineralization under continuous site specific nutrient management in an Ultisols under cassava. *Commun. Soil Sci. Plant Anal.,* **52**:11-21. https://doi.org/10.1080/00103624.2020.1836209. (NAAS Score: 6.70).

Shyla, G., Uma, S.K., Gayathri, M., Amrutha, M., Geetha, S., Vineeth, K. T. V., Sreekumar, J., Chandrika. S.K., Dileep, V., Chandra, N.S.R., Nelson, S.S., Sanil, G. and Tessy, M.T. 2021. SSTP1, a host defense peptide, exploits the immuno modulatory IL6 pathway to induce apoptosis in cancer cells. *Front. Immunol.*, **12**: DOI:10.3389/fimmu.2021.740620. (NAAS Score:13.56).

Sooraj, S., Nisha, M.S. and Kumar, H.K. 2020. *In vitro* potency evaluation of *Metarhabditis rainai* against *Odontotermes obesus* (Rambur). *Indian J. Nematol.,* **50**(1): 65-67. (NAAS Score: 5.23).

Suja, G., Harishma, S.J., Byju, G., Neeraja, C.R. and Sheeba, B.S. 2021. Geotagged characterization of organic growers in Kerala. *Indian J. Agric. Sci.,* **66**(3): 272-278. (NAAS Score: 6.21).

Suja, G., Sreekumar, J., Byju, G., Veena, S.S., Sunitha, S., Ramesh, V., Lintu. C. Maria and Rakhi K. Raj. 2021. Organic management of Chinese potato: growth, yield, quality, soil health and economics. *Int. J. Veg. Sci.,* **27**(6): 585-683. https://doi.org/10.1080/19315260.2021.1907829 . (NAAS Score: 6.94).

Suja, G., Sreekumar, J., Byju, G., Jyothi, A.N. and Veena, S.S. 2021. Weed cloth, an option for integrated weed management for short duration cassava. *Agron. J.,* **113**(2): 1895-1908. https://doi.org/10.1002/agj2.20528. (NAAS Score: 7.68).

Sujayanand, G. K., Akram, M., Konda, A., Nigam, A., Bhat, S., Dubey, J., Kumar, K., and Muthusamy, S. K. 2021. Distribution and toxicity of *Bacillus thuringiensis* (Berliner) strains from different crop rhizosphere in Indo-Gangetic plains against polyphagous lepidopteran pests. *Int. J. Trop. Insect Sci.,* **41**: 2713–2731. (NAAS Score: 6.77).

Sunitha, S., Gupta, V.K., Shirly Raichal Anil and Suresh Kumar, J. 2021. Performance of heat tolerant clones of potato in tropical coastal region of India. *Int. J. Curr. Microbiol. Appl. Sci.,* **9**(8): 2961-2967. (NAAS Score: 5.38)

Sunitha, S., Sathosh Mithra, V.S. and Sreekumar, J. 2021. Phenology and productivity of elephant foot yam *(Amorphophallus paeoniifolius)* in relation to planting time under humid tropical conditions. *Curr. Hort.,* **9**(2): 36–40. (NAAS Score: 4.53).

Susan John, K., Karthika, D., Sruthi, T., Sreekumar, J., Sunilkumar, K. and Anju, P.S. 2020. Status and requirement of boron for tropical tuber crops under laterite (Typic Kandi Usult) soils. *J. Root Crops*, **46**(1): 25-32.

Tadigiri, S., Jayaprakas, C.A., Kumar, K.K. and Kumar, H.K. 2020. Bioefficacy of cassava based biopesticides against *Meloidogyne incognita* under *in vitro* conditions. *Indian J. Nematol.,* **50**(1): 68-70. (NASS: 5.23).

Tay Fernandez, C.G., Pati, K., Severn-Ellis, A.A., Batley, J. and Edwards, D. 2021. Studying the genetic diversity of yam bean using a new draft genome assembly. *Agron*., **11**(5): 953. (NAAS Score: 9.42).

Tengli, M.B., Sivakumar, P.S., Paul, P., and Kesava Kumar, H. 2021. Addressing VitaminA deficiency through biofortified sweet potato: the prioritizing states of India for biofortification interventions. *Curr. Sci.,* **121**(7):950-957. (NAAS Score: 6.73).

Visalakshi, C., Shirly Raichal Anil, Sheela, M.N., Vivek Hegde, Jyothi, A.N., Sreekumar, J. 2021.Genetic variation for important processing traits and identification of potential parents for developing hybrid clones suitable for processing in sweet potato (*Ipomoea batatas* L. Lam). *S. Afr. J. Bot.,* **141**: 255-264. https://doi.org/10.1016/j.sajb.2021.04.005. (NAAS Score:8.30).

Vivek Hegde, Makeshkumar, T., Sheela, M.N., Koundinya, A.V.V., Senthilkumar, K.M. and Mohan, C. 2021. Cassava (*Manihot esculenta*) synthetic seed production for germplasm exchange. *Indian J. Plant Genet. Resour.,* **34**(3): 404–410. (NAAS Score: 5.54).

Popular Articles (Tropical Tuber Crops)

Byju, G. 2021. Cassava for food and nutrition security. *In*: Agriculture and Environment Series 3, *Yoganadam*, 16 July 2021.

Byju, G. 2021. Tapioca better than potato for diabetics. *Kala Kaumudi*, 13 June 2021.

Byju, G. 2021. Madhuragramam- a model for women empowerment. *In*: Home Nutrition Garden Series 2*, Mahilarathnam*, July 2021.

Byju, G. 2021. Madhuragramam :importance of quality seeds. *In*: Home Nutrition Garden Series 3, *Mahilarathnam*, August 2021.

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Crop Improvement	V.B.S.Chauhan et al.,	1	HYV of taro	English
	A.V.V. Koundinya et al.,	2	CMD resistant varieties of cassava;Tuber crops based food products; Techno incubation centre	Telugu
	K. Pati et al.,	1	Bio fortified varieties of sweet potato	English
Crop Production	G. Byju et al.,	5	Agro techniques; Climate change	Bengali, Gujarati, English
	R. Muthuraj et al.,	15	Quality planting material production	English, Malayalam, Tamil
	G. Suja et al.,	17	Organic production; Conservation agriculture	Manipuri, English, Malayalam
	S. Sunitha et al.,	10	Nursery techniques in cassava	English, Malayalam, Hindi, Tamil, Kannada, Telugu, Gujarati, Marati
	J. Suresh Kumar et al.,	5	Nursery techniques in sweet potato	Malayalam, Telugu, Gujarati, English
	K. Susan John et al.,	12	Soil fertility and nutrient management	English, Malayalam
Crop Utilization	C. Pradeepika et al.,	5	Value added food products; Post harvest machineries	Telugu
	M.S. Sajeev et al.,	1	Entrepreneurial opportunities and value addition	Malayalam
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Our Activities through Media Lens


പന്നിയെ ക്ഷുദ്രജീവിയായി പ്രഖ്യാപിക്കേണ്ടത് അനിവാര്യം: മന്ത്രി വീണാ ജോർജ്


Tenkasi farmers trained in cultivating high-yielding tubers


சிறுகிழங்கு பயிர் உற்பத்தி மதிப்பு கூட்டுதல் பயிற்சி


Tailor-made micronutrients for Chinese potato developed


மரவள்ளி பயிர் சாகுபடி கருத்தரங்கம்


சிறுகிழங்கு பயிர் உற்பத்தி மதிப்பு கூட்டுதல் பயிற்சி


Farmers go in for high-yielding Chin

CTCRI establishes frontline demonstration-cum-seed villages at Kuthapanjan and Rajangapuram

The Indian Council for Agricultural Research's Central Tuber Crop Research Institute (CTCRI) in Thiruvananthapuram has established frontline demonstration-cum-seed villages for high-yielding Chinese potato at Kuthapanjan and Rajangapuram in Tenkasi district as this district has been a major producer of the crop for the past several decades.

Besides providing seeds to the farmers opting for cultivation of high-yielding and disease-resistant Chinese potato variety 'Sree Dhara', these two villages will also have demonstration fields, which agriculturists can visit to understand the cultivation and crop management practices.

Chinese potato, a delicious tuber crop that sell like hotcakes during the months of January and February in the markets here and also in Kerala, is being cultivated on a large scale by the farmers of Tenkasi district.

Hence, the CTCRI recently trained the farmers of the district in growing its 'Sree Dhara' variety that gives yield up to 20 tonnes per

Chinese potato seeds being given to a woman farmer in Rajangapuram village in Tenkasi district.


కొత్త వంగడాలతో అధిక దిగుబడులు

19.0 Linkages & Collaborations

The Institute is having linkages with international, national and state level organizations for research and development activities

International

International Potato Centre (CIP), Lima, Peru; International Centre for Tropical Agriculture (CIAT), Cali, Columbia

National

The ICAR-CTCRI is having linkages with most of the ICAR Institutes| SAU's|KVK's|ATARI's, Department of Horticulture|Agriculture, Government of Kerala, Tamil Nadu, Odisha, Andhra Pradesh|Telengana and NE States. In addition, the Institute has specific collaboration with the following institutes|organizations.

National Agricultural Innovation Fund (NAIF); Protection of Plant Varieties & Farmers' Rights Authority (PPV&FRA); National Institute of Agricultural Extension Management (MANAGE), Hyderabad; DST; DBT; Department of Atomic Energy, Govt. of India; BARC; Coconut Development Board; Rashtriya Krishi Vikas Yojana (RKVY), Govt. of Odisha and Govt. of Kerala; Odisha University of Agriculture & Technology, Bhubaneswar; Tamil Nadu Agricultural University; North Eastern Hill University, Tura; Indian Institute of Crop Processing Technology, Thanjavur; Dr. YSR Horticultural University, Andhra Pradesh; Indian Institute of Technology, Roorkee; Central Agricultural University (CAU), Imphal; Indira Gandhi Krishi Vishwavidyalaya, Chhattisgarh, Central Agricultural University, Tripura, Bhubaneswar City Knowledge Innovation Cluster (An initiative of Office of the Principal Scientific Adviser to the Government of India)

State

Kerala State Planning Board; Small Farmers Agri-business Consortium (SFAC); Kerala State Council for Science, Technology and Environment (KSCSTE); Kerala State Horticulture Mission; Kerala State Industrial Development Corporation (KSIDC); Kerala Development and Innovation Strategic Council (KDISC); Kerala Start-up Mission; University of Kerala.

The AICRP on Tuber Crops at ICAR-CTCRI headquarters has collaboration with 21 centres spread over 18 States and one Union Territory.

20.0 Distinguished Visitors

Dr. Vasuki, IAS, Director, Department of Agriculture Development and Farmers Welfare, Government of Kerala, 8 March

Dr. C. George Thomas, Chairman, Kerala State Biodiversity Board, 22 March

Shri. P. Prasad, Hon'ble Minister of Agriculture Development and Farmers Welfare, Government of Kerala, 23 July

Dr. K.P. Sudheer, Executive Vice President, KSCSTE & Ex Officio Secretary, DST, Government of Kerala, 23 July

Ms. Arya Rajendran, S. Respected Mayor, Thiruvananthapuram Corporation, 12 August

Smt. R. Sreelekha, IPS, Former DGP, Government of Kerala, 1 November

Smt. C.A. Latha, IAS, Secretary, Department of Agriculture Development and Farmers Welfare & Public Relations, Government of Kerala, 17 November

Dr. Jiju P Alex, Member, Kerala State Planning Board & Former, Director of Extension, KAU, 17 November

Padmashri Lakshmykutty Amma, Kallar, Thiruvananthapuram, 17 November

Dr. S. Gopakumar, Director of Education, KAU, 3 December

Shri. Kadakampally Surendran, Hon'ble MLA, Kazhakuttam constituency, Thiruvananthapuram, 23 December

21.0 Staff Welfare Committees

Institute Joint Staff Council (IJSC)

The XVI IJSC of the Institute started functioning from 25 November with Dr. M.N. Sheela, Director (A) as the chairperson. The IJSC has 12 members, five each in the official and staff side and one as CJSC member. The members of the council meets every quarter to discuss about the issues related to general fuctioning of the Institute and welfare of the staff.

Women Cell

The Women Cell is constituted to maintain a harmonious atmosphere at the Institute to help women employees to pursue their work with dignity and reassurance. The women cell is functioning very efficiently at the Institute for the welfare of women employees.

Staff Welfare Committee

The Staff Welfare Committee was reconstituted with eight members for a period of two years with effect from 3 September 2021. The committee ensures favourable working environment for all the staff members. It also looks after the needs of the staff and deeply connected to the range of the institutional activities contributing to the success of the organization.

Public Grievance Cell

The Public Grievance Cell is entrusted with the responsibility of redressal of public grievances. The cell is actively involved in regularly addressing the public grievances.

Recreation Club

The Republic day and 75th Independence Day programmes were coordinated by the recreation club. The club organized a talk by Dr. Amar .S. Fettle, State Nodal officer for Covid-19, Kerala on 12 March on the topic, 'The Covid-19 vaccine: myths and facts'. Candle March was conducted to pay homage to the ICAR employees, who lost their lives due to Covid-19 (Fig. 215).

Fig. 215. Candle March

Guest House

Guest House Facility

The Institute guest house facility is extended in a complex of two buildings *viz.,* guest house and international training hostel in an area of around 25 cents in block II of the Institute premises. The amenities in the guest house includes 3 suite rooms,16 double bedded rooms and one single bedded room catering to the needs of national and international guests and trainees. The guests are provided with all necessary facilities such as fully furnished room, comfortable bed, air-conditioner, TV, hot and cold water supply and also round the clock security. As per the request from the Department of Health, GoK, international training hostel was provided as a quarantine centre for covid patients during certain period.

☎ : 0471-2592203

22.0 Annexure

Annexure I

Personnel

Dr. V. Ravi
Director (Acting) (till 31-05-2021)
Principal Scientist |Plant Physiology| Crop Production

Dr. M.N. Sheela
Director (Acting) & Project Co-ordinator (i|c), AICRP-TC (since 01-06-2021)
Principal Scientist |Plant Breeding | Crop Improvement

ICAR-CTCRI Headquarters, Thiruvananthapuram, Kerala

Heads (A) | Scientist in Charge | Discipline | Division | Section
Dr. M.N. Sheela (Head) (A) Principal Scientist | Plant Breeding | Crop Improvement
Dr. V. Ravi (Head) (A) (till 31-05-2021) Principal Scientist | Plant Physiology | Crop Production
Dr. G. Byju (Head) (A) (since 01-06-2021) Principal Scientist | Soil Science | Crop Production
Dr. C.A. Jayaprakas (Head) (A) (till 24-03-2021) Principal Scientist | Agricultural Entomology | Crop Protection
Dr. M.L. Jeeva (Head) (A) (since 25-03-2021) Principal Scientist | Plant Pathology | Crop Protection
Dr. M.S. Sajeev (Scientist in Charge) Principal Scientist | Agriculture Structure and Process Engineering | Crop Utilization
Dr. Sheela Immanuel (Scientist in Charge) Principal Scientist | Agricultural Extension | Extension & Social Sciences
Mr. Ramdeen, SAO (till 03-11-2021)
Mr. Krishnakumaran, SF&AO (till 31-03-2021)
Mr. T.D.S. Prakash, SF&AO (since 16-10-2021)

Scientific

Name | Designation | Discipline | Division | Section
Dr. A. Asha Devi Principal Scientist | Genetics | Crop Improvement
Dr. K. I. Asha Principal Scientist | Economic Botany | Crop Improvement
Dr. L.K. Bharathi (Since 4-10-2021) Principal Scientist | Vegetable Science | Crop Improvement
Dr. E.R. Harish Senior Scientist | Agricultural Entomology | Crop Protection
Dr. D. Jaganathan Senior Scientist | Agricultural Extension | Extension & Social Sciences
Dr. C.A. Jayaprakas Principal Scientist | Agricultural Entomology | Crop Protection
Dr. A.N. Jyothi Principal Scientist | Organic Chemistry | Crop Utilization
Dr. H. Kesava Kumar Scientist | Nematology | Crop Protection
Dr. A.V.V. Koundinya Scientist | Vegetable Science | Crop Improvement
Dr. T. Krishnakumar Scientist | Agricultural Structure & Process Engineering | Crop Utilization
Dr. N. Krishna Radhika Senior Scientist | Agricultural Biotechnology | Crop Improvement

Dr. T. Makeshkumar
Principal Scientist | Plant Pathology | Crop Protection

Dr. C. Mohan
Principal Scientist | Plant Breeding | Crop Improvement

Dr. P. Murugesan
Principal Scientist | Horticulture | Crop Improvement

Dr. R. Muthuraj
Principal Scientist | Seed Technology | Crop Production

Dr. C. Pradeepika
Scientist | Vegetable Science | Crop Utilization

Dr. P. Prakash
Scientist | Agricultural Economics | Extension & Social Sciences

Dr. V. Ramesh
Principal Scientist | Soil Science, Soil Physics & Soil and Water Conservation | Crop Production

Dr. B.G. Sangeetha
Scientist | Agricultural Biotechnology | Crop Protection

Dr. Sanket J.More
Scientist | Vegetable Science | Crop Production

Dr. V.S. Santhosh Mithra
Principal Scientist | Computer Applications in Agriculture | Extension & Social Sciences

Dr. Saravanan Raju
Principal Scientist | Plant Physiology | Crop Production

Dr. K.M. Senthilkumar
Scientist | Agricultural Biotechnology | Crop Improvement

Dr. P. Sethuraman Sivakumar
Principal Scientist | Agricultural Extension | Extension & Social Sciences

Dr. Shirly Raichal Anil
Principal Scientist | Genetics & Cytogenetics | Crop Improvement

Dr. J. Sreekumar
Principal Scientist | Agricultural Statistics | Extension & Social Sciences

Dr. G. Suja
Principal Scientist | Agronomy | Crop Production

Dr. K. Sunilkumar
Principal Scientist | Horticulture | Crop Production

Dr. S. Sunitha
Principal Scientist | Agronomy | Crop Production

Dr. J. Suresh Kumar
Scientist | Vegetable Science | Crop Production

Dr. K. Susan John
Principal Scientist | Soil Science | Crop Production

Dr. S.S. Veena
Principal Scientist | Plant Pathology | Crop Protection

Dr. C. Visalakshi Chandra
Scientist | Genetics & Plant Breeding | Crop Improvement

Dr. Vivek Hegde (Till 07-10-2021)
Scientist | Vegetable Science | Crop Improvement

Technical

Name | Designation
Shri. K. Chandran | Technician
Smt. B.S. Deepa | Senior Technical Assistant
Shri. V. Ganesh | Technical Officer
Dr. S. Karthikeyan | Senior Technical Assistant
Shri. C. Krishnamoorthy | Senior Technician
Shri. M. Kuriakose | Assistant Chief Technical Officer
Shri. L. Luke Armstrong | Senior Technical Assistant
Shri. A. Madhu| Assistant Chief Technical Officer
Shri. T. Manikantan Nair | Technician
Shri. A.S. Manikuttan Nair | Technical Officer
Shri. B.S. Prakash Krishnan | Technical Officer
Shri. I. Puviyarasan (Till 31.07.2021) | Assistant Chief Technical Officer
Shri. T. Raghavan | Technical Assistant
Dr. L.S. Rajeswari | Chief Technical Officer
Shri. D.T. Rejin | Senior Technician
Shri. B. Renjith Kishor | Assistant Chief Technical Officer
Shri. C.S. Salimon (Till 31.03.2021) | Assistant Chief Technical Officer
Shri. V.R. Sasankan | Assistant Chief Technical Officer

Shri. B. Satheesan | Senior Technician

Shri. G. Shajikumar | Senior Technical Assistant

Dr. S. Shanavas | Technical Officer

Shri. T.M. Shinil | Senior Technician

Smt. S.S. Sneha | Technician

Shri. V.S. Sreekumar | Senior Technical Officer

Smt. N. Sujatha Kumari | Chief Technical Officer

Shri. K. Sunil | Senior Technical Assistant

Shri. G. Suresh | Technical Officer

Shri. K. Velayudhan | Senior Technician

Administrative

Name | Designation

Shri. R.S. Adarsh | Upper Division Clerk

Shri. Arjun Murali | Assistant

Shri. D. Arunraj | Lower Division Clerk

Shri. O.C. Ayyappan | Assistant

Smt. C.G. Chandra Bindu | Upper Division Clerk

Shri. C. Chandru | Upper Division Clerk

Shri. S. Hareendrakumar | Assistant

Smt. Jessymol Antony | (Transferred on 05.11.2021) Assistant Finance and Accounts Officer

Shri. P.C. Noble | Assistant Administrative Officer

Shri. M. Padmakumar | Personal Assistant

Smt. K. Padmini Nair (VRS on 01.11.2021) | Private Secretary

Smt. B. Presanna | Assistant

Smt. Rohini K. Nair | Lower Division Clerk

Shri. S. Sasikumar | Private Secretary

Shri. S. Sreekumar | Assistant

Smt. S. Sunitha | Personal Assistant

Shri. P.S. Suresh Kumar | Assistant

Shri. Stiphin George | Lower Division Clerk

Shri. K. Unnikrishnan Nair | Assistant

Shri. T. Vijayakumara Kurup | Assistant Administrative Officer

Skilled Support

Name

Shri. S. Abhishek

Ms. S. Anjitha

Smt. R. Anuja

Shri. P. Aswin Raj

Shri. A. Chandran

Smt.C.P. Gayathri

Smt. S.L. Jyothi

Shri. T. Lawrence

Shri. G. Madhu

Smt. R. Nijamol

Shri. S. Radhakrishnan Nair

Smt. V.S. Remya

Smt. Rini Alocious

Shri. L. Samynathan

Shri. K. Saratchandra Kumar

Shri. N. Shiju

Shri. K. Sivadas

Shri. S. Sreekumaran

Shri. SreenathVijay

Shri. S. Sudhish

Shri. P. Udayakumar

Smt. S. Ushakumari

Smt. P. Vidhya

Regional Station, Bhubaneswar, Odisha

Scientist in Charge

Dr. M. Nedunchezhiyan
Principal Scientist | Agronomy

Scientific

Name | Designation | Discipline

Dr. R. Arutselvan | Scientist | Plant Pathology

Shri. K. Hanume Gowda | Scientist | Vegetable Science

Dr. Kalidas Pati | Senior Scientist | Vegetable Science

Dr. K. Laxminarayana | Principal Scientist | Soil Science

Shri. Venkatraman V. Bansode (Transferred on 25.01.2021) | Scientist | Food Technology
Dr. Vijay Bahadur Singh Chauhan | Scientist | Vegetable Science

Technical

Name | Designation
Shri. Bibhuti Bhusan Das | Senior Technical Officer
Shri. Keshab Paikaray | Senior Technician
Shri. Pramod Kumar Mati | Technical Officer
Shri. K. Raja | Technical Assistant
Shri. Sushanta Kumar Jata | Technical Officer

Administrative

Name |Designation
Shri. P. K. Acharya |Private Secretary
Shri. Amit Vengraj| Upper Division Clerk (on deputation)
Shri. A. Lakshmana Rao |Assistant

Skilled Support

Name
Shri. Babuli Sethi
Shri. Prakash Kumar Nayak
Shri. Samsuddin Khan
Shri. Sauri Pradhan

Transfers

Name	From	To	With effect from
Shri. V.V. Bansode	ICAR-CTCRI (RS), Odisha	ICAR-CCRI, Nagpur	25.01.2021
Dr. L.K. Bharathi	ICAR-IIHR, Bengaluru	ICAR-CTCRI (HQ), Thiruvananthapuram	04.10.2021
Smt. Jessymol Antony	ICAR-CTCRI (HQ), Thiruvananthapuram	ICAR-CPCRI, Kasargod	05.11.2021
Shri. T.D.S. Prakash	ICAR-IISR, Kozhikode	ICAR-CTCRI (HQ), Thiruvananthapuram	16.10.2021
Shri. Ramdeen	ICAR-CTCRI (HQ), Thiruvananthapuram	ICAR-CAZRI, Jodhpur	03.11.2021
Dr. Vivek Hegde	ICAR-CTCRI (HQ), Thiruvananthapuram	ICAR-IIHR, Bengaluru	08.10.2021

Promotions

Name	From	To	Date
Smt. C.G. Chandra Bindhu	Lower Division Clerk	Upper Division Clerk	12.11.2021
Shri. K. Chandran	Skilled Support Staff	Technician	20.11.2021
Shri. N. Jayachandran	Lower Division Clerk	Upper Division Clerk	12.11.2021
Dr. S. Karthikeyan	Technical Assistant	Senior Technical Assistant	08.06.2020
Shri. C. Krishnamoorthy	Technician	Senior Technician	03.10.2021
Shri. L. Luke Armstrong	Technical Assistant	Senior Technical Assistant	05.04.2019
Smt. Padmini Nair	Personal Assistant	Private Secretary	09.07.2021

Dr. B.S. Prakash Krishnan	Senior Technical Assistant	Technical Officer	04.04.2021
Dr. L.S. Rajeshwari	Assistant Chief Technical Officer	Chief Technical Officer	07.06.2019
Shri. B. Renjith Kisor	Senior Technical Officer	Assistant Chief Technical Officer	27.10.2019
Shri. V.R. Sasankan	Senior Technical Officer	Assistant Chief Technical Officer	10.05.2019
Shri. S. Sasikumar	Personal Assistant	Private Secretary	01.11.2021
Dr. S. Shanavas	Senior Technical Assistant	Technical Officer	02.04.2021
Smt. S.S. Sneha	Skilled Support Staff	Technician	31.05.2021
Shri. K. Sunil	Technical Assistant	Senior Technical Assistant	12.05.2019
Smt. Sunitha	Stenographer	Personal Assistant	12.07.2021
Shri. G. Suresh	Senior Technical Assistant	Technical Officer	25.09.2020
Dr. Susanta Kumar Jata	Senior Technical Assistant	Technical Officer	07.04.2021
Shri. Stifin George	Skilled Support Staff	Lower Division Clerk	15.11.2021
Shri. K. Velayudhan	Technician	Senior Technician	06.12.2021

MACP

Name & Designation	Pay matrix level (present) (₹)	Pay matrix level (up graded) (₹)	MACP I/II/III (w.e.f)
Shri. A. Chandran	21700-69100 (3)	25500-81100(4)	14.10.2021
Shri. S. Radhakrishnan Nair	21700-69100(3)	25500-81100(4)	01.10.2021
Shri. J. Unni	35400-112400(6)	44900-142400(7)	12.02.2020

Retirement

Name	Position held	Date of Retirement
Dr. V. Ravi	Director (A)	31.05.2021
Shri. P. Krishnakumaran	Finance & Accounts Officer	31.03.2021
Smt. Padmini Nair	Private Secretary	01.11.2021
Shri. Patric Mascrene	Technical Officer	31.12.2021
Shri. I. Puviyarasan	Assistant Chief Technical Officer	31.07.2021
Shri. C.S. Salimon	Assistant Chief Technical Officer	31.01.2021

Annexure II

Quality planting material production of tuber crops at ICAR-CTCRI-HQ and RS during 2021

Name of the Crop	Varieties	Quantity of planting material produced
Cassava (No. of stems)	Sree Vijaya	32000
	Sree Jaya	26000
	Sree Reksha	55000
	Sree Suvarna	6000
	Sree Sakthi	6000
	Total	125000
Elephant foot yam (tonnes)	Gajendra	36.50
	Sree Padma	0.50
	Total	37.00
Greater yam (tonnes)	Sree Shilpa, Sree Roopa, Sree Keerthi, Sree Karthika, Sree Nidhi	33.00
White yam (tonnes)	Sree Priya, Sree Dhanya	2.00
Lesser yam (tonnes)	Sree Latha	2.50
	Total	37.50
Taro (tonnes)	Muktakeshi, Telia	3.00
Sweet potato (No. of vine cuttings)	Bhu Sona	900000
	Bhu Krishna	1000000
	Kishan	100000
	Sree Arun	4000
	Sree Kanaka	3000
	Gouri	3000
	Total	2010000
Chinese potato (No. of vine cuttings)	Sree Dhara	40000
Yam bean (kg)	RM-1	200

Annexure III

Statistics on tropical tuber crops

Global scenario

Area, production and productivity of tropical tuber crops (2020)

Crop	Area (million ha)	Production (million tonnes)	Productivity (t ha^{-1})
Cassava	28.24	302.66	10.72
Sweet potato	7.40	89.49	12.09
Taro	1.81	12.84	7.10
Yams	8.83	74.83	8.47
Tannia	0.03	0.40	12.44
Other roots and tubers	0.73	8.34	11.47
Total	47.04	488.55	Average: 10.38

Source: FAOSTAT, 2020

Indian Scenario

Area, production and productivity of tropical tuber crops in India (2020)

Crop	Area (lakh ha)	Production (million tonnes)	Productivity (t ha^{-1})
Cassava	1.64	5.04	30.75
Sweet potato	1.16	1.19	10.22
Taro	0.40	0.61	15.21
Yams	0.27	0.75	27.78
Elephant foot yam	0.33	0.80	24.27
Others	0.20	0.35	17.50
Total	4.00	8.74	Average: 20.96

Note: Cassava, sweet potato and elephant foot yam data for the year 2020; Taro, yams and others for the year 2018

Annexure IV

Status of export and import of cassava starch in India

Country wise export and import of cassava starch in India (HS Code: 110814)

Country	Average (2011- 2019)							
	Export				Import			
	Quantity (tonnes)	Value ('000US$)	Quantity (% share)	Value (% share)	Quantity (tonnes)	Value ('000US$)	Quantity (% share)	Value (% share)
UAE	504	51	12.84	7.85	42	18	0.24	0.25
Saudi Arabia	55	7	1.40	1.14	-	-	-	-
Sri Lanka	240	20	6.11	3.09	-	-	-	-
Bangladesh	436	33	11.12	5.03	-	-	-	-
Kenya	98	22	2.48	3.41	-	-	-	-
Nepal	85	11	2.15	1.67	-	-	-	-
Malaysia	921	235	23.46	36.22	-	-	-	-
Indonesia	114	131	2.90	20.26	-	-	-	-
South Africa	1082	125	27.57	19.25	-	-	-	-
Qatar	129	29	3.29	4.41	-	-	-	-
Cambodia	-	-	-	-	4521	2218	26.35	30.48
Vietnam	-	-	-	-	7308	2879	42.60	39.58
Thailand	-	-	-	-	4929	1950	28.73	26.81
UK	-	-	-	-	347	177	2.02	2.43
Total	3925	649	100	100	17157	7275	100	100

Source: World Integrated Trade Solution (WITS)

Annexure V

Weather Data 2021

ICAR-CTCRI, Head Quarters, Thiruvananthapuram, Kerala

Month	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No. of rainy days
	Max.	Min.	FN	AN		
January	31.4	22.4	99	62	0	0
February	33.5	22.6	96	48	0	0
March	33.6	22.9	92	78	60.2	2
April	34.0	22.9	89	73	81.8	8
May	31.5	24.4	86	80	695.7	17
June	30.7	24.6	87	81	94.2	8
July	30.3	24.3	92	85	186.7	11
August	30.0	24.0	93	90	136.1	13
September	30.3	24.3	89	79	219.0	13
October	30.0	23.9	91	85	309.4	18
November	29.4	23.5	89	79	336.7	17
December	30.4	23.1	84	72	7.6	1

ICAR-CTCRI Regional Station, Bhubaneswar, Odisha

Month	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No. of rainy days
	Max.	Min.	FN	AN		
January	30.5	16.3	93	39	0.0	0
February	32.8	15.3	92	28	0.0	0
March	37.7	23.0	94	33	7.5	1
April	38.5	25.8	90	44	7.2	2
May	36.5	26.1	89	58	200.3	9
June	34.0	26.3	93	69	352.0	15
July	33.5	26.1	93	75	265.5	14
August	33.3	26.1	93	75	285.1	17
September	32.4	25.5	95	80	579.4	16
October	33.0	24.7	93	67	77.2	8
November	30.2	21.8	87	69	82.6	4
December	26.8	15.2	91	73	72.6	3

Notes

‘Produce Tuber
Ensure food, nutrition
and livelihood security’

For further details please contact

E-mail : director.ctcri@icar.gov.in
Website : http://www.ctcri.org