आज़ादी का अमृत महोत्सव

CTCRI/QSF/RP/400

अनुसंधान विशिष्टताएं
Research Highlights

2021

भा कृ अ 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

भाकृअनुप ICAR

CTCRI केकफअसं

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ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE

(Indian Council of Agricultural Research)

Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

ICAR- Central Tuber Crops Research Institute
Sreekariyam, Thiruvananthapuram 695 017, Kerala, India
Tel.No.: (91) (0471) 2598551 to 2598554
Fax: (91) (0471) 2590063
E-mail: director.ctcri@icar.gov.in
Website: http://www.ctcri.org

Published by
Dr. M.N. Sheela
Director (A)

Editor-in-Chief
Dr. K. Susan John

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Design & Layout: St. Joseph's Press, Thiruvananthapuram, Kerala
Ph: 0471-2322888

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
ICAR-CTCRI 2021, Research Highlights 2021. ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India, 40p.

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 in a miniature vesion as the Research Highlights 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 farmers 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 document are gratefully acknowledged.

Sreekariyam
23.05.2022

Dr. M.N. Sheela
Director (A)

Contents

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.

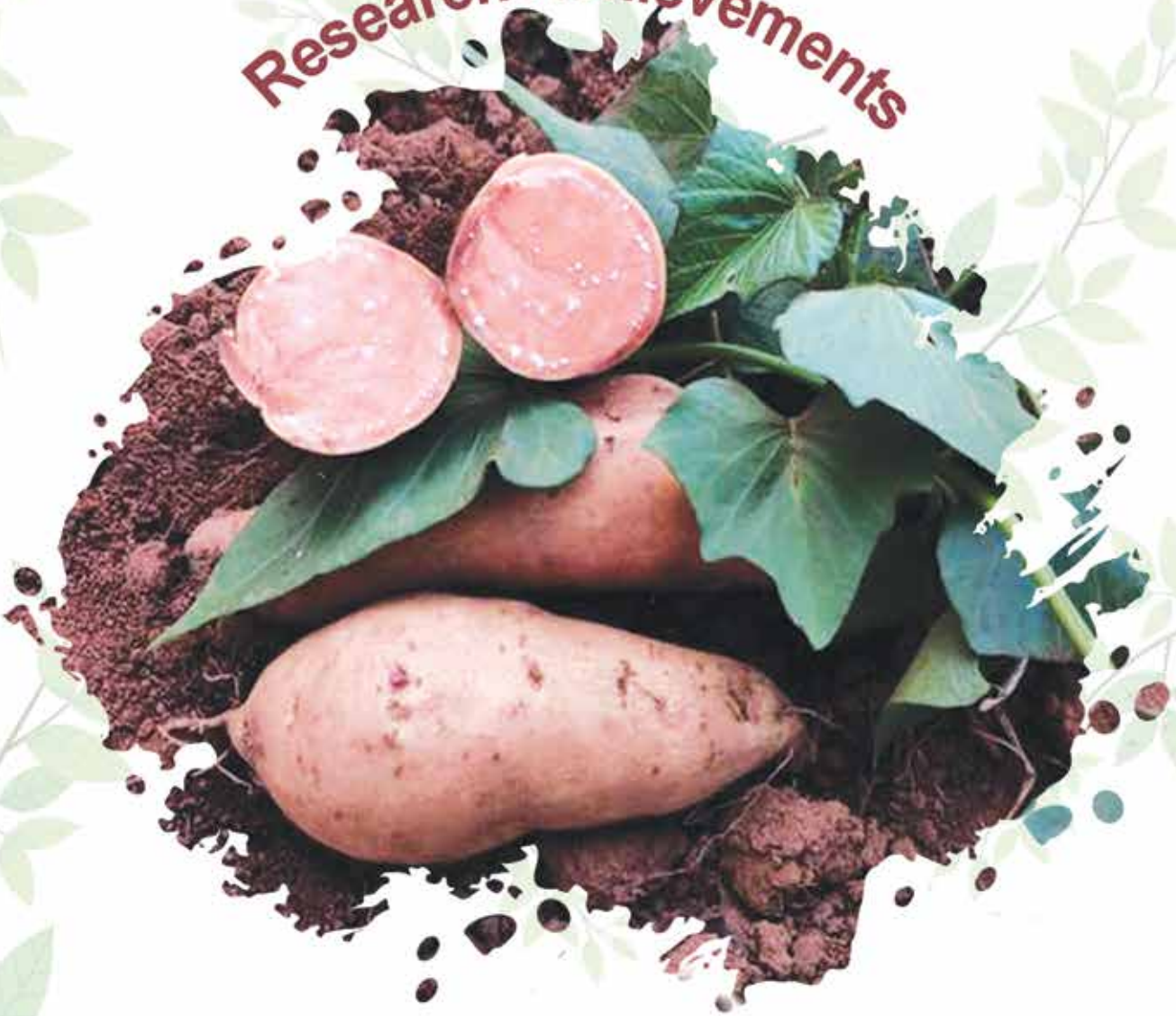
Mission

- 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

Research Achievements



Crop Improvement

This Division has two Institute projects and six externally funded projects

Institute projects

- Conservation and utilization of germplasm of tuber crops for sustaining production
- Genetic improvement of tuber crops through conventional breeding and molecular approaches

Externally funded projects

- Development of standards of DUS testing for varietal gene bank in elephant foot yam and taro
- Establishment of varietal gene bank and development of standards of DUS testing in yam bean (*Pachyrhizus erosus*) and greater yam (*Dioscorea alata*)
- Establishment of varietal gene bank and development of standards of DUS testing in cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*)
- *In vitro* quality planting material production of tuber crops to meet the demand of Odisha
- ICAR-CTCRI-CIP Collaborative work plan activity on crop improvement and varietal selection of sweet potato
- Applied mutagenesis in cassava for improved agronomic, disease resistance and post harvest traits

Salient research achievements

- The field gene bank (FGB) maintains 1226, 1110, 1121, 683 and 307 accessions of cassava, sweet potato, yams, edible aroids and minor tuber crops respectively at Head Quarters (HQ) and 1248 accessions of the above crops at Regional Station (RS).
- Of the total cassava accessions, 552 accessions maintained in the FGB were characterized for 29 vegetative, flower and fruit characters and incidence of Cassava Mosaic Disease (CMD).

- The characters of 375 indigenous cassava accessions pertaining to 51 traits were published as 'Catalogue of cassava genetic resources revised (Part-1)'.
- Cassava variety, 8S501(Sree Kaveri) with CMD resistance, drought tolerance and high yield (61.30 t ha^{-1}) was recommended by AICRP on tuber crops for central release for Kerala, Tamil Nadu and Andhra Pradesh for industrial use.

Fig. 1. Seed multiplication of 8S501

Fig. 2. Tubers of 8S501

- 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 tissues in the pith region of the stem in susceptible genotypes.
- Transcriptome sequencing of cassava accessions, 8S501 and H97 revealed that, 126 genes were up regulated and 129 genes were down regulated in both the genotypes and 2916 genes were up regulated in the genotype 8S501 and 1038 genes were down regulated in H97 under drought stress conditions.
- Identified the mutant cassava clones flowered in M_1V_2 generation of Sree Jaya having more female flowers with 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 from 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.

Fig. 3. Tuber yield of F_1 seedling progenies

Fig. 4. Tuber yield of F1 clonal progenies

- 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 carotenoids content of 2-20 mg 100g^{-1} on fresh weight basis.
- 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.

H-562/32 H-473/8 H-38/46 H-110/28

Fig. 5. Selected hybrid sweet potato accessions

- 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.

SB/21/57 RS-111-3 B × 7 S-162 SP-123

Fig. 6. Sweet potato genotypes identified for drought tolerance

- 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) sweet potato hybrids are under evaluation at RS, Odisha.

Fig. 7. Orange fleshed sweet potato hybrid lines

Fig. 8. Purple fleshed sweet potato hybrid lines

- 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 entries, DRS -1047 recorded the highest tuber yield (88.5 t ha^{-1}).
- Among the non trailing yam, 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}).

a. DRS-1047 b. SD-15 -tuber c. SD-15 :Plant

Fig. 9. Selected white yam accessions

- Optimized the *in vitro* pollen germination medium for greater yam to test the pollen viability of male parents.
- In 2021, the edible aroid germplasm was augmented with a total of 20 new accessions. The FGB of aroids consisted of 683 accessions comprising taro (429), elephant foot yam (203), tannia (48) and *Alocasia* (3).
- 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 the range in tuber yield as 5.25 t ha^{-1} (TCR-144) to 34.90 t ha^{-1} (SAASV-15). Of these, 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 five 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.

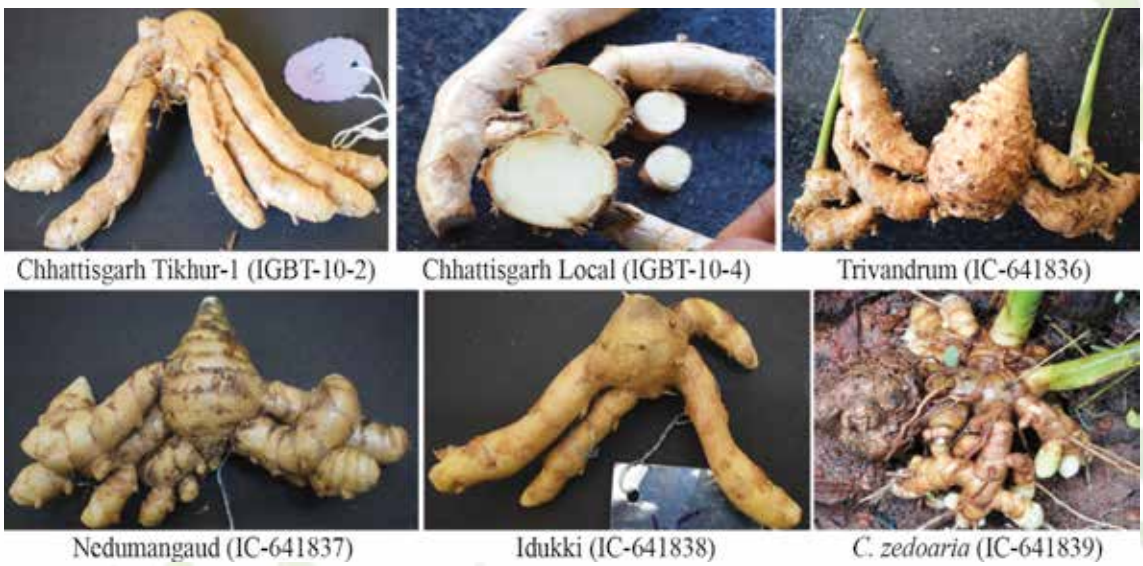


Fig.10. Rhizomes of *Curcuma angustifolia* and *Curcuma zedoaria*

- Methanolic extract of *C. angustifolia* showed antibacterial effects against *Staphylococcus aureus, Klebsiella pneumoniae, Mycobacterium smegmatis, Vibrio cholerae, Salmonella typhi* and antifungal effects against *Candida albicans.*

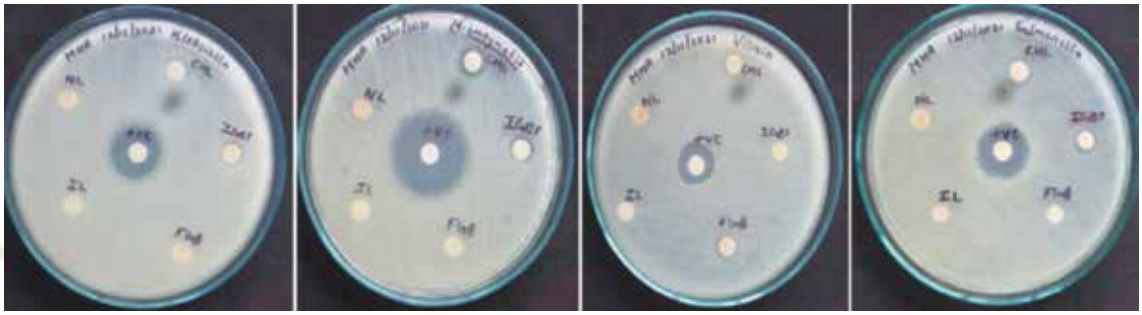


Fig.11. Antibacterial effects of *Curcuma angustifolia* accessions against different bacterial strains

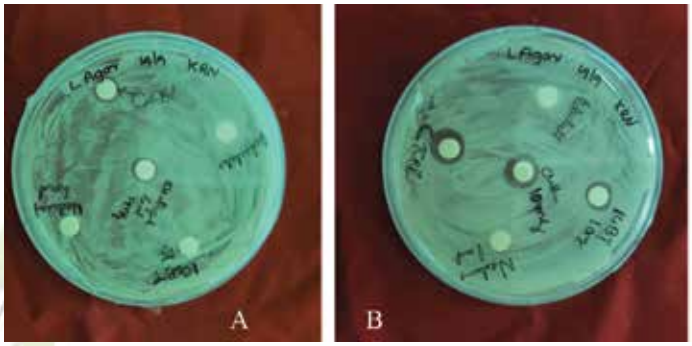


Fig.12. Dose dependent effects of *C. angustifolia* accessions against *S. aureus.* A.10 mg B. 5 mg

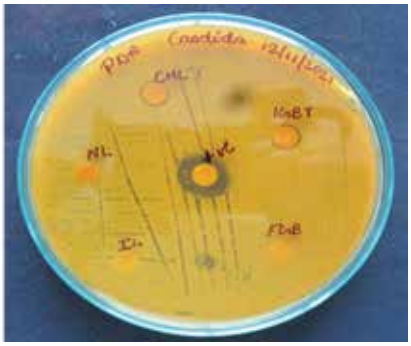


Fig. 12. Anti fungal effect of *C. angustifolia* accessions against *Candida albicans*

- Genetic variations were studied in 30 yam bean cultivars using molecular markers and biochemical characteristics.

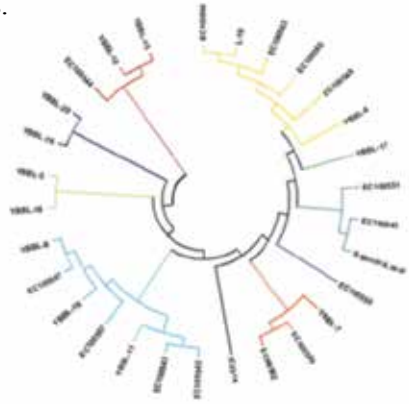


Fig.13. Dendrogram showing clusters of the 30 yam bean cultivars

- Proton induced X-ray emission (PIXE) technique was employed for the first time to determine the nutrient contents of 30 yam bean genotypes.

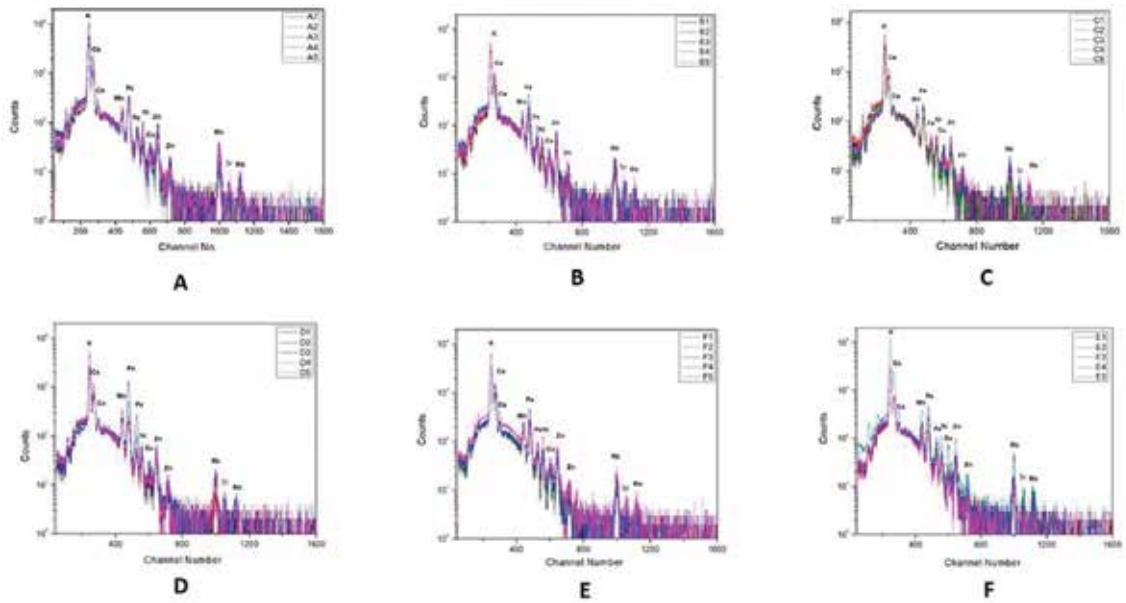


Fig.14. PIXE spectrum of 30 yam bean genotypes

- Five best yam bean hybrid lines (3×5, 3 ×8, 3×9, 3×10 and 9×10) were evaluated for yield and other biochemical traits at RS, Odisha along with the check variety (RM-1).

Fig.15. Best yam bean hybrid lines

- 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 recorded in dark black seed coat is due to the infection with *Penicillium sp.* and *Macrophomina phaseolina* in seed health test.

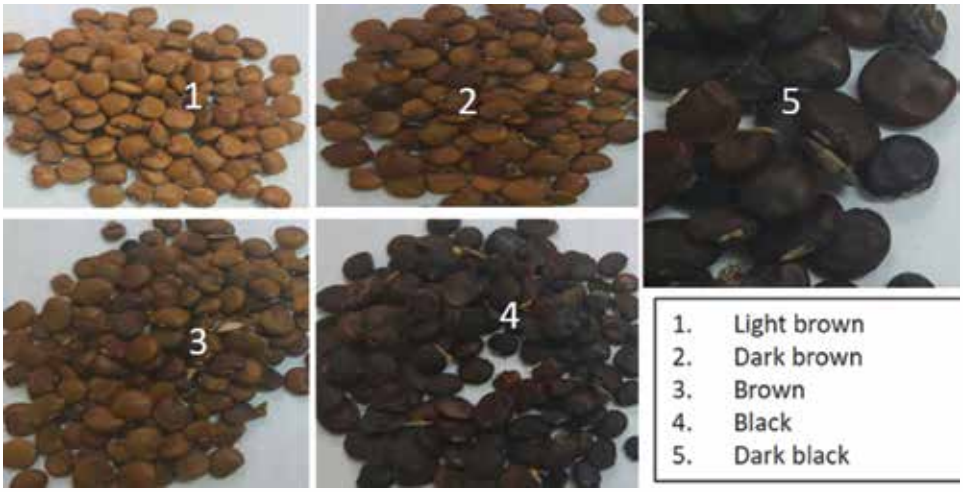


Fig. 16. Variation in the seed coat colour of yam bean seeds

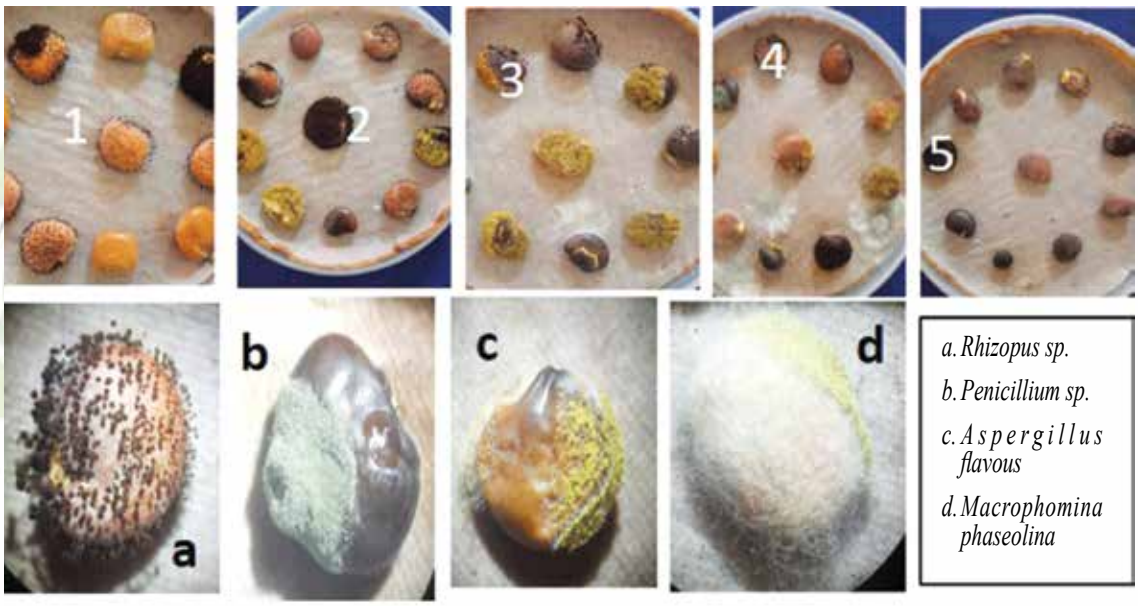


Fig.17. Seed health: Blotter test

- 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, 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 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 (Sree Dhara).
- DUS testing guidelines were developed for taro, elephant foot yam, greater yam and yam bean.

Crop Production

This Division has two Institute projects and seven externally funded projects

Institute projects

- Resource management and climate smart agriculture for sustainable production of tropical tuber crops
- Quality planting material production of tropical tuber crops

Externally funded projects

- All India-Network Programme on Organic Farming (AI-NPOF)
- Potential impact of climate change on tropical tuber crops yield in major growing areas of India
- Higher productivity and profitability from coconut gardens through soil health management in tuber crops
- Popularization of climate resilient and nutritionally rich varieties of tuber crops for economic development and nutritional security of farmers of Odisha
- Area expansion of sweet potato in Angul, Bolangir, Boudh, Deogarh, Keonjhar and Mayurbhanj districts of Odisha
- Chlorophyll fluorescence kinetics and monitoring of photochemical efficiency in cassava (*Manihot esculenta* Crantz) genotypes for energy efficient cassava
- 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

Salient research achievements

- 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.

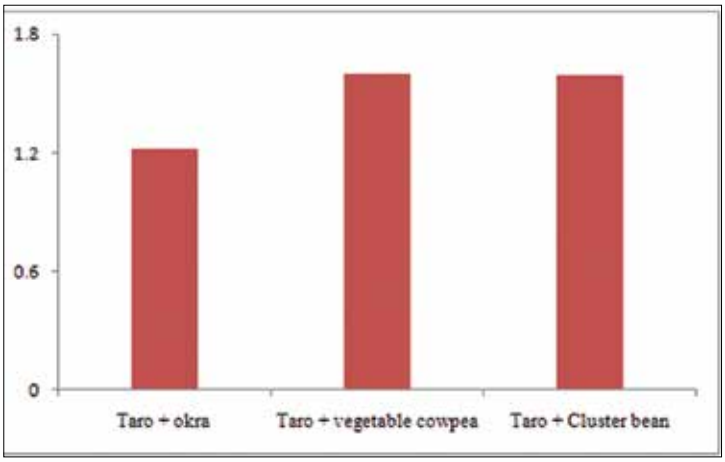


Fig.18. Effect of intercropping vegetables in taro on LER

- Organic farming of elephant foot yam based cropping systems with vegetables *viz., Amaranthus*, okra and cucumber under five different nutrient management options revealed better performance of all the above vegetables under organic practices.

Fig. 19. Field view of okra intercropped in elephant foot yam (EFY)

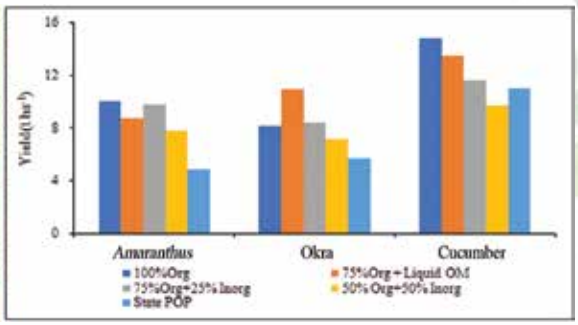


Fig. 20. Management options on the yield of vegetables intercropped in EFY

- 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 and corm and cormel yield as 7.54 and 18.31 t ha^{-1} respectively with higher gross and net returns and BC ratio (2.76).

- 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 74,000 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}).

Fig. 21. Fertigation studies in taro

- 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%) as compared to present recommendations.

Fig.22. On station experiments of SSNM in tropical tuber crops

- Balanced application of N:P: K @ 80:60:100 kg ha^{-1} resulted in higher yield response (94%) over NK (52%), > NP (46%) > and PK (43%) with the highest dehydrogenase and urease activities under N:P: K @ 80:60:80 kg ha^{-1} in greater yam.
- 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 had higher macro and micronutrients in tubers and leaves.

- Among the different INM approaches under the long term fertilizer experiment (LTFE), the soil and plant test based customized fertilizers (CF) resulted in the highest tuber yield (32.0 t ha^{-1}) on par with low input management strategy (LIMS) (27.7 t ha^{-1}) in cassava.

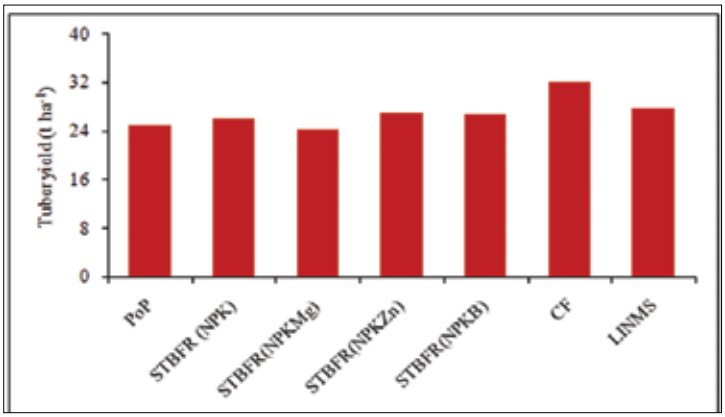


Fig. 23. Tuber yield under different nutrient management practices

- Soil application of borax @ 25 kg ha^{-1} (half each at basal and 3-4 MAP), foliar application of solubor @ 0.1% along with calcium nitrate @ 1% (during 3-4, 5-6 and 7-8 MAP) and soil application of lime @ 2 t ha^{-1} emerged as a corrective measure for the suspected B deficiency in yams.

Fig .24. View of the yam experiment to diagnose the suspected B deficiency

- Soil B critical level for tuber cracking in sweet potato was found as below 0.5 ppm.

Fig. 25. Effect of soil B on tuber cracking in sweet potato

- Application of nutrients *viz.,* P, K, Ca, Zn and Si resulted in the reduction of mean percentage disease incidence (PDI) of CMD 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 and lowest in red soils (5.8 g kg^{-1}), labile carbon was maximum in clay loam (546.0 mg kg^{-1}) and the lowest under laterites (263.5 mg kg^{-1}).

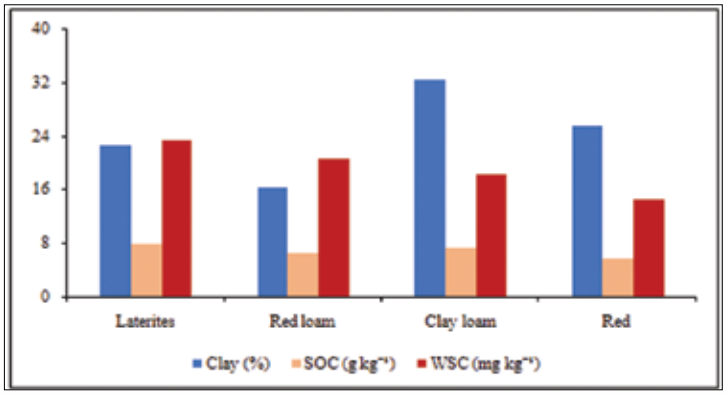


Fig.26. Influence of soil types on carbon fractions

- 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}).

Fig. 27. On station field experiment on climate smart agriculture

- 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.
- The first year results showed that, foliar application of 1% KNO_3 (T_5) 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.

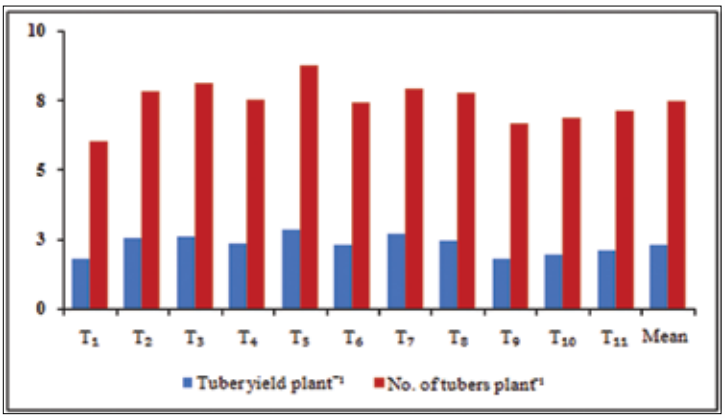


Fig. 28. Effect of nutrients on cassava tuber characters under early season water deficit stress

- 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.

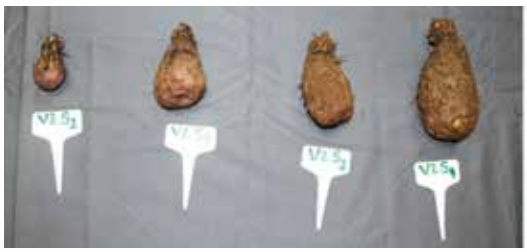


Fig. 29. Effect of seed yam size on tuber bulking in greater yam

Fig. 30. Yam crop planted with minisetts

- 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, in 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 control light treatment (4.31±0.32 kg) compared to intermittent high light condition (4.11±0.44 kg) and was found to be tolerant to light fluctuations.
- A total of 1,15,000 cassava stems, 37.5 MT elephant foot yam, 32.5 MT greater yam, 3 MT white yam, 3.50 MT lesser yam, 14,10,000 sweet potato vine cuttings, 30,000 Chinese potato vine cuttings and 200 kg yam bean were produced as quality planting material.

Fig. 31. Quality planting material production in yams

- 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.
- Refined the Integrated organic farming system (IOFS) model 1 and developed model 2 comprising, cropping systems involving horticulture and food crops (fruit crops, tuber crops, vegetables, pulses, oilseeds), hedge crops, fodder and dairy unit which fetched a tuber equivalent yield of 20.2 tonnes and net return of ₹ 15030 from an area of 75 cents.

Fig. 32. General view of IOFS model-2

- Under RKVY in Kerala, quality planting materials of elephant foot yam, cassava and sweet potato were produced in an area of 5.5, 2 and 0.5 acres respectively.
- Under RKVY in 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.

Fig. 33. Yam+maize intercropping

Fig. 34. EFY planting material under storage

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

Crop Protection

This Division has two Institute projects and one externally funded project

Institute projects

- Development of innovative technologies for the intensification of pest management in tuber crops through biorational approaches
- Development and refinement of integrated disease management and forecasting system for improved tuber crops production

Externally funded projects

- Development and application of diagnostics to viruses infecting tuber crops (elephant foot yam, cassava, sweet potato and yams)

Salient research achievements

- Screening of biopesticides *viz., Nanma* along with five other biopesticides *viz.,* Nimbeicidine, 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 (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% mortality) and flonicamid 50% WG (Ulala®) (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.

Fig. 35. Chrysomelid beetle attack in EFY leaves

- 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.

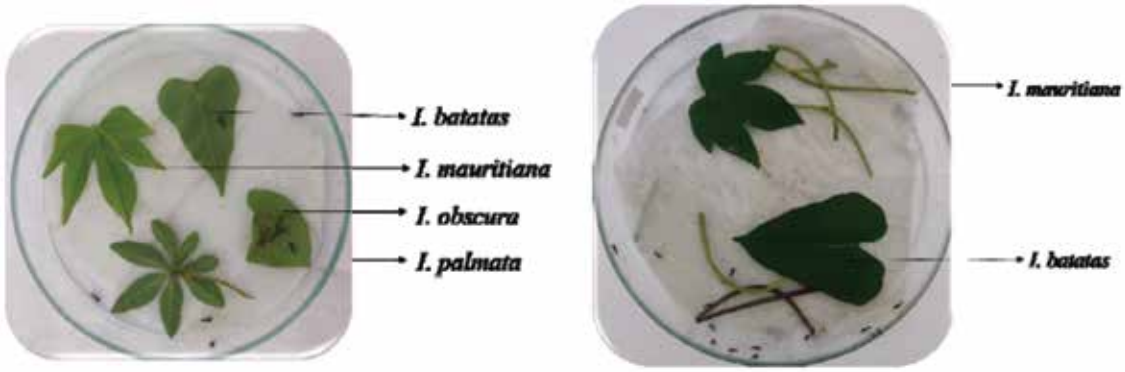


Fig. 36. Morphological screening of leaves and vines of *Ipomoea batatas* and different *Ipomoea* sp. against SPW

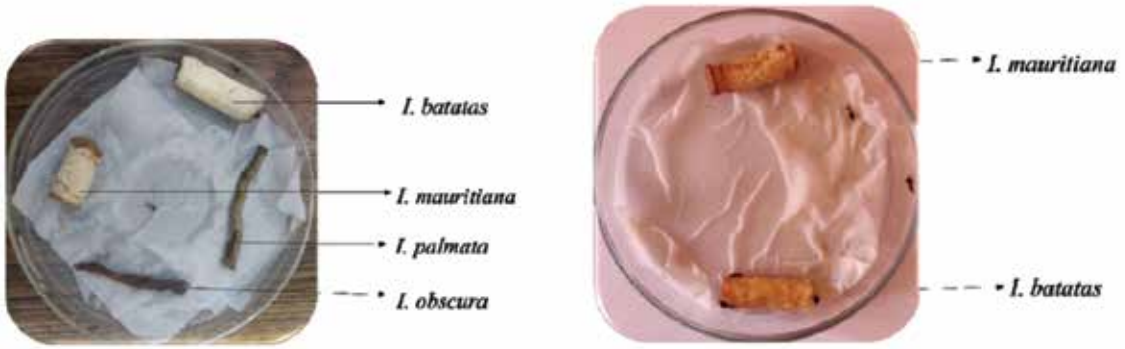


Fig. 37. Morphological screening of tubers of *Ipomoea batatas* and different *Ipomoea* sp. against SPW

- PCR amplification of protease inhibitor, cysteine protease inhibitor and kunitz trypsin inhibitor genes with specific primers were established in four *Ipomoea* sp.
- Velum Prime (0.5 & 0.75 ppm) was the most effective among the tested chemicals causing cent percent mortality and hatching inhibition of *Meloidogyne incognita,*under *in vitro* at 24, 48 and 72 hrs after treatment.

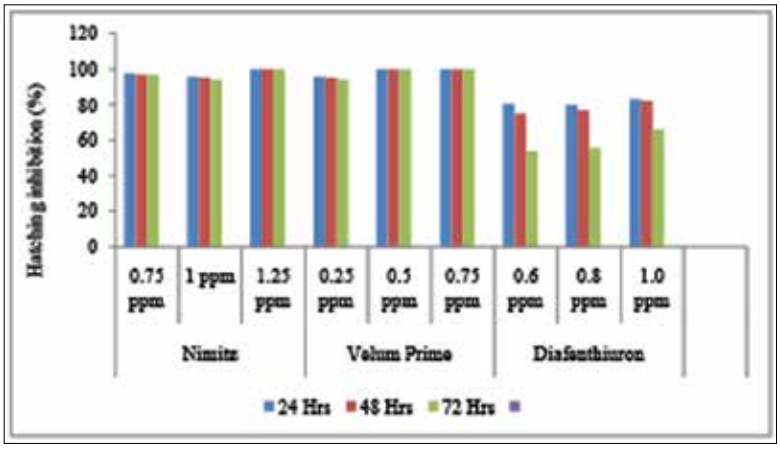
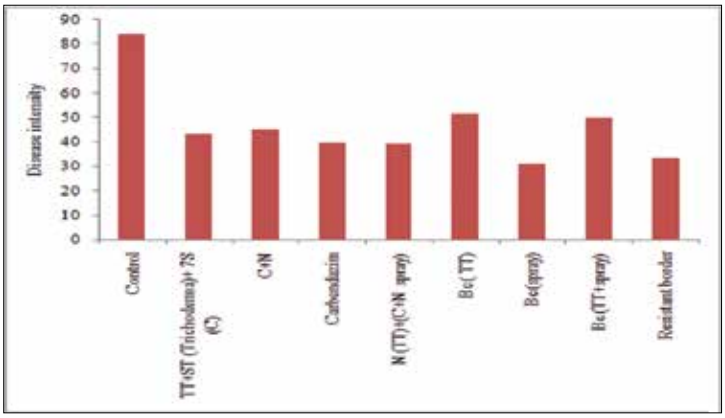


Fig. 38. Effect of chemicals on hatching inhibition at different intervals

- Fungal bioagent *Trichoderma asperellum* (isolate Tr-9) was highly compatible with the nematicide carbofuran, while the biopesticide, *Nanma* was highly incompatible with *Trichoderma,* under *in vitro*
- In cassava, the pathogen associated with stem and root rot belongs to FSSC (*Fusarium solani* species complex) Clade 3. In the 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 .

Fig. 39. Cassava root and stem rot symptoms

- 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%).



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

Fig. 40. Effect of treatments on anthracnose intensity in greater yam (var. Orissa elite)

- 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 µg ml^{-1}, difenconazole and carbendazim + mancozeb were highly effective against *C. gloeosporioides*, with 100% mycelial inhibition at 18.75 µg ml^{-1}, whereas hexaconazole and difenconazole were highly inhibitory to *S.rolfsii*, with 100% mycelial inhibition at 3.125 µg 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}).

Fig. 41. DSS developed for taro leaf blight

- Compatibility studies of *Trichoderma asperellum* with twelve fungicides at concentrations ranging from 3.125 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 districts *viz.,* Thiruvananthapuram, Kozhikode and Kottayam 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.

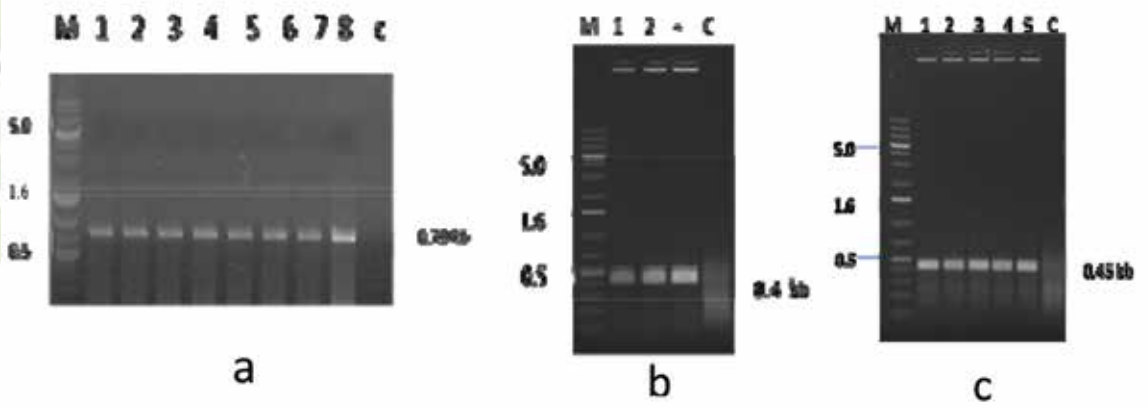


Fig. 42. RPA based diagnosis of virus infection. a. SLCMV, b. DsMV and c. SPFMV

- 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

This Section has one Institute project and two externally funded projects

Institute projects

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

Externally funded projects

- Techno Incubation Centre (ICAR-CTCRI-HQ)
- Establishment of techno incubation centre at the ICAR-CTCRI-RS, Odisha for commercialization of value added products from sweet potato and other tuber crops

Salient research achievements

- The biomass distribution of leaves, stem, peel and tuber of different varieties of cassava indicated the stem weight ranged from 27.45 % (H-226) to 42.23 % (Sree Vijaya), tuber mass fraction ranged from 43.38 % (Sree Vijaya) to 61.97 % (H-226) (Sree Suvarna). The Vellayani Hraswa had the maximum leaf mass fraction (19.05 %) while Sree Pavithra had the minimum (2.44 %).
- Drying characteristics of the cassava stem under sun and mechanical tray drying indicated the average drying rate as 0.358 g water min^{-1} $100g^{-1}$ bone dry material under sun drying and 0.739 g water min^{-1} $100g^{-1}$ bone dry material under mechanical drying.
- Standardization of method for extraction of starch from cassava stem by varying the size of the stem (fine, medium and large) and soaking time (8, 16 and 24 h) indicated the starch recovery from cassava stem ranged from 10.1 to 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 preparation 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.

Fig. 43. Thermoplastic starch sheet from cassava starch-rice husk composite flour

- 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.

Fig 44. Thermoplastic starch sheet from cassava starch-paddy straw composite flour

- 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 soyabean 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.

Fig. 45. (a) Cassava starch-graft-soybean oil maleate (CS-SOMA) and (b) Biodegradable film prepared from CS-SOMA

- The reaction conditions were standardized for synthesizing different levels of cross linked cassava starch by using sodium tri poly phosphate (STPP) and sodium tri meta phosphate (STMP) reagents in different molar ratios and some of which could withstand high temperatures and were found to be non gelatinizable.

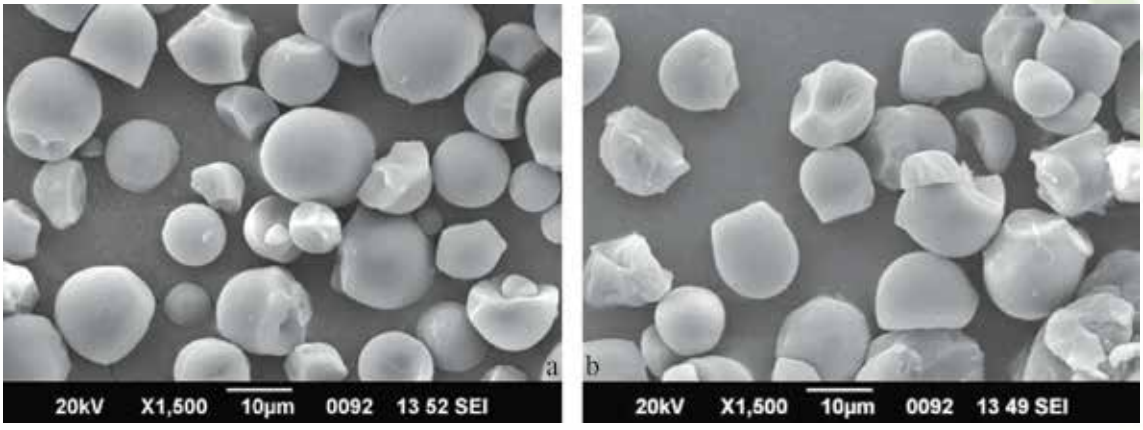


Fig. 46. Scanning electron micrograph of (a) native cassava starch and (b) cross linked cassava starch

- Wet milling of *Alocasia* tubers after pretreatment with sodium meta bisulphite 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.

a) Small b) Medium c) Large

Fig. 47. Different commercial grades of Chinese potato tubers

- Chinese potato grader was designed and developed with one ton capacity per hour which can separate tubers based on size as small, medium and large.

Fig. 48. Power operated Chinese potato grader

- 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 content (59.61 %) on dry weight basis (DWB).

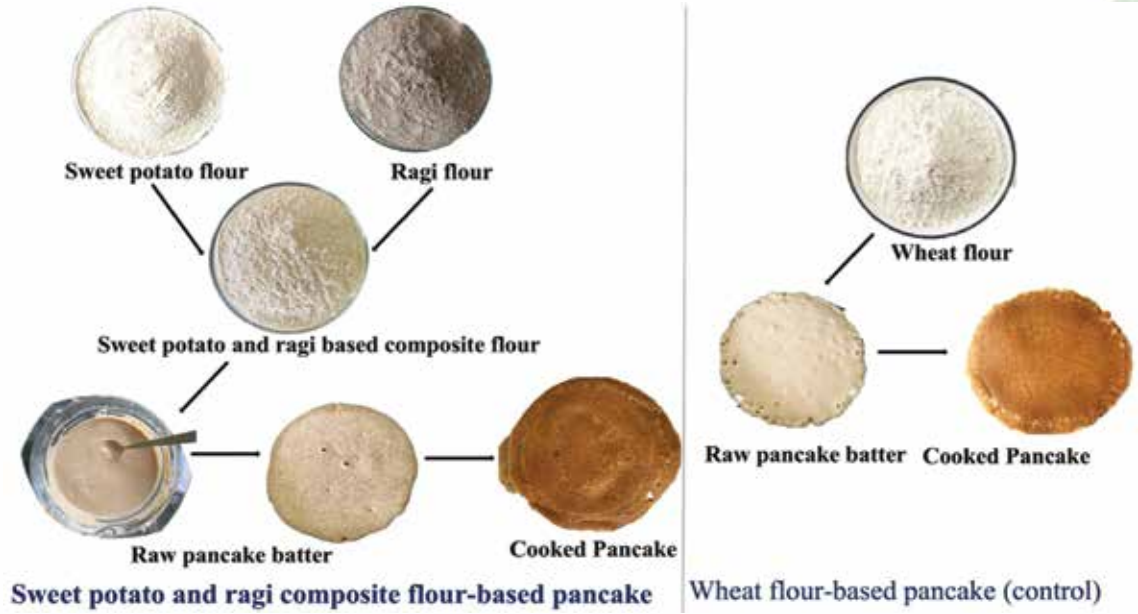
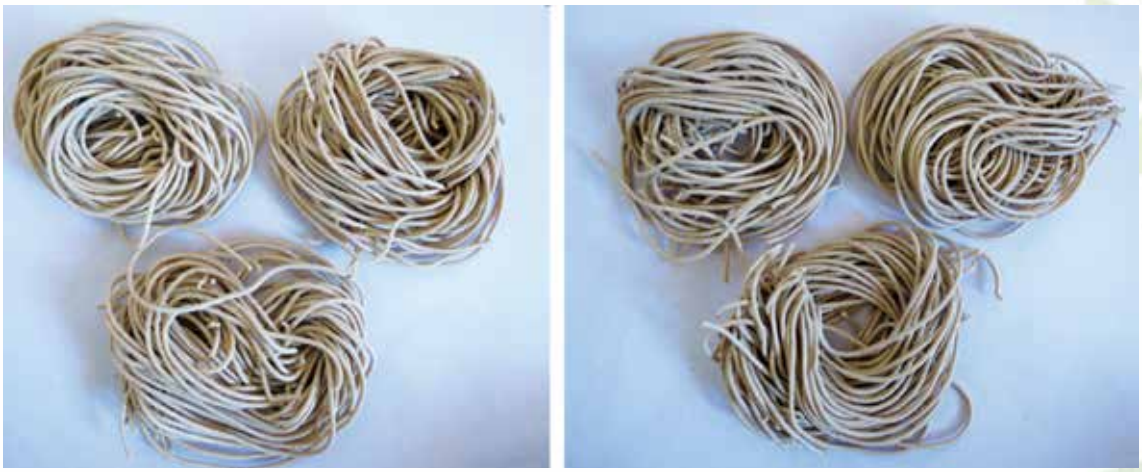


Fig.49. Sweet potato-ragi composite flours based pancake mix and products and control (wheat based pancake mix and pancake product)

- Functional noodles were made with a composite flour containing 66.3% sweet potato, 13.69% banana flour and 20.60% maida.



Banana flour based sweet potato noodles | Control

Fig. 50. Sweet potato based functional noodles

- Functional pasta was made with a composite flour containing 72.45% sweet potato, 24.92% maida and 2.63% *Moringa* leaf powder.

Control | *Moringa* leaf based pasta

Fig. 51. Sweet potato based functional pasta

- The Techno Incubation Centre at HQ and RS organized nine on campus, 25 off campus and 24 practical demonstration cum trainings on value added products from tuber crops and entrepreneurship development benefitting 1410 farmers and 15 entrepreneurs from Kerala and Odisha.

Extension and Social Sciences

This Section has one Institute project and five externally funded projects

Institute projects

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

Externally funded projects

- Development of smart solutions for managing biotic and abiotic stresses in cassava, sweet potato and taro through artificial intelligence
- Improving rural agro system through horticultural crops based smart farming technologies
- Smart cassava farms: Validation and upscaling of AI & an IOT device
- National Agricultural Innovation Foundation (NAIF) - Component I - Innovation Fund
- NAIF-Component II-Agribusiness Incubator

Salient research achievements

- Fifteen FLDs on improved varieties of Chinese potato (Sree Dhara) conducted in Tirunelveli and Tenkasi districts of Tamil Nadu showed that, the yield of Sree Dhara (24.43 and 24.87 t ha^{-1}) was higher than the yield of local varieties (21.17 and 21.93 t ha^{-1}). Net income realized from Sree Dhara was ₹ 2.79 lakh and ₹ 3.22 lakh ha^{-1} with B:C ratio: 3.51 and 3.84 in comparison to local varieties, which was ₹ 2.31 lakh and ₹ 2.74 lakh

Fig. 52. FLDs on Chinese potato var. Sree Dhara at Tirunelveli and Tenkasi

ha^{-1} with 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 for school children in Arunachal Pradesh and college students in Tripura indicated, orange fleshed sweet potato (OFSP) had better preference than purple fleshed and white fleshed sweet potato 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.

Fig. 53. Sensory evaluation and consumer assessment of biofortified sweet potato pasta

- Mapping of women empowerment in Tenkasi and Tirunelveli districts of 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. 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.

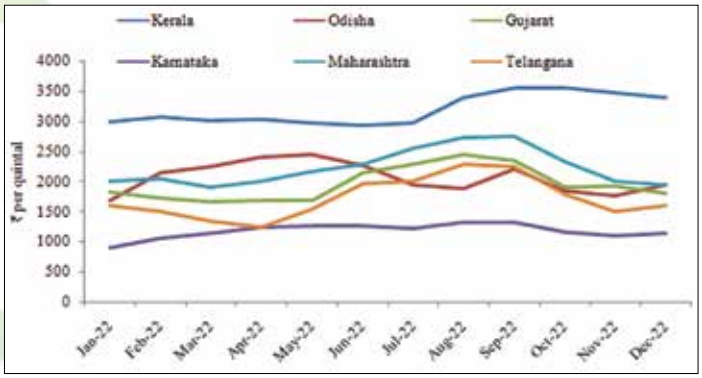


Fig. 54. Forecasted price of sweet potato in selected states of India using SARIMA

- e-Crop based smart farming technology was developed and demonstrated in sweet potato field by setting up a smart fertigation facility on station.

Fig. 55. e-Crop units installed at ICAR-CTCRI-HQ and a Panchayat in Thiruvananthapuram

- 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.

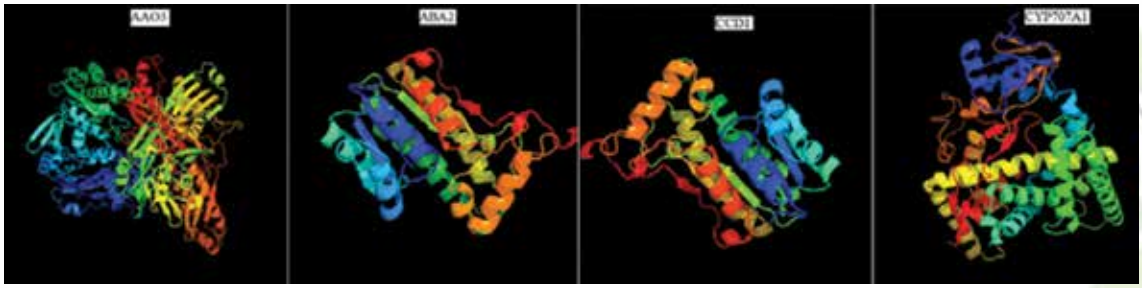


Fig. 56. Protein structure of the representative genes involved in the carotenoid biosynthetic pathway

- *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 developed for cassava intra species PPI.
- D-Script deep learning technique was performed in python environment.
- Mobile application named ‘ Krishi Krithya’ app was used for smart farming.

Fig. 57. Views of mobile app 'Krishi Krithya'

- A patent for 'Apparatus and process for extraction of biopesticides from cassava bio wastes' developed by ICAR-CTCRI was granted for 20 years from 5 March 2012.

Fig. 58. Patent document

Fig. 59. Apparatus for extraction of biopesticides

- Four technologies were commercialized to 11 entrepreneurs and one contract research is underway.

Technologies Generated and Transferred

a. 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 ton 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

b. 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 Andhra 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 of cassava at Thirupathisaram, Tamil Nadu

c. 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

General Achievements

- The 21st annual group meeting of AICRP-TC held at ICAR-CTCRI during 27-28 May, recommended one cassava variety and four greater yam varieties for release along with four management technologies.
- Under SCSP, 185 demonstrations on improved varieties and production technologies of tuber crops were conducted in Kerala, Tamil Nadu and Andhra Pradesh. Twenty nine outreach programmes were conducted for the benefit of 2097 farmers and other stakeholders.
- Under NEH, six outreach programmes 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.
- Under MGMG, a total of 44 villages were adopted by 44 scientists as ten teams in Thiruvananthapuram and different districts of Odisha.
- Under soil health card programme, soil health cards were issued to MGMG farmers of Pothencode, Kazhakuttam and Andoorkonam during the World Soil Day and farmers under SCSP of the Perunkadavila and Kunnathukal panchayats of Perunkadavila block.
- Under Swachh Bharat Abhiyan, Swachhata Pakhwada and Special National Swachhta Campaign on 'Waste to health' were organized. An awareness programme on 'Waste to Wealth' was organized for 50 farmers of Chenkal and neighbouring villages of Thiruvananthapuram. Two lectures on the composting of farm waste and family net vessel composting were delivered. The staff of the Institute cleaned the premises of the nearby primary health centre at Pangappara. At RS, Odisha, the

campaign was organized at Madhuban village, Cuttack district which was attended by 60 farm women.

- A total of 25 scientists, four technical staff , four administrative|accounts staff and two skilled support staff attended various training programmes
- A total of 13 training cum seminars on tuber crops technologies were conducted benefitting more than 2500 stakeholders
- Under the education programme, 62 PG students did their project work, 114 students underwent professional internship, 20 students are doing their Ph.D, two sudents were awarded doctorate and three students completed their rural work experience programme.
- Under Azadi Ka Amrit Mahotsav, 29 webinars including international were conducted and 16 important national | international days and nine iconic events were celebrated.
- Sixteen exhibitions were conducted as a part of the trainings on 'Improved technologies of tuber crops for increasing farm income'
- The Institute HQ and RS was visited by 575 farmers, 96 students and 23 officials from all over the nation
- Scientists of the Institute had served as resource persons for more than 125 classes on different aspects *viz.,* tuber crops varieties, production, protection, processing, value addition and entrepreneurship development.
- Field problems as reported by the farmers from Kerala, Tamil Nadu, Andhra Pradesh and Odisha were addressed by the scientist. Queries put forth by the farmers were answered on timely basis.
- Krishi Vigyan Award 2021, Government of Kerala was received for the smart farming initiatives in tuber crops
- Publications included 58 research papers with a total impact factor of 88.12 during this year, 53 popular articles, two books, 26 book chapters, 57 presentations, 7 technical bulletins, 7 course manuals, 76 leaflets/folders, one compendium paper, four Institute publications and one e- publication
- Social media activities included four TV programmes, eight radio talks, one YouTube and six facebook live programmes.

'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

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