# RESEARCH HIGHLIGHTS

## Commercial Crop Improvement

- The high-yielding FCV tobacco variety FCJ-11 (CTRI Naveena), developed through somaclonal variation, has been released for commercial cultivation in the Northern Light Soil (NLS) zones of Andhra Pradesh. This variety gives a mean yield of 3300 kg/ha, enhanced nutrient use efficiency, and resistance to black shank and waterlogging. It has been notified through the Central Variety Release Committee (CVRC).
- The FCV line FCR-15 (CTRI Sreshta), recording a yield of 2400 kg/ha and resistance to Tobacco Mosaic Virus (TMV), was developed through targeted breeding and is now released for cultivation in Southern Light Soil (SLS) zones of Andhra Pradesh, and notified through CVRC.
- Two FCV cultivars (FCH 2 & FCRH 11) and one *bidi* variety (NBD 316) have been identified for release in Karnataka.
- The novel CMS-based FCV hybrid FCHH-2 (yielding 3300 kg/ha) significantly outperformed CH 3 (yielding 2700 kg/ha) in on-farm trials conducted at Harave village, Periyapatna. FCH 2 demonstrated an average yield increase of approximately 20% over checks (CH 3, Kanchan, and FCH 222) and showed no *Fusarium* wilt incidence.
- Entries SJ-14 and SJ-16 recorded significantly higher cured leaf yields (3492 kg/ha and 3264 kg/ha, respectively) and grade index values (2143 and 2075) under NLS conditions, surpassing the check variety Kanchan.
- Genotypes RS 52, RS 53, RS 54 and RS 55 recorded significantly higher cured leaf yield (1589 to 1678 kg/ha) with 16-22% improvement over the check CTRI Sulakshana in black soils.
- In Karnataka, FCH-272 and FCH-276, two high-yielding FCV lines, exhibited promising leaf yields in the KLS agro-climatic zone.
- Selected advanced breeding lines (V 5148, V 5149, V 5152, V 5154, RS 49, RS 53, RS 54, and KDB 3) demonstrated drought tolerance at the seedling stage under controlled artificial conditions.
- Six FCV entries (RS 37, RS 40, SJ 14, SJ 16, FCH 266, KRB 3) contributed to the initial varietal trial (IVT) for multilocation evaluation under the All India Network Project on Tobacco (AINPT).
- Out of 33 released varieties evaluated, three (Dhanadayi, Hema and Kanakaprabha) exhibited promising performance in bright leaf quality under SLS conditions.
- A total of 1,517 germplasm accessions, encompassing various tobacco types and wild *Nicotiana* species, have been regenerated.
- A core germplasm collection comprising 230 accessions was developed from 2,600 accessions representing 14 tobacco types, utilizing an advanced heuristic-based sampling strategy with PowerCore (Version 10).
- Molecular marker analysis identified 83 polymorphic markers capable of differentiating *Fusarium* wilt resistant and susceptible genotypes within FCV tobacco.
- Gene expression profiling revealed elevated expression levels of CYP82E4, CYP82E5, and CYP82E10 genes implicated in the biosynthesis of Tobacco-Specific Nitroso Amines (TSNAs), in high-nicotine-converting lines across all leaf positions.
- In chilli, promising genotypes *viz*., Kashi Gourabh, Dinhata Local 4, and DinCh-330, which exhibited higher yields. Additionally, King Chilli 2 showed increased pericarp thickness, Jalpaiguri local demonstrated higher carotenoid content, and Tamenlong King Chilli had elevated capsaicin levels.

- 453 Withania somnifera accessions collected from NBPGR were multiplied and characterized for DUS traits.The genotypes WS 139 (high root yield), WS 4 (dry root yield), and WS 296 (Withaferin A content: 1225 ìg/mg) were identified for further evaluation.

## New Research Initiatives in the Division of Crop Improvement

Addressing challenges posed by climate change, evolving consumer preferences, and export bottlenecks, the division has initiated multiple research programs focusing on tobacco and other mandated crops.

1. In collaboration with M/s Alliance One Industries India Ltd., a project has been launched to develop and evaluate burley hybrids with enhanced leaf yield and quality for non-traditional cultivation regions.
2. Joint research initiated with M/s GPI Ltd. aiming to exploit burley germplasm for water stress tolerance, leveraging donor genotypes to breed drought- and waterlogging-tolerant cultivars.
3. To accelerate cultivar development via molecular breeding, whole-genome sequencing of 100 diverse indigenous and exotic germplasm accessions (comprising FCV, burley, and *bidi* types) is underway.
4. A project, in partnership with M/s ITC Ltd., seeks to identify molecular markers for *Fusarium* wilt resistance to streamline the development of resistant tobacco cultivars.
5. Studies on host-parasite interactions of tobacco *Orobanche* parasitism are progressing through transcriptomic and metabolomic analyses in collaboration with M/s ITC Ltd.
6. CRISPR-based gene editing targeting CYP82E4, CYP82E5, CYP82E10, and the vacular nitrate transporter gene CLCNt2 is being pursued to reduce TSNA levels in burley and chewing tobacco.
7. To ensure timely seed supply, advanced automated seed packaging machinery has been installed and is operational under the ICAR-NIRCA RF scheme.
8. Germplasm collected from North-east India, Kashmir, and local sources aims to identify high-value chilli lines rich in bioactive compounds and colour.
9. Breeding efforts are ongoing to develop chilli lines with enhanced bioactive content and value-added traits.
10. Research is underway to identify chilli genotypes suitable for processing into products such as chilli powder and flakes, based on capsaicin and pigment profiles.
11. Efforts are in progress to secure Geographical Indication (GI) status for Durgada chilli, a high-color and medium-pungency variety cultivated in the erstwhile East Godavari district.

## Crop Production Management in Commercial Agriculture

### Agro-technologies

- The highest cured leaf yield, grade index and system productivity, based on Tobacco Leaf Equivalent Yield (TLEY), amounted to 1635 kg/ha under wide spaced paired row planting (WSPRP) of tobacco + chickpea (0.6 m × 0.35 m + 2.5 m). This system demonstrated superior performance in terms of leaf quality and overall productivity.
- Integration of intercultural operations with a power weeder, coupled with a pre-emergence application of pendimethalin (0.6 kg a.i./ha, 38.7% SC) and a post-emergence application of Quizalofop-ethyl (5% EC at 0.06 kg a.i./ha), resulted in enhanced weed control efficiency (89.9%). This approach also yielded higher productivity in chilli, with an observed yield of 2541 kg/ha.

- The novel suckericide SUCKERSTOP™ effectively suppressed sucker growth (by 93–95%) across diverse agro-climatic zones of Andhra Pradesh and Karnataka, as well as in Vinukonda burley tobacco, with residue levels remaining below the Guidance Residue Levels (GRL).
- In Burley tobacco cultivation, varieties YB-22 and Banket A1 recorded higher yields at Giddaluru; however, their yields were statistically comparable. Similarly, YB-22 and Win-5 achieved higher yields at Nandyal, both statistically on par. At Vinukonda, all three burley varieties YB-22, Banket A1 and Win-5 are on par with each other.
- A 15% increase in fresh red chilli yield was achieved through application of Plant Growth Promoters (PGP), specifically formulations PGP-2 (indigenous strain), Arbuscular Mycorrhizae and Arka Samhita.
- The innovative Rice Husk Ash-Potassium Functional Organic Fertilizer (RHA-K-FOF), combined with Recommended Dose of Fertilizers (RDF), significantly improved yield and quality parameters in turmeric. Optimal production was observed when planting was done in the first week of April at selected locations.
- In turmeric, maximum rhizome yield was obtained with planting schedules aligned to local agro-climatic conditions, notably in the Eastern Himalayan zone. The highest yield was recorded with FYM (40 t/ha) combined with microbial consortia - formulated by ICAR-IARI, which enhances nutrient bioavailability and plant growth.

## Resource Optimization

- The FCJ-11 variety with a nitrogen (N) fertilization of 135 kg/ha and potassium (K) of 150 kg/ha exhibited superior agronomic and economic efficiencies, including higher AUEN (Agronomic Use Efficiency of Nitrogen), NREN (Nutrient Responsiveness Efficiency), partial factor productivity of nitrogen, and overall economic efficiency. Physiological efficiency (16.08–16.88), Nutrient Harvest Index (58.73–59.68), and internal efficiency (21.87–22.54) remained consistent across treatments. Notably, nitrogen application at 135 kg/ha outperformed 180 kg/ha concerning efficiency metrics.
- The same variety FCJ-11 with N135 and K100 application rates demonstrated higher AUEK (Agronomic Use Efficiency of Potassium), FUEK (K Use Efficiency), physiological efficiency of potassium, translocation index (NHIK), internal efficiency of potassium, PFPK (Physiological Fertilizer Productivity of Potassium), and economic efficiency of potassium.
- Recommendations includes the application of customized fertilizers supplemented with TracssureTM and AkreshieldTM products to optimize nutrient use and crop yields in tobacco given to farming community.
- A novel potassium supplement, Boronated Potassium Schoenite, was recommended at 652 kg/ha in three splits (1:2:1 ratio at 10, 30 and 45 days after planting) for FCV tobacco in the NLS region of Andhra Pradesh, and 522 kg/ha in two equal splits (1:1 at 10 and 30 days) for the KLS region of Karnataka.
- The Sunnhemp–Tobacco cropping system recorded the highest soil organic carbon (SOC) sequestration (34 Mg/ha), followed by Fallow–Tobacco (30 Mg/ha), while the Korra–Tobacco system recorded the lowest (25 Mg/ha).
- Among five auction platforms in the Northern Light Soils of Andhra Pradesh, Jangareddygudem-II exhibited the highest Shannon-Weiner Diversity index (H'), indicating greater functional microbial diversity.
- Green manuring with *in situ* sunnhemp mulch combined with integrated nutrient management (INM) by incorporating inorganic fertilizers (RDF), FYM (5 t/ha), *Azospirillum*, and *Trichoderma* biocapsules, resulted in the highest yields of turmeric rhizomes, achieving 46.9 t/ha fresh weight, 8.4 t/ha dry weight, and a curcumin content of 3.45%.

## Cropping systems

- The Turmeric–Blackgram (*Kharif*) – Tobacco (*Rabi*) – Groundnut relay cropping system yielded higher net returns compared to other turmeric-based systems, with Korra–tobacco securing significantly higher net income.
- The Aggregatum onion cultivated as a sole crop achieved the highest net returns (~Rs. 3,54,790/ha) and system productivity (18.89 t/ha). The Moringa–Ashwagandha intercropping system demonstrated a higher Land Equivalent Ratio (LER) of 1.76, indicating better land use efficiency.
- Among castor-based cropping systems, Castor + Cluster bean (1:3) and Castor + Groundnut (1:3) yielded the highest net returns under SLS conditions.

### Biotic stress management

- Whitefly (*Bemisia tabaci*) infestation in tobacco led to elevated peroxidase activity (4.41 U/gm leaf), indicating plant response to biotic stress.
- Screening of 153 *Jati* and *Motihari* tobacco germplasm accessions identified 70 accessions exhibiting moderate resistance to whitefly infestation.
- Application of Fluopyrum 400 SC at 0.05% significantly reduced root-knot disease incidence (root-knot index (RKI)) from 3.64 to 1.56 and decreased soil nematode population by approximately 50.9%.

## Post-Harvest Produce Management

### Assessment of Phyto-chemicals

- Ricinoleic acid extracted from castor seed oil using a novel GC-MS-based analytical method was estimated at 311.9 µg/mL. Additionally, a modified alkali pyrolysis reaction was employed to extract 2-octanol from the ricinoleic acid fraction, indicating a promising approach for bioactive compound analysis.
- In chilli, total carotenoid content was monitored during storage at room temperature. Results revealed a declining trend in carotenoids over 120 days. Pre-harvest treatments effectively mitigated this decline compared to untreated controls. Among these, blanching with 0.2% sodium metabisulfite retained the highest levels of total carotenoids and capsaicin, underscoring its potential for extending chilli's shelf life and maintaining quality.

### Development of efficient protocols

- A novel LC-MS/MS analytical method was developed for the quantification of flupyradifurone residues in tobacco. The study indicates a pre-harvest interval (PHI) of approximately 8 to 9 days to ensure pesticide residues remain within acceptable limits in FCV tobacco.
- An LC-MS/MS method for quantifying capsanthin in chilli was established. The protocol utilizing green ultrasonication-assisted extraction determined capsanthin content at 22.64 µg per gram of dry chilli, facilitating accurate residue and quality assessment.

### Value addition

An innovative curcumin-based beverage mix was developed and registered under FSSAI License No. 10124999000157. In addition, various value-added products, including herbal tea bags, turmeric dhoop sticks, turmeric sandal soaps, chilli flakes, chilli chocolates, ashwagandha capsules and turmeric capsules, were formulated and are undergoing phytochemical and sensory analyses as part of diversifying product portfolios.

## Extension and Market Intelligence

### Value Chain Analysis

- The share of chilli in spice and agricultural exports has increased from 6% and 0.7% in 1960-61 to 9% and 3% in 2023–24, respectively, reflecting growing international demand. Trade potential analysis indicates significant untapped markets in China, USA, Thailand, Bangladesh, Malaysia, Indonesia and Sri Lanka, collectively representing approximately $847 million USD in export revenue. This translates to an additional foreign exchange inflow of about Rs. 7,150 crore.

### ICT models

- A price forecasting model was developed in Prophet using training data and validated with 'Max price' as testing data for chilli price forecasting.
- The Online Soil Fertilizer Recommendation Software was operationalized by integrating soil test-based crop response models with fertilizer response equations tailored for FCV tobacco in KLS, SLS and SBS zones, facilitating site-specific nutrient management.
- The Tobacco Seed Portal was redesigned and upgraded by the institute, enabling rapid seed distribution of all tobacco types across regions, thereby improving supply chain efficiency.
- An Android application, "CROP SURAKSHA", was developed using Xamarin (.NET) and Android Studio, providing comprehensive Integrated Pest Management (IPM) information for cereals, pulses, oilseeds and commercial crops.

### Frontline extension

- Critical determinants for tobacco export promotion and demand-driven value addition in turmeric and chilli crops were identified, guiding strategic interventions.
- To enhance the value chain of turmeric-based Farmer Producer Organizations (FPOs), key expectations of FPOs include access to credit, market intelligence, certification, and export facilitation. ICAR-CTRI intervention is required to introduce high-yielding, high-curcumin varieties, mechanization in processing, and strengthening market linkages are prioritized.

### Technology outreach activities

A total of 12 OFTs and FLDs and 21 capacity building programmes were conducted for the farmers and line departments on scientific tobacco and other commercial crops management practices.

### Capacity building programmes

Scientists and staff members have undergone training at different institutes during 2024 to nurture their professional skills.

### KRISHI VIGYAN KENDRAs

### KALAVACHARLA

A total number of 13 OFTs, 23 FLDs, 7 training/awareness programmes/workshops, 6 collaborative programmes, 3 sponsored trainings were conducted. KVKs Golden Jubilee Year 2024 was celebrated on 02.07.2024 by receiving the Torch from KVK, Kondempudi.

### KANDUKUR

A total number of 23 OFTs, 24 FLDs, 32 training programmes, 3 field days, 4 skill development trainings, 4 inservice trainings, 4 Farmers Field Schools and 4 Research-Extension-Farmers interface (REFI) meetings were conducted. Mobile app 'CROP SURAKSHA' was developed which consists of Integrated Pest Management (IPM) practices of 15 major crops grown in Andhra Pradesh.

### ALL INDIA NETWORK PROJECT ON TOBACCO

Two tobacco varieties *viz*. FCJ-11 (CTRI Naveena), FCR-15 (CTRI Sreshta) were notified in the Central Variety Release Committee (CVRC). Three tobacco varieties *viz*., FCH-2 & FCRH-11 (FCV) and NBD-316 (*Bidi*) were identified in the Varietal Identification Committee meeting held on 29/08/24 at ICAR-CTRI, Research Station, Hunsur.

FCV tobacco grown with groundnut as intercrop has recorded significantly higher number of leaves harvested per plant (21.8), green leaf yield (12993 kg/ ha), cured leaf yield (1642 kg/ha), tobacco equivalent yield (1948 kg/ha), land equivalent ratio (1.71), area time equivalent ratio (1.53), monetary advantage index (Rs. 1,41,097/ha) and benefit cost ratio (2.60).

Prediction model on Frog Eye Spot disease was found to be true to the tune of 70% and 78.94% in nursery and field, respectively.

A total of 5 FLDs/ OFTs, 11 training programmes, 4 technology demonstrations and 11 field visits were conducted in different centres.

### Service functions

Analytical service units (Leaf Quality evaluation laboratory, Soil testing laboratory, Smoke laboratory, Seed testing laboratory) provide service to Tobacco Board, trade and AINPT Centres apart from CTRI Research Stations. During 2024, a total number of 3501 samples were analysed and Rs. 5,20,026 revenue was generated.

### Awards and Recognitions

A total number of twenty two awards were received by the scientists. Dr.M.Sheshu Madhav, Director, was conferred the Fellow of National Academy of Agricultural Sciences, New Delhi on 05.06.2024. Eight scientists received ISTS awards in various categories, three awards were presented by Tobacco Institute of India, best publication and research paper and other recognitions were received.

### SC Sub-Plan

ICAR-CTRI and research stations and KVKs implemented the SCSP programme. Different interventions encompassing the awareness programmes/ training programmes on production technology and good agricultural practices in tobacco and post-harvest technologies were implemented. A total number of 4091 SC farmers benefitted under this programme. Critical inputs such as bale pressing tools, poly tray medium pressing tools, topping tools, spades, crowbars, turmeric seed, bengal gram seed, ashwagandha seed, HDPE drums, tarpaulins etc. were distributed.

### Tribal Sub-Plan

ICAR-CTRI has implemented the Tribal Sub-Plan by organizing different capacity building progammes and critical inputs such as cattle feed, battery operated sprayers, spades, crowbars, bale pressing tools, poly tray medium pressing tools, topping tools, turmeric seed, etc were distributed. A total number of 3646 beneficiaries were covered under this programme.

### NEH Scheme

One-day training program on Orchid cultivation was organized by ICAR-NRCO in Agartala, Tripura that was attended by 300 farmers from different districts of Tripura on 27.11.2024.

ICAR-CTRI collaborated with MTTC & VTC, College of Fisheries, Lembucherra, on a project titled "Establishment of Honey Bee Rearing Units at Farmers' Fields in West Tripura" to promote sustainable beekeeping practices in the region.

### Research Collaborations and Functional Industry-Institutional linkages

ICAR-CTRI has signed a total of fourteen MoUs *viz*., one with IOCL (PPP mode), Hyderabad; four with universities, Vignan University of Guntur, Siksha 'O' Anusandhan of Bhubaneswar, Mangalayatan University of Jabalpur, Uttar Banga Krishi Viswavidyalaya of Cooch Behar (WB); two with private firms SS Enterprise,

East Godavari & M/s Veerabhadra Rao of Anakapalli for commercialization of equipment; four with M/s Kalaga Herbal of Hyderabad, M/s Braintree Consultancy of Hyderabad, M/s Syngenta India of Pune & M/s Bayer India of Thane; one with a NGO Grameen Foundation of New Delhi and one with FPO Andhra Pradesh Community Managed Natural Farming.

## GOI Programmes

Implemented Government of India programmes *viz*., World IP Day, PM Kisan Samman Nidhi live telecast, Hindi Diwas, Swachata Hi Seva, International Yoga Day, Vigilance Awareness week and other activities.

## Foundation Day Celebrations

The ICAR-CTRI has celebrated the 77$^{th}$ Foundation Day on 01-05-2024. Dr. Trilochan Mohapatra, Chairperson, PPV & FRA and Former Secretary, DARE & DG, ICAR, New Delhi, was the Chief Guest and Dr. R.C. Agrawal, Deputy Director General (Education), ICAR, was the eminent guest, Dr. K. Padma Raju, Vice Chancellor, Adikavi Nannaya University, Rajahmundry; Dr. R. Sarada Jayalakshmi Devi, Vice Chancellor, ANGRAU; Dr. T. Janakiram, Vice Chancellor, Dr.YSRHU; Dr. K. Suresh, Director, ICAR-IIOPR were the other reputed guests.

## Way Forward

- GI tagging for Durgada chilli and local species of commercially important crops.
- Development of robust AI based Apps and technologies.
- Reducing the carbon foot prints in tobacco cultivation.
- Mechanization of (i) Suckericide application, (ii) Customized intercultivation and (iii) Harvesting in tobacco.
- Exploration of economically useful compounds from castor oil.