भाकृअनुप
ICAR

ICFTCA 2023
INTERNATIONAL CONFERENCE

75 Years ICAR CTRI 1947-2022

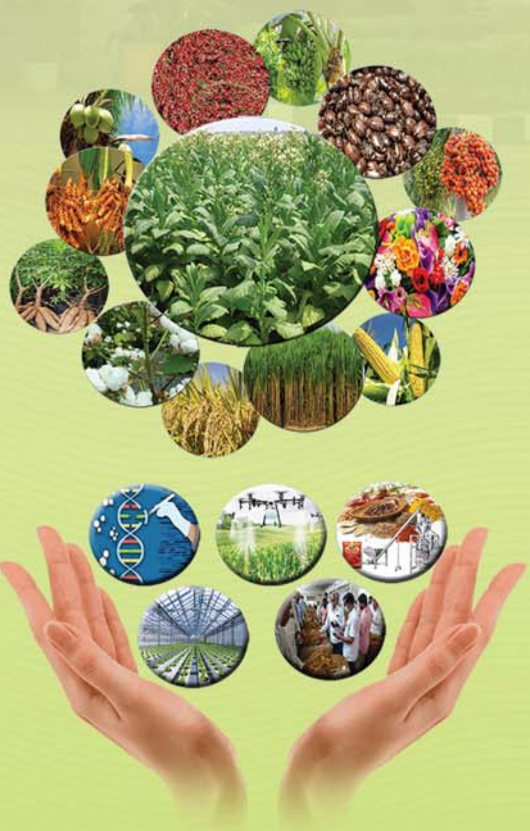
INTERNATIONAL CONFERENCE

Frontiers in Tobacco and Commercial Agriculture
Towards Preparedness for Future Farming

14-16 December, 2023

Venue: Adikavi Nannaya University, Rajahmundry

SOUVENIR



Organized by

INDIAN SOCIETY OF TOBACCO SCIENCE

and

ICAR-CENTRAL TOBACCO RESEARCH INSTITUTE

(ICAR-NATIONAL INSTITUTE FOR RESEARCH ON COMMERCIAL AGRICULTURE)

RAJAHMUNDRY - 533105, ANDHRA PRADESH

ISTS

ICAR-CTRI

SOUVENIR

INTERNATIONAL CONFERENCE

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Published in December 2023

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KAILASH CHOWDARY

कृषि एवं किसान कल्याय
राज्य मंत्री
भारत सरकार
MINISTER OF STATE FOR AGRICULTURE
& FARMERS WELFARE
GOVERNMENT OF INDIA

MESSAGE

I am happy to know that ICAR-Central Tobacco Research Institute is partnering with Indian Society of Tobacco Science (ISTS) in organising a three day "International Conference on "Frontiers in Tobacco and Commercial Agriculture towards Preparedness for Future Farming" at Advikavi Nannaya University, Rajahmundry, Andhra Pradesh, India, during 14-16 December, 2023 on the occasion of Platinum Jubilee Celebrations.

In the past 75 years ICAR-CTRI has done a commendable work to increase the productivity and quality of different tobacco types grown in the country. The concerted efforts of ICAR-CTRI lead to enhancing productivity and exports.

Tobacco, chilli, turmeric, castor and ashwagandha are the major crops contributing phenomenally to the Indian exports. The challenges faced in enhancing the exports of these crops are to be addressed by developing agro-technologies for farmers' centric problems. The conference will provide the platform for all the scientific fraternity and stakeholders for critically analysing the constraints in production, value addition, marketing and exports of all commercial crops. I hope that the conference will prepare a road map for alleviating the production and post production challenges for enhancing the exports.

I wish the conference a grand success.

Dated 28.11.2023
New Delhi

(Kailash Choudhary)

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शोभा करांदलाजे
SHOBHA KARANDLAJE

राज्य मंत्री
कृषि एवं किसान कल्याण
भारत सरकार
Minister of State For
Agriculture & Farmers Welfare
Government of India
D.O. No..................MOS(A&FW)/VIP/2022-23/

MESSAGE

It is heartening to note that ICAR-Central Tobacco Research Institute (CTRI), Rajahmundry has completed 75 years of service to the tobacco farming community while India is celebrating Azadi Ka Amrit Mahotsav. To mark the celebrations, ICAR-CTRI organizing International Conference on "Frontiers in Tobacco and Commercial Agriculture towards Preparedness for Future Farming" in association with Indian Society of Tobacco Science which will act as a niche for appraising the advancement of science in the respective areas. The conference themes are apt and I am sure that the science lead deliberations will result in developing strategies for resilience and enhancing commercial value of tobacco and other commercial crops *viz*., turmeric, chilli, ashwagandha and castor. The conference also addresses the issues related to technology dissemination, digital agriculture, market intelligence for effective transfer of technologies and seamless marketing of their produce. I hope that the conglomeration of eminent researchers across the globe will provide insight about the new avenues of competitive product placement for the benefit of Indian entrepreneurs and farmers in respective commercial crops.

I am pleased to extend my warmest greetings to everyone attending the conference and I am confident that we all can envision India of tomorrow by putting our best and make India as Visva Guru a reality

28th November, 2023

(SHOBHA KARANDLAJE)

Kakani Govardhan Reddy
B.E., M.B.A., M.A.,
Minister for Agriculture & Cooperation,
Marketing & Food Processing
Government of Andhra Pradesh

Room No. 211, Ist Floor
2nd Buildin, A.P. Secretariat,
Velagapudi - 522 238
AMARAVATHI
Ph : 0863 - 2442572

MESSAGE

I am very happy to know that the International Conference on "Frontiers in Tobacco and Commercial Agriculture towards Preparedness for Future Farming" will be held at Adikavi Nannaya University in during December 14-16, 2023, which is being organised by the ICAR-Central Tobacco Research Institute, Rajahmundry, one of the ICAR institutes in state of Andhra Pradesh in Rajahmundry, Andhra Pradesh, In association with Indian Society of Tobacco Science.

In order to develop farmer centric technologies, it is imperative to develop and disseminate the accurate information in commercial crops like tobacco, chilli, turmeric and castor. The sustainability of tobacco in India will rely on reducing its cost of cultivation, making it less harmful using tobacco as a source for high-value commercial products and creating products that are good for humanity in addition to ongoing efforts to raise the productivity and quality of the tobacco crop. At this critical juncture, enhancing the farm income through post harvest value addition and also through various market strategies is very much essential for sustainability and also for attracting the rural youth towards farming. The state of Andhra Pradesh is immensely benefited as these crops are extensively cultivated in sizeable area. The outcome of the conference will help in preparing a road map for enhancing the exports of all the commercial crops.

I convey my sincere and hearty congratulations to the organizers and participants and wish the International conference a grand success.

9th December, 2023

(Kakani Govardhan Reddy)

सत्यमेव जयते

डॉ. हिमांशु पाठक

DR. HIMANSHU PATHAK

सचिव (डेयर) एवं महानिदेशक (आईसीएआर)

Secretary (DARE) &

Director General (ICAR)

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद,
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली - ११० ००१

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH AND EDUCATION (DARE)
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR)
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
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MESSAGE

I am happy to know that ICAR-Central Tobacco Research Institute is organising International Conference on "Frontiers in Tobacco and Commercial Agriculture towards Preparedness for Future Farming" in collaboration with the Indian Society of Tobacco Science (ISTS) during December 14–16, 2023 at Advikavi Nannaya University, Rajahmundry, Andhra Pradesh, India. Tobacco is one of the most important commercial crops in India and contributes significantly to the national exchequer. India occupies second place to China in area and production. High-value commercial crops like tobacco provides farmers assured yield and profits. Apart from tobacco, India is a leading producer and exporter of cash crops such as chilli, turmeric, castor, ashwagandha, sugar cane and cotton. India's position as a global exporter of agriculture commodities must be strengthened by increasing productivity, quality, value addition and secondary agriculture. In order to increase commercial value, scientists must play a pivotal role in genetics and crop management for robust commercial farming, novel insights into value addition and post-harvest technologies, innovative market interventions for commercial agriculture to increase exports, as well as next-generation technologies for digital agriculture and information dissemination.

I hope that this conference will serve as a springboard for productive conversations, partnerships, and ideas sharing that will open doors for ground-breaking studies, policy changes, and practical applications. Together, let's investigate innovative methods, state-of-the-art tools, and flexible strategies to guarantee the long-term growth of tobacco and other commercial crops. I hope that the conference will prepare an action plan to mitigate production and post-production challenges to increase exports.

I wish the Conference a grand Success.

6th December, 2023
New Delhi

(HIMANSHU PATHAK)

भाकृअनुप
ICAR
डॉ. तिलक राज शर्मा
उप महानिदेशक (फसल विज्ञान)

Dr. T.R. Sharma, Ph.D
FNA, FNAAS, FNASc, JC Bose National Fellow
Deputy Director General (Crop Science)

भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन-II, पूसा,
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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II, PUSA, NEW DELHI-110 012 (INDIA)

MESSAGE

I am extremely delightful to learn that ICAR-Central Tobacco Research Institute, in association with Indian Society of Tobacco Science (ISTS) is organizing an "International Conference on "Frontiers in Tobacco and Commercial Agriculture towards preparedness for future farming" during 14 -16 December, 2023 at Advikavi Nannaya University, Rajahmundry, Andhra Pradesh, India, on the occasion of Platinum Jubilee Celebrations. The contributions made by ICAR-CTRI to the farming community in enhancing the yield, quality, farm income and exports through varieties and agro technologies are appreciable. The concerted efforts of ICAR-CTRI placed India in 2nd position both in production and exports after China and Brazil, respectively. India export earnings need to be further improved to fullfill the invisioned dream of 5 trillion dollars economy by 2025.

The initiative taken by ICAR - CTRI to conduct this international conference with a focus on various facets of commercial agriculture is very apt in line with Govt. of India's policies on doubling the farmers' income, secondary agriculture and post harvest & value addition. The conference will help in deliberating extensively the contemporary issues of enhancing export earnings pertaining to the commercial crops *viz.,* tobacco, chilli, turmeric, ashwagandha and castor and also other facets of commercial agriculture. I sincerely wish that the outcome of the conference will help in strengthening the India's pre-emptive position as a global exporter of commercial crops.

I congratulate the organizers for their meticulous planning and wish the conference a grand success

23rd November, 2023
New Delhi

(T.R. Sharma)

ICAR-CENTRAL TOBACCO RESEARCH INSTITUTE

(ICAR-NATIONAL INSTITUTE FOR RESEARCH ON COMMERCIAL AGRICULTURE)

RAJAHMUNDRY - 533 105, A.P., INDIA

ICAR-CTRI

Dr. M. SHESHU MADHAV
Director

MESSAGE

It is delightful that ICAR-Central Tobacco Research Institute in association with Indian Society of Tobacco Science is organising an International Conference on “Frontiers in Tobacco and Commercial Agriculture towards Preparedness for Future Farming” during 14-16, December, 2023 at Advikavi Nannaya University, Rajahmundry, Andhra Pradesh, India, on the occasion of Platinum Jubilee Celebrations. On this occasion, a souvenir featuring expert opinions on various aspects of the chosen themes as well as technological advancements also being published.

Research on high value commercial crops like tobacco need to be continued in view of its contribution to national economy and employment. Apart from tobacco, India being leading producer and exporter of cash crops such as chilli, turmeric, castor, ashwagandha, sugar cane and cotton. India’s position as a global exporter of agriculture and horticulture commodities need to be strengthened by increasing productivity, quality, post harvest & value addition and secondary agriculture. The five themes selected for the conference are very apt to deliberate and to prepare a road map for selected commercial crops. The conference would also cover the institutional, technological, and policy support needed to unlock the commercial crops’ inherent export potential.

I have no doubt that the conference will provide a forum for all parties involved in commercial crops to discuss opportunities, obstacles, and constraints in order to plan ahead for commercial agriculture in the future. It is my sincere hope that the conference’s recommendations will help to devise plans for tackling today’s obstacles and clear the path for Indian farming in the future.

I wish the conference a grand success

(M. SHESHU MADHAV)
DIRECTOR

9th December, 2023
Rajahmundry

Dr. (Smt.) B. Neeraja Prabhakar
M.Sc. (Ag.) Horti., Ph.D.

Vice – Chancellor & Chairman, RAC, ICAR-IIOPR.
Sri Konda Laxman Telangana State Horticultural University (SKLTSHU)
Mulugu, Siddipet, Telangana 502279 Email: vcskltshu@gmail.com

MESSAGE

My heartfelt congratulations to ICAR- Central Tobacco Research Institute (CTRI) for organizing an International Conference on "Frontiers in Tobacco and Commercial Agriculture towards Preparedness for Future Farming (ICFTCA-2023) to be held from 14 -16 December, 2023 at CTRI, Rajahmundry. Hoping that this conference provides a common platform for farmers, scientists, research scholars, students, policy makers and other stakeholders at national and international level to discuss upon the challenges and opportunities to develop a road map of Commercial Horticulture.

Indian Horticulture sector has been the mainstay of Indian Agriculture with a contribution of about 30 per cent to the agricultural GDP from about 14 per cent area and 40 per cent of total export earnings in agriculture as a whole. Horticulture production increased 13-folds from 25 million metric tons during 1950-51 to 342.30 million tonnes during 2021-22 surpassing food grain production.

India has got a pre-eminent position in the global production and exports of high-value commercial crops such as Grapes, Pomegranates, Mangoes, Bananas, and Oranges account for the larger portion of fruits exported from the country while Onions, Mixed Vegetables, Potatoes, Tomatoes, and Green Chilli contribute largely to the vegetable export basket.

In order to make Indian Agriculture future-ready, Climate Smart- Nutrition Sensitive Horticulture has become the need of the hour to feed ever growing population of the world. The key research thrust areas to be focused involves integration of several initiatives such as promoting innovative technologies, market linkages, drones, IoT applications and various digital initiatives for enhancing the production and quality with low cost of cultivation to improve the farmers income and agricultural exports while ensuring the sustainability of agro-ecosystem.

I wish the organizers of the Conference and the participants a grand success.

9th December, 2023
Siddipet

B. NEERAJA PRABHAKAR
VICE CHANCELLOR
SKLTSHU, Mulugu, Telangana.

Dr. Y.S.R. Horticultural University
Admin Office,
Venkataramanagudem - 534101
West Godavari District, Andhra Pradesh

Dr. T. Janakiram
Vice-Chancellor

MESSAGE

In India, the traditional agriculture sector is fast moving towards commercialization and commercial agriculture, particularly in the context of horticulture, plays a crucial role in the country's economy and agricultural landscape. Horticulture sector contributes to 30.4% to the Gross Domestic Product of the country with a mere 13.4% gross cropped area, thus forging ahead as an important growth engine for the country. The productivity of horticultural crops increased from 8.80 t/ha (2001-02) to 12.51 t/ha (2022-23) *i.e.* an increase by 1.42 times in two decades. India has produced 351.92 million tonnes from horticultural crops during 2022-23, the highest ever in the country. The horticulture sector has gained prominence due to increasing demand for high-value crops, nutrition security, changing dietary patterns, neutraceuatical properties and the potential for export.

Commercial horticulture in India encompasses a wide range of crops including fruits, vegetables, plantation and flower crops. Apart from these, important spices like black pepper, cardamom, chilli, turmeric and seed spices are also grown commercially. The horticulture sector has become a significant contributor to India's export earnings. During 2022-23, Rs. 13185.30 crores worth fresh fruits and vegetables, Rs. 18090.81 crores worth processed fruits and vegetables, Rs. 2892.2 crores worth cashew, Rs. 31761 crores worth of spices were exported from India.

Innovative technologies and modern agricultural practices such as precision farming, greenhouse cultivation and the use of high-yielding varieties have become integral to maximizing yields and quality of horticultural crops. The holistic growth in the sector depends on availability of quality planting material/seed, financial assistance, adoption of technical know-how and establishment of market linkages.

Further, adoption of alternative, high-value crops brings small and marginal farmers into the fold of commercial horticulture for increased incomes and crop diversification helps in reducing the risks associated with traditional crops. With an increasing global demand for organic produce, there has been a growing interest in organic horticulture. The total volume of organic products export during 2022-23 was 312800.51 MT, with a value of Rs. 5525.18 Crores. The sustained demand forged many farmers to adopt organic farming practices, thus supplying chemical-free horticultural products.

The success of commercial horticulture also draws attention to the challenges and opportunities in the sector. Inadequate infrastructure, especially in terms of transportation and storage, is leading to post-harvest losses, sometimes to the extent of 20 to 40%. Farmers often face challenges in accessing markets, particularly in fruits and vegetables. The price volatility of the commodities affects the income of the farmers. As most of the horticultural products are perishable, development of cold chain infrastructure, including cold storage facilities and refrigerated transportation are crucial to encourage exports while, establishment of processing facilities would ensure minimization of postharvest loses, reduce market gluts and ensure price stabilization.

Vagaries in climate are anticipated in the future as the earth braces climate change. Unpredictable weather patterns and climate change pose risks to horticulture/agriculture, affecting crop yields and quality. Short, medium and long term strategies for countering the effects of climate change such as development of climate resilient varieties/ technologies and access to such modern agricultural practices/latest technologies is essential for sustained growth.

Commercial horticulture in India is a dynamic and evolving sector that offers substantial opportunities for economic growth and livelihood improvement. To harness its full potential, development and adoption of modern technology, investment in infrastructure, continued government support, market intelligence and linkages are essential.

My heartfelt greetings for the organizers and wish the conference a grand success. I hope the deliberations in the conference would help the farmers, researchers, academicians and all other stake holders.

20th November, 2023
Venkataramannagudem

(Dr. T. Janakiram)

हर कदम, हर डगर
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डॉ. तुषार कांति बेहेरा
निदेशक

Dr. Tusar Kanti Behera
Director

F.No. DIR/IIVR/2023-24/
17th November, 2023

MESSAGE

I am indeed very happy to learn that ICAR-Central Tobacco Research Institute (CTRI) in association with Indian Society of Tobacco Science (ISTS) is organizing the "International Conference on Frontiers in Tobacco and Commercial Agriculture towards Preparedness for Future Farming" during 14-16th December, 2023 at Rajahmundry (Andhra Pradesh). The present event is a timely venture to address the various issues of tobacco and other important commercial crops for emerging challenges in research, education and extension.

India needs to strengthen its position as a major exporter of agricultural and horticultural products by putting more emphasis on improving productivity, quality, secondary agriculture and value addition. To make Indian agriculture future-ready in line with government policies, it is imperative to address the challenges brought on by climate change, declining natural resources, low fertility, and low productivity. It is a matter of great pleasure that such an important issue is being taken up for discussions in five major themes encompassing the different facets of commercial agriculture covering the Tobacco, Chilli, Turmeric, Ashwagandha, Castor, Cotton and Sugarcane and that too by inviting eminent personalities who have contributed immensely in this field. I am glad that this conference is addressing a number of important issues, and that the association is reiterating its commitment to upholding the highest standards of allegiance to the country as a whole.

I congratulate the organizers for their devoted service and profoundly wish the International Conference a great success.

(Tusar Kanti Behera)

Phone & Fax No.: 0542-2635247 (O), Mo. No. 9868342628
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Dr. R Dinesh
Director,
ICAR-Indian Institute of Spices Research
Kozhikode

MESSAGE

I am delighted to know about the International Conference on frontiers in tobacco and commercial agriculture towards preparedness for future farming, organized by the ICAR-CTRI in association with Indian Society of Tobacco Science (ISTS). The topic of the conference resonates the growing concerns about the sustainability of the modern commercial agriculture and the need for the primary agricultural production systems to adopt smart, sustainable and ecofriendly technologies without compromising on efficiency. Even though there is a consensus about the critical role played by commercial agriculture in feeding the world's growing population, there is an increasing awareness about the challenges faced by the sector in terms of environmental sustainability, social equity, and economic viability. Given this backdrop, I am sure that the conference will deliberate on the ways to mitigate these challenges.

Apart from the use of advanced technologies, machinery, and inputs to maximize production and efficiency, commercial agriculture must adopt sustainable practices, ensure fair labour practices, and adapt to changing market conditions. These are often fundamental changes and would require a facilitative policy environment to shepherd the change. Understanding the confluence of production environment, technology landscape and policy design for addressing the identified challenges can be achieved through such platforms for deliberation and information exchange. I do hope that this conference will bring together leading experts, researchers, and industry stakeholders who can provide a clear roadmap on the desirable growth and development trajectory for the focus crops.

The outcomes from the conference, which can indicate a new approach to agriculture that utilizes technology to optimize resource use, improve crop yields, and reduce environmental impact, would be eagerly awaited by the technology specialists and policy planners alike. I wish an abundance of fruitful deliberations, keen insights and practical policy directives from the conference. Above all, I am sure that the conference would play a significant role in delivering sustained impact on agricultural productivity and sustainability in the target crops.

I congratulate the organizers of the conference in selecting a pertinent issue for deliberation and wish the conference all success.

17th November, 2023
Kozhikode

Sd/- xxxx
(R Dinesh)

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Dr. Kancherla Suresh
Director

MESSAGE

The ICAR-Central Tobacco Research Institute (CTRI), Rajahmundry has been undertaking frontier and inclusive research on tobacco since 1947 and serving stakeholders and farming community for the last seven and half decades. I take this opportunity to congratulate the Director and staff of ICAR-CTRI during the Platinum Jubilee celebrations of the Institute. ICAR-CTRI has always been a big brother for ICAR-Indian Institute of Oil Palm Research, Pedavegi and cooperating in all aspects relating to Research and Administration.

In the agriculture sector, commercial crops like chilli, cotton, tobacco, turmeric and sugarcane play a pivotal role in contributing to national economy and ensuring profitable returns to the farmers. I am happy to note that ICAR-CTRI in association with Indian Society of Tobacco Science is organizing an International Conference on "Frontiers in Tobacco and Commercial Agriculture towards preparedness for future farming" during December 14-16, 2023 at ICAR-CTRI, Rajahmundry. The theme of the Conference has been aptly designed to make Indian Agriculture in general and commercial crops in particular, future-ready, in tune with the Government policies. I feel that organizing such a Conference is the need of hour in order to take the commercial crops to a level of an export-oriented venture.

I hope that the deliberations of Conference would result in providing concrete recommendations and solutions to address the present and future challenges in improving productivity and sustainability of tobacco and commercial crops.

I wish the Conference, a grand success and compliment the organizers for their great and untiring efforts.

(KANCHERLA SURESH)
Director, ICAR-IIOPR

Dated: November 17, 2023
Pedavegi

The Tobacco Institute of India

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MESSAGE

I am happy to know that ICAR-CTRI, in association with Indian Society of Tobacco Science (ISTS), is organizing the "International Conference on Frontiers in Tobacco and Commercial Agriculture Towards Preparedness for Future Farming" during 14 -16 December, 2023 in Rajahmundry.

I take this opportunity to acknowledge the contribution of the Central Tobacco Research Institute (CTR) for its unstinting work in research and crop enhancement programmes that have been instrumental in improving the quality and yield of tobacco crop in India.

Tobacco has a huge socio-economic significance in India. The country ranks as the 2nd largest producer and a leading exporter of tobacco in the World. Tobacco provides livelihood for more than 4.5 crore Indians, including farmers, farm labourers, tribals and women. According to an ASSOCHAM study, the Tobacco Sector in India contributed Rs.11,79,498 crores to the country's economy in 2016. The current value, adjusted for inflation based on consumer price index from 2016 to date, would be Rs.15,81,357 crores.

India's leaf tobacco exports reached a record high during 2022-23 both in volume and value terms. India exported tobacco and tobacco products worth Rs. 9,740 crore during the year with Cigarette type tobaccos namely FCV and Burley being the major contributors.

India has around 13% share of the world's tobacco production. However, we account for only 5% value share of the global tobacco leaf exports. We export only around 30% of the tobacco produced in the country, whereas other leading tobacco growing countries viz., Brazil, USA and Zimbabwe, export between 60 to 90% of their production. Thus, there is a huge potential to increase India's share of global tobacco exports and claim our rightful position in the world trade.

The research and development carried out by the CTRI and the determined efforts made by it to encourage adoption of contemporary and sustainable farming practices in co-ordination with Industry stakeholders, will continue to facilitate improvement in yields, productivity, quality and global competitiveness of Indian tobaccos.

I am sure CTRI will continue its efforts to provide common platform for scientists, trade, farmers and other stakeholders to address the challenges being faced by the tobacco crop in the country. One of the priorities, would be to find ways to mitigate the adverse impact of climate change on crops and its effect on livelihood of farmers in the country.

I extend my warm greetings and good wishes to the organizers and participants of the event and wish the conference all success.

Sharad Tandan
Director

Enduring Value

Mr. HN. Ramprasad
Divisional Chief Executive
ITC Ltd – Agri Business Division

MESSAGE

With immense pleasure and pride, I heartily congratulate the Indian Society of Tobacco Science and Central Tobacco Research Institute for organising the "International Conference on Frontiers in Tobacco and Commercial Agriculture Towards Preparedness for Future Farming" during 14-16th December, 2023, Rajahmundry. The themes of the conference that encompass Genomic strategies, new vistas in crop management, next generation technologies and innovative market interventions are quite contextual in the current challenging environment like Climate Change which has a direct & significant impact on Agriculture supply chains and the livelihoods of the farmers and workforce depending on it.

We are witnessing surge in Indian Tobacco exports from the last two years, driven by positive tail winds from geo-political environment and changing sourcing foot-print on the grounds of sustainability & ESG requirements by Global manufacturers. It's the right time to grab and ring fence these opportunities to increase Indian Tobacco exports through stable crop production & sustainable product supplies.

Research & Development should play a vital role to strengthen Indian Tobacco crop competitiveness globally by overcoming the key challenges being faced by the farmers like weather aberrations, small operational holdings limiting technology adoption, depletion of natural resources and increasing cost of production.

We are living in time of such rapid change and uncertainty of challenges around. Demonstrating agility in R&D programmes by integrating conventional research with contemporary technologies, adopting latest climate science and joint collaborations are vital to fast-rack research programmes and develop sustainable solutions addressing current challenges & mitigating future risks. A mechanism to expedite the process of technology transfer is also a major area to deal with for enabling the faster deployment and large-scale adoption to be globally competitive in capturing emerging export opportunities.

I am glad to note that this international conference is well designed and provide a common platform for scientists, farmers, industry and other stakeholders to deliberate on the contemporary issues of tobacco and other commercial crops. My heartiest congratulations to the organisers for all their efforts to make this conference an intellectual memorabilia and wish the conference a great success.

(HN.Ramprasad)

EXECUTIVE COMMITTEE (2023-2025)

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Dr.K. Prabhakara Rao

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Sri G. KRISHNA KUMAR, Vice-President, Leaf Operations, ITC LTD.
Sri D.S. JITENDRA KUMAR, Senior Vice-President, GPI LTD.
Dr. T. LAKSHMI NARASAIAH, Vice-President (Leaf), VST Industries LTD.
Sri N. RAMACHANDRA RAJU, GM (Sales), AOI LTD.
Dr. M. MANI, Retired Chief Scientist, ILTD Division, ITC LTD.
Dr. M. SHESHU MADHAV, Director, ICAR-CTRI & Convener

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Dr. K. Sarala, Head, Div. of Crop Improvement, ICAR-CTRI	Member
Dr. K.Rajasekhara Rao, Head, Div. of Crop Management, ICAR- CTRI	Member
Dr. S. Kasturi Krishna, Nodal officer, PME Cell, ICAR-CTRI	Member
Dr. H. Ravisankar, Principal Scientist, ICAR-CTRI & Treasurer, ISTS	Member
Dr. M. Anuradha, Head i/c, ICAR-CTRI RS, Kandukur	Member
Dr. Y. Subbaiah, Head i/c, ICAR-CTRI RS, Jeelugumilli	Member
Dr. S. Ramakrishnan, Head i/c, ICAR-CTRI RS, Hunsur	Member
Dr. M.Kumaresan, Head i/c, ICAR-CTRI RS, Vedasandur	Member
Dr. Partha Saha, Head i/c, ICAR-CTRI RS, Dinhata	Member
Dr. P.Venkateswarlu, Head i/c, ICAR-CTRI RS, Guntur	Member
Dr. P. Manivel, Principal Scientist, ICAR-CTRI RS, Vedasandur	Member
Dr. K. Suman Kalyani, Principal Scientist, ICAR-CTRI, Rajahmundry	Member
Dr. P. Srinivas, Senior Principal Scientist, ABD,ITC Ltd.	Member
Dr. B. S. R. Reddy, Senior Lead Scientist, ABD, ITC Ltd.	Member
Sri M. Prabhakara Rao, GM (Leaf) , GPI Ltd.	Member
Sri Y.S. Patil, DGM (Leaf), GPI Ltd.	Member
Dr. K. Prabhakara Rao, Senior Scientist, ICAR-CTRI, Rajahmundry	Member
Dr. T. Kiran Kumar, Senior Scientist, ICAR-CTRI, Rajahmundry	Member
Dr. V. Venkateswarlu, Senior Scientist, ICAR-CTRI, Rajahmundry	Member
Dr. J. Poorna Bindu, Senior Scientist, ICAR-CTRI, Rajahmundry	Member
Sri K. Viswanath Reddy, Scientist, ICAR-CTRI & Editor, ISTS	Member
Dr. B. Hema, Scientist, ICAR-CTRI, Rajahmundry	Member
Smt. B. Sailaja Jayasekharan, Scientist, ICAR-CTRI, Rajahmundry	Member
Dr. Anindita Paul, Scientist, ICAR-CTRI, Rajahmundry	Member

FOREWORD

Indian Society of Tobacco Science (ISTS) is a professional organization serves tobacco research and promotes development through various scientific activities. As part of set goals and roles, ISTS organizes and promotes national/international seminars/symposia/ conferences on critical and challenging tobacco-related issues and promotes tobacco research and development. In keeping with its tradition, the society is now organizing a three-day international conference on "Frontiers in Tobacco and Commercial Agriculture towards Preparedness for Future Farming" during December 14 –16, 2023 at Advikavi Nannaya University, Rajahmundry, Andhra Pradesh, India.

Tobacco, Chilli, Turmeric, Castor and Ashwagandha, are the main crops that contribute to India's export performance. The challenges in increasing the export performance of these crops need to be addressed through the development of agro-technologies that focus on the needs of farmers. The conference will offer a space for the scientific community and other stakeholders to critically evaluate the precincts in the production, post harvest & value-addition, marketing and exports of all the commercial crops.

In this conference invited speakers from R&D, Tobacco Trade & Industry and Academics will present invited and lead lectures on different aspects of tobacco and other commercial crops. I am pleased to announce that a souvenir will be published with all the invited and lead articles on this occasion for the use of all delegates. Renowned national and international scientists have contributed scientific articles to the Souvenir. About 160 research papers on various aspects of Tobacco and other Commercial crops are organized in the 5 poster sessions of the conference. These presentations are published in a book called Book of Abstracts for reference to all stakeholders of Tobacco and other Commercial crops.

I take this opportunity to express my sincere thanks to all the dignitaries who contributed to the completion of the Souvenir and gave lectures during the technical sessions. All the chairpersons and members of the various committees deserve our sincere thanks for the smooth and successful conduct of this mega event in such a grand manner. We hope to create a viable action plan to increase the income of tobacco and other commercial crop farmers. Finally, I would like to express my thanks and appreciation for the kind support, cooperation, practical advice and guidance I have received from everyone.

(M. SHESHU MADHAV)
President, ISTS

CONTENTS

INDIAN SOCIETY OF TOBACCO SCIENCE - A PROFILE

In accordance with the wishes of all the stake-holders in Indian tobacco, a Scientific Society called Tobacco Research Workers Association was started in the year 1973 and got registered in 1974 (No.120/1970) under Societies Registration Act XXI of 1860 with head quarters at the Central Tobacco Research Institute, Rajahmundry, Andhra Pradesh. The main objective of the society is to encourage and promote dissemination of scientific knowledge in all spheres of tobacco research and development. The association was later renamed as Indian Society of Tobacco Science (ISTS) in 1982. Most of the tobacco research workers in the country has joined the Society as members and some of the Indian tobacco companies became patrons of the Society. At present, the Society has 354 life members including honorary members, patrons, foreign members and 10 ordinary members. Bonafide students of Universities and Research organisations have also been offered membership of the Society at a concessional subscription fee. The present membership fee is as follows with an admission fee of Rs. 50/- or $ 2.00.

a) Ordinary member Rs. 200/- or U.S $ 20.00 (Annual)

b) Life member Rs. 2000/- or U.S $ 125.00

c) Student member Rs.150/-

d) Institutional subscription Rs.1000/- or U.S $ 40.00 or £ 15.00

e) Patron Rs.1,00,000/-

All the members and patrons of ISTS will receive the TOBACCO RESEARCH journal on gratis. However, members who completed 10 years as life members will continue to receive the journal if they pay Rs 500/- (for 5 years) or Rs 1,000/- (for 10 years). Otherwise members can get soft copy of the journal on request.

Activities of the Society

The Indian Society of Tobacco Science serves as a forum for interaction between tobacco R & D fraternity in India and other stake holders. ISTS is also playing a key role in the tobacco research activities carried out at some of the National Institutions, Tobacco Industry and Agricultural Universities.

Publication of Journal

The ISTS started publication of an half-yearly journal Tobacco Research with Research findings on all aspects of tobacco in the year 1975 and the first issue was released on 9th June, 1976 coinciding with the Silver Jubilee celebrations of CTRI. Initially, circulation of the journal was limited and now it has wide range of subscribers including universities and publishing houses.

Symposia/Conferences

The Society has so far conducted fourteen National Symposia, one National Group Discussion on Tobacco and one National Conference apart from the lectures organized on contemporary issues.

1. 1st National Symposium on Tobacco, January 09-10, 1976 at CTRI, Rajahmundry.
2. 2nd National Symposium on Tobacco, January 09-10, 1977 at GAU, Anand.
3. 3rd National Symposium on Tobacco, January 09-10, 1979 at CTRI Research Station, Pusa.
4. 4th National Symposium on Tobacco, January 19-22, 1981 at CTRI Rajahmundry.
5. 5th National Symposium on Tobacco, February 15-18, 1984 at CTRI, Rajahmundry.
6. 6th National Symposium on Tobacco, February 13-17, 1986 at CTRI, Rajahmundry.
7. 7th National Symposium on Tobacco, December 26-30, 1987 at CTRI Research Station, Guntur.
8. Group discussion on 'Quest for Quality and Productivity of Tobacco' January 21-22, 1992 at CTRI, Rajahmundry.
9. 1995 Tobacco Symposium on "Search for High Quality," February 1-3, 1995 at CTRI, Rajahmundry.

10. 1998 Tobacco Symposium on "Indian Tobacco - Problems and Prospects", January 20-23, 1998 at CTRI, Rajahmundry.

11. 2000 Tobacco Symposium on "Together We Sustain", December 13-16, 2000 at CTRI, Rajahmundry.

12. National Symposium on Tobacco on "Facing Future Challenges" January 23-25, 2003 at Guntur.

13. National Conference on Tobacco-2005 "Scientific Strategies for Sustaining Growth of Farm Economy and Export", October 3-7, 2005.

14. National Symposium on Tobacco-2009 "Challenges and Opportunities", November 24-26, 2009.

15. XIV National Symposium on Tobacco "New Frontiers in Tobacco Science" December 20-22, 2011.

16. National Symposium on 'Approaches and Strategies for Augmenting Tobacco Farmers Income' during 19-20th July, 2019.

Other Symposia Organised by ISTS

1. National Symposium on 'Problems and Prospects of Botanical Pesticides in IPM' during January 21-22, 1990 sponsored by ICAR and ITC Limited at Rajahmundry.
2. World Neem Conference, Feb 24-28, 1993 at Windsor Manor, Bangalore (in collaboration with ITC and sponsored by ICAR).

In addition, the ISTS has also organised a work shop on Soil fertility and leaf quality evaluation of FCV tobacco, Brain storming sessions on 'Energy Conservation and Mechanisation in Flue-cure tobacco production' on 29th January, 2008 at Rajahmundry, 'Tobacco in India- Concerns, Contradictions and Compelling needs' on 24th August 2015 at Rajahmundry, A Seminar on Alternative crops to FCV tobacco in Andhra Pradesh on 19th August, 2008 at Rajahmundry and training programmes on tobacco production technologies for the Tobacco Board officials.

A series of lectures were conducted in association with ICAR-CTRI during the celebrations of Azadi ka Amrut Mahotsav.

Lecture on "Food Loss and Waste Reduction Policies" by Dr. B. Rajender, IAS, Minister (Agriculture), APR to FAO, WFP & IFAD, Embassy of India, Rome, Italy on 11.11.2021.

Lecture on 'Self Reliant India through Self Sufficient Agriculture' by Dr. J.P. Sharma, Vice Chancellor, SKUAST- Jammu on 4.12.2021.

Soil ecological stewardship – soil health and microbial inoculants by Dr D. L. N. Rao on 23.04.2022.

Processing and value addition in high value commercial crops by Dr Ch. V.V. Satya Narayana on 27.05.2022.

Tobacco Improvement activities in North West of Iran by Dr Reza Darvishzadeh on 14.07.2022.

Genomic Resources and Oppurtunities for Genome Wide Association Studies (GWAS) by Dr. Rupesh Deshmukh on 09.12.2022.

A meeting was conducted with tobacco board, trade and farmers on Yield gap analysis of tobacco, strategies and way forward on 30.12.2022.

An Interaction meeting with industry on convergence of trade and CTRI for accelerated gain in tobacco exports was conducted on 28.01.2023.

Publications

The ISTS published the following books in 1992.

1. Botanical Pesticides in IPM. Edited by M.S. Chari and G. Ramaprasad, ISTS, Rajahmundry, 1992, pp 500.
2. Neem in Agriculture: A bibliography of world literature. Compiled by Y.V. Suryanarayana and M. Ramam, ISTS, Rajahmundry, 1992. Pp 64.

Felicitations

ISTS has been honouring eminent tobacco scientists, executives from industry and progressive tobacco growers and traders for their contributions to the development of tobacco in India.

YEAR	PRESIDENT	VICE-PRESIDENT	SECRETARY	TREASURER	EDITOR
1974-76	Dr. N.C. Gopalachari	Dr. G.J. Patel	Dr. K.V. Satyanarayana	Sri D.Ch. Raja Rao	Dr. M.K. Chakraborthy
1976-78	Dr. N.C. Gopalachari	Dr. G.J. Patel	Dr. K.V. Satyanarayana	Sri D.Ch. Raja Rao	Dr. M.K. Chakraborthy
1978-80	Dr. G.J. Patel	Dr. B.V. Ramakrishnayya	Dr. K. Nagarajan	Sri D.Ch. Raja Rao	Dr. M.K. Chakraborthy
1980-82	Dr. N.C. Gopalachari	Dr. B.G. Jaisani	Sri M. Bangarayya	Sri D.Ch. Raja Rao	Dr. K. Nagarajan
1982-84	Dr. T.D. Prasada Rao	Dr. K. Srinivasa Rao	Sri K. Appa Rao	Sri D.Ch. Raja Rao	Dr. K. Nagarajan
1984-86	Dr. N.C. Gopalachari	Sri K. Appa Rao	Sri K.S.N. Murthy	Sri A. Hanumantha Rao	Dr. B.V. Kameswara Rao
1986-88	Dr. M.S. Chari	Dr. T. S. Subramaniam	Sri D.Ch. Raja Rao	Sri C.R. Nageswara Rao	Dr. B.V. Kameswara Rao
1988-90	Dr. M.S. Chari	Dr. T.S. Subramaniam	Sri D.Ch. Raja Rao	Sri C.R. Nageswara Rao	Dr. C.V. Rao
1990-93	Dr. M.S. Chari	Dr. T.S. Subramaniam	Sri V.V. Ramana Rao	Dr. T. Venkateswarlu	Dr. P. Harishu Kumar
1993-95	Dr. M.S. Chari	Dr. P.P. Singh	Sri C.R. Nageswara Rao	Dr. T. Venkateswarlu	Dr. C.V. Narasimha Rao
1995-97	Dr. M.S. Chari	Dr. T.S. Subramaniam	Sri N.S. Murthy	Dr. J.A.V. Prasad Rao	Dr. C.V. Narasimha Rao
1997-99	Dr. K. Nagarajan Co-President: Dr. T.S. Subramaniam	Sri P.S. Hari Prasada Rao	Dr. P.R.S. Reddy	Dr.C.A. Raju	Sri N.S. Murthy
1999-2001	Dr.T.S.Subramaniam Co-President : Dr. K. Nagarajan	Dr.B.S.Krishna Murthy	Dr. P.R.S. Reddy	Dr. C.A. Raju	Sri N.S. Murthy
2001-03	Dr. K. Deo Singh Co-President: Sri S. Janardhan Reddy	Dr. B.S. Krishnamurthy	Dr. K. Nageswara Rao	Sri C.V. Krishna Reddy	Dr. T.G.K. Murthy
2003-05	Dr. K. Deo Singh Co-President: Sri S. Janardhan Reddy	Sri CH. Narendranath	Dr. V. Krishnamurthy	Dr. U. Sreedhar	Dr. T.G.K. Murthy
2005-07	Dr. K. Deo Singh Co-President: Sri S. Janardhan Reddy	Sri M.M. Yusuff	Dr. V. Krishnamurthy	Dr. U. Sreedhar	Dr. C.V. Narasimha Rao
2007-09	Dr. V. Krishnamurthy	Dr. M. Mani	Dr. C.V. Narasimha Rao	Dr. M. Anuradha	Dr. U. Sreedhar
2009-11	Dr. V. Krishnamurthy	Dr. M. Mani	Dr. U. Sreedhar	Sri M. Appa Rao	Dr. C.C.S. Rao
2011-13	Dr. V. Krishnamurthy	Dr. T. Lakshmi Narasaiah	Dr. U. Sreedhar	Sri M. Appa Rao	Dr. C.C.S. Rao
2013-15	Dr. D. Damodar Reddy	Dr. M. Mani	Dr. A.V. S. R. Swamy	Dr. K. Prabhakara Rao	Dr. K. Siva Raju
2015-17	Dr. D. Damodar Reddy	Dr. M. Mani	Dr. Y. Subbaiah	Dr. Dr. K. Prabhakara Rao	Dr. K. Siva Raju
2017-23	Dr. D. Damodar Reddy	Sri. M. Prabhakara Rao	Dr. K. Prabhakara Rao	Dr. K. Viswanath Reddy	Dr. J. Poorna Bindu
2023-25	Dr. M. Sheshu Madhav	Sri G. Krishna Kumar	Dr. L.K. Prasad	Dr. H. Ravisankar	Sri K. Viswanatha Reddy

Awards

- ISTS combined award for outstanding research contribution in tobacco.
- Tobacco Board award for outstanding contribution in tobacco research and development.
- Young Scientist award for exceptional contributions made by budding scientists in Tobacco
- Award for the Best papers presented at the symposium.

Fellow of ISTS

ISTS has been conferring Fellow of ISTS on its life members for the overall contributions in two categories (a) Research and (b) Extension, Development, Trade & Industry, Policy & Regulation based on their contributions in respective sectors.

Specific score cards have been developed for each award and fellows for evaluation purpose.

ISTS Website

ISTS maintains its own website, www.istsindia.org. The website provides a comprehensive information on various aspects pertaining to the Society such as (1) About ISTS (2) Members of ISTS (3) Executive Committees (4) List of FISTS (5) Publications (6) Tobacco Research Journal including archives (7) Other linkages (8) Symposium circulars (9) Awards etc.

PROFILES OF FELLOWS OF INDIAN SOCIETY OF TOBACCO SCIENCE (FISTS)

1995

Dr. N.S. Reddy : For outstanding ontribution for the light soil tobacco development in India and release of the tobacco varieties 16/103 and Spl. FCV which are cultivated even today.

Dr. G.J. Patel : For outstanding contribution in the improvement of Bidi tobacco by way of improving yields from 800 to 3000 kg/ha and for releasing high yielding varieties Anand-2, Anand-119, GT-2, GT-4, GT-5 and GT-6.

Dr. N.C. Gopalachari : For outstanding contribution for the overall development of tobacco research in India.

Dr. M.S. Chari : For outstanding contribution in projecting the image of ISTS nationally and internationally and making it a premier Society amongst the Scientific Societies. His contribution towards coordinated scientific research not only of tobacco but also of neem is well acclaimed all over the world.

Dr. T.S. Subramaniam : For outstanding contribution towards projecting the image of ISTS by taking the initiative to conduct the First National botanical Symposium and World Neem Conference and for the initiative being taken to organize the CORESTA Conference for the first time in India. His contribution to light soil tobacco development in NLS and KLS is well acknowledged. The eco-friendly agri-inputs developed by him are a step in the right direction for production of clean tobacco.

Dr. K.V. Satyanarayana : For outstanding contribution in guiding the plant breeding group in right direction to produce outstanding varieties useful for the nation. His own contribution in releasing of high yielding varieties Gauthami and VT-1158 is significant.

Dr. K. Nagarajan : For outstanding contribution towards imparting resistance to varieties for Tobacco Mosaic Virus and Black Shank which have great economic impact on tobacco crop. His coordination with other departments in producing these outstanding varieties is greatly acknowledged.

Dr. T. Sitaramachary : Traditional tobacco forms a major part of flue-cured tobacco in India. His contribution by releasing the variety 'Hema' has revolutionalised the yields of black soil tobacco resulting in an average yield of 1500 to 1700 kg/ha brought laurels not only from the scientific community but also from the farmers.

G.V.G. Krishnamurthy : His work on Orobanche is internationally renowned and he is an authority on Orobanche research in India. His scientific contribution towards control of this dreaded pest on tobacco is acknowledged nationally and internationally.

Dr. M.K. Chakraborty : For his outstanding contribution in alternate use of tobacco like Nicotine Sulphate, Solanesol, Leaf Protein, etc. and also for laying foundation in technological parameters of FCV and non-FCV tobacco in India. He also developed a suitable technology for reduction of tar in the manufacture of bidis.

V.V. Ramana Rao : For his outstanding contribution in the development of high yielding varieties of Natu tobacco like Viswanadh, Natu Special and also for his contribution in the development of FCV tobacco with special reference to transfer of resistance to pests and diseases.

1998

Dr. B.V. Ramakrishnayya : For outstanding contributions in imparting mass Training Programmes, creating awareness on quality in KLS tobacco and researches on Potash deficiency in NLS and recommending omission of P and K in heavy soils.

Dr. T.D. Prasada Rao : For outstanding contribution in revolutionizing the Northern Light Soil crop from the filler tobacco to semi-flavourful tobacco. Introduced the concept of ripeness and grading of tobacco according to ripeness.

Dr. R. Lakshminarayana : For releasing high yielding FCV tobacco varieties viz., CTRI Spl. Gauthami, VT-1158 and many of the ruling varieties in non-FCV tobacco; his contributions in physiological and genetic basis of drought resistance in tobacco.

G. Ramaprasad : For outstanding contribution in control and management of tobacco insect-pests, viz., tobacco caterpillar, aphid and ground beetles. Also for contributions in neem products and IPM.

Dr. D.J. Patel : For outstanding contribution in the control and management of root-knot nematodes, damping-off and cigarette beetle on bidi tobacco.

Dr. J.A.V. Prasad Rao : Major contributions are on nitrogen requirement of 16/103 and CM-12, saving of phosphorus in NLS and seed bed management. Published several popular articles in English and Telugu.

G.S.B. Prasannasimha Rao : Major contributions involved in the release of high yielding varieties viz., Hema, Gauthami, VT-1158, Hema (MR) and 16/103 (MR), besides chewing tobacco varieties of Tamil Nadu and Natu varieties grown in Andhra Pradesh.

A.T. Muddappa : For identifying agro-climatic zones for the development of Burley tobacco and popularizing the CTRI package of practices through on-farm trials in NLS and SLS.

M. Umamaheswara Rao : For outstanding contribution in developing agronomical practices of newly released varieties and the effect of crop rotation sequences on the yield and quality of flue-cured Virginia tobacco in black cotton soils of Andhra Pradesh.

Dr. V. Krishnamurthy : Contributions centered around the influence of potassium on the yield and quality of FCV tobacco in NLS, besides highlighting the balanced fertilizer requirement for healthy growth of tobacco.

2000

Dr. A.D. Patel : For his outstanding contribution in releasing different bidi (GT 4, GT5, GT7, GTH1) and chewing (GT6, G8, GC1 and GCT 2) tobacco varieties and hybrids to increase the productivity.

Dr. P.P. Singh : For his research and developmental activities in the utilization of tobacco waste and for his contribution in lowering the tar and nicotine delivaries of Indian Cigarette brands.

Dr. M.M. Shenoi : For his contribution towards integrated pest and disease management of tobacco, biological and pathological studies on pests and diseases and association in the development of FCV tobacco cultivars K-326 and Ratna.

S. Sitaramaiah : For his contribution towards IPM practices for the management of insect pests on tobacco in popularizing the use of neem in the 2000 management of tobacco caterpillar and work on biological control.

Dr. P.R.S. Reddy : For his contribution to the growth and development of Indian Society of Tobacco Science and to the tobacco research in the field of phosphorus and potassium nutrition in Vertisols and leaching loss of nitrogen in NLS.

C.R. Nageswara Rao : For his active participation in the society activities and efforts to strengthen the society financially.

2003

Dr. K. Deo Singh : Dr. Kapil Deo Singh has shown flair for excellent Research in relevant fields of tobacco right through his career. He has made significant contributions in developing and standardizing highly remunerative production technologies and cropping systems for FCV tobacco in Andhra Pradesh and non-FCV tobacco in Bihar and West Bengal. His keen insight into the most important feature of Indian Tobacco namely low TSNA levels made him project the image of Indian Tobacco at the World meet of CORESTA Congress 2002. His efforts to provide infrastructure facilities and aesthetic look to CTRI are well appreciated.

Dr. P. Dayachari : Dr. P. Dayachari, IAS, Chairman, Tobacco Board has although exhibited a scientific approach to tackle the problems facing tobacco production, marketing and exports. His strong support to research and development and excellent encouragement to scientific community is commendable. His effort to bring all the agencies responsible for production and export of tobacco together to boost up export of Indian tobacco is laudable.

S. Janardhan Reddy : Sri S. Janardhan Reddy Chief Executive, ITC Ltd., ILTD Division strived to extend the results of scientific research to cultivators so as to improve their economic well being. He established successful network of scientists, farmers and trade to enhance the economic potential of the crop and boost exports. He worked for further strengthening of the Society and its relationship with trade.

Dr. B.K. Patel : Dr. B.K. Patel has been an outstanding scientist in the Soil Science and Agricultural Chemistry. His achievements include nitrogen and irrigation management in bidi and Rustica tobacco, sucker control, and reduction of pesticide residues in bidi tobacco. He has also contributed on maximization of tobacco leaf protein concentrates and tobacco seed oil.

K. Appa Rao : In view of his contribution to the farming community through release of promising varieties and original work Cytogenetics of tobacco, as well as his association with ISTS in different capacities, Late Sri K. Appa Rao was conferred the FISTS posthumously.

Dr. S.R. Prabhu : Dr. S.R. Prabhu in his long service worked on tobacco aroma, botanical pesticides and alternate uses of tobacco with far reaching implications in the cultivation and product manufacture. His work on botanical pesticides comprising Pongamia and neem are encouraging. Similarly, his research on Solanesol and nicotine sulphate is promising.

A.I. Narayanan : Sri A.I. Narayanan in his 25 years of service contributed for cultivar development in FCV and Burley tobaccos. The recent FCV tobacco varieties Kanthi (Cy 79) for SLS area and Swetha (BSRB 2) for agency burley area of Andhra Pradesh are first such varieties developed for the respective tracts. His contribution in tobacco Cytogenetics and mutation breeding are worth mentioning.

Dr. P. Harishu Kumar : Dr. P. Harishu Kumar was conferred FISTS for his contribution in cropping systems research and development of appropriate crop production technologies in vertisols and his contribution to ISTS as Editor.

2005

Dr. C.V. Narasimha Rao : For his research contribution towards leaf and smoke chemistry, analytical methods for extraction of phytochemicals especially solanesol and for evolving suitable approaches for reduction of harmful constituents like tar and nicotine. He made significant contribution for growth of ISTS.

Dr. K. Palanichamy : He contributed for the improvement of different types of tobacco especially chewing tobacco of Tamil Nadu. His work on Biometrical and biochemical genetics and mutation breeding is outstanding.

Dr. B.N. Bhat : His contributions in the development of bidi tobacco varieties for the Nipani area of Karnataka is well recognised.

R. Subba Rao : He developed crop production technologies for non-FCV tobaccos such as cigar filler, chewing, HDBRG, wrapper, especially in burley tobacco. He also made significant contribution in FCV tobacco grown in Vertisols of Andhra Pradesh.

M. Sannibabu : He worked on water management of FCV tobacco grown under NLS and also on fuel saving methods in flue-curing. He served the tobacco farming community by transferring tobacco production technologies.

Dr. U. Sreedhar : For his research contribution in use of cultural practices, biologicals and selective insecticides for management of tobacco pests, development and demonstration of IPM modules in tobacco which helped in reducing pesticide residues in Indian tobaccos. He made significant contributions to the growth and image of ISTS.

Dr. M. Mani : He contributed for development of high yielding varieties and hybrids in FCV tobacco. He designed and developed the tray nursery system for the usage of hybrid seeds. He served the ISTS in various capacities.

2009

Dr.T.G.K.Murthy : He contributed for the development of high yielding FCV tobacco varieties (Siri and Kanthi), FCV tobacco hybrids (CH-1, CH-3, TBSH-1 &TBSH-2) and black shank resistant Burley variety, BSRB-2. He also developed several resistant lines for insect pests particularly tobacco aphid.

M.M.Yusuff : Instrumental in formation of core committee in Karnataka for leaf development activities. Contributed towards barn insulation with paddy straw, furnace modification with venturi furnace enabling fuel saving in tobacco curing and identification of alternative sources of fuel for tobacco curing . He made significant contribution to the growth of ISTS.

Dr. C.C.S Rao : His major contributions include fertilizer adjustments to leaching losses in FCV tobacco in light soils of A.P., omission of P and K in FCV tobacco grown in vertisols, recommendation of calcium nitrate, potassium nitrate and rock phosphate in FCV tobacco.

Dr. T.L. Lakshmi Narasaiah : For his contributions in research and developmental activities pertaining to HDBRG, sun-cured Natu, DWFC, light soil burley and Oriental tobaccos. He has contributed to the growth of ISTS.

2011

Dr. S. Amarnath for his contributions in development of high yielding and disease resistant chewing and hookah tobaccos. He has developed chewing tobacco varieties viz., Lichhivi, Vaishali Special, PT 76 and hookah tobacco variety Torsa.

Dr. T.S. Vageesh for his major contributions in soil and nutrient management in FCV tobacco. Recycling of industrial wastes for agricultural purposes, nutrient uptake pattern of irrigated cropping systems and long-term changes in soil fertility under irrigated cropping systems.

Dr. K. Siva Raju: His contributions include DNA fingerprinting of tobacco types, effect of cultural factors on quality and neutral volatile aroma compounds in different tobacco types, development of SSR markers specific for tobacco and registered 75 sequences in NCBI.

2019

Dr. D. Damodar Reddy for his outstanding research contributions in the field of soil science and for able leadership in research management relating to tobacco in the country. The core areas of his research contributions include tropical soil fertility and nutrient management for production efficiency and produce quality, innovative techniques for efficient use of organic resources for soil health improvement, new analytical methods for nutrient and pesticide assay, developing high yielding and superior quality tobacco varieties, improved production practices for tobacco and agri-extension services for the benefit of farmers.

Dr M. Anuradha for her contributions in identification and management of nutritional disorders, development of climate resilient technologies in FCV tobacco cultivation and crop intensification strategies in rain fed areas. She advocated these technologies to farmers of southern region of Andhra Pradesh which helped to minimize the yield losses under changed climatic scenario. She has contributed for the growth and development of ISTS.

Dr. K. Sarala for her significant contributions in releasing tobacco varieties (5 No.), micropropagating elite entries, phenotyping and genotyping of tobacco genetic resources and *bt* transgenics/trasplastomics, developing mapping populations, designing gene specific primers, DNA barcoding *Nicotiana* species (24 No.), managing tobacco germplasm (3370 accessions), developing softwares (5) and a mobile app, etc.

Dr. S. Kasturi Krishna for her major contributions in production technologies including integrated nutrient management in FCV and burley tobacco, higher biomass yield for alternative uses, integrated weed management in nursery and field crop, Orobanche management in tobacco. Developed economically sustainable cropping systems in FCV tobacco, alternative crops/ cropping systems to tobacco. Contributed to tobacco development by publishing 65 research papers and imparted trainings to Tobacco board staff, trade and tobacco growers.

Dr L. K. Prasad for his significant contributions in developing GIS-based decision-supporting tools, soil fertility spatial maps of water and soil quality FCV tobacco growing areas, i.e NLS, SBS, SLS and KLS, developed protocols for pesticide residue assessment and augmenting planting time for high fertilizer utilization under light soil-grown FCV Tobacco and non- destructive estimation of leaf quality parameters.

Dr. D.V. Subhashini for her significant contributions in developing biofungicide against *pythium aphanidermatum,* maintainanace of promising microbial cultures as resources, supplied bioinoculants for tobacco farmers, acquired accession numbers for nucleotide sequences for novel microbes from NCBI developed novel technique for staining AM fungal roots, developing protocols for mass multiplication of arbuscular micorrhizae fungi.

Sri. G. Krishna Kumar, Vice President, Leaf Operations, ITC Ltd for his significant contributions in Extension, Development, Industry & Trade, Policy & Regulation.

Dr. P. Srinivas, Principal Scientist, ITC Ltd., Agribusiness Division, Rajahmundry for his contributions in Extension, Development, Industry & Trade, Policy & Regulation.

Sri. D. S. Jithendra Kumar, Vice President, GPI Ltd, for contributions in Extension, Development, Industry & Trade, Policy & Regulation.

CTRI A Catalyst for Transforming Tobacco and other Commercial Crops ready for Future Farming

M. Sheshu Madhav

ICAR-Central Tobacco Research Institute
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Indian Central Tobacco Committee (ICTC) established the Central Tobacco Research Institute in 1947 to conduct research on myriad aspects of different tobacco types grown in India. Subsequently, the institute was brought under the aegis of the Indian Council of Agricultural Research (ICAR) in the year 1965. A unique feature of tobacco production in India is that myriad styles of FCV (Flue-Cured Virginia) and non-FCV tobacco are cultivated under widely differing agro-ecological situations. FCV, Bidi, Burley, *rustica*, *Hookah*, burley, Chewing, Cigar-wrapper, Cheroot, Oriental, HDBRG, *Lanka*, *Pikka and* Natu, *etc.,* are the tobacco types grown in the country. Among the different tobacco types, *bidi,* FCV tobacco, rustica, burley and chewing tobaccos occupies 37, 30, 13, 7.5 and 6% respectively. India accounts for 14% share in global tobacco area and 13% share in global tobacco production**.** India ranks second in the world tobacco area and production, after China and fourth in productivity after China, USA and Brazil. It is grown in an area of 0.433 M ha in the country, with a production of 758 M kg, During 2022-23, tobacco made a significant contribution of Rs. 33,097 crore to the Indian economy in terms of excise revenue (Rs. 23,357 crore) and export earnings (Rs. 9740 crore). It provides direct and/or indirect employment to about 45.7 million people.

ICAR-CTRI is the only research institute in the country which has the exclusive mandate of providing research backup for the production and processing of varied tobacco types grown across the different agro-ecologies of the country. It has made outstanding research contributions in varieties development, Agro-techniques for production and post-harvest produce management, resource use efficiency, leaf quality improvement, sucker control, integrated pest and disease management, energy conservation in curing, reduction of harmful constituents in smoke and alternative uses of tobacco. Further, the ICAR-CTRI has been providing very crucial and exclusive services to the farmers and other clients in terms of production and supply of pure seed, analytical services and in-season contingency advisory services. Major contributions of ICAR-CTRI in research given below

I. Basic Research

a) Germplasm Resources: ICAR-CTRI is a National active Germplasm site (NAGS) for tobacco under the National Network on Conservation of Plant Genetic Resources. A total No of 3386 germplasm accessions of *N. tabacum* and *N. Rustica* and wild nicotiana species are being maintained. A core collection of 305 accessions of *N. tabacum* and *N. rustica* were created and characterised for 25 selected morphological traits. A total no. of 75 varieties has so far been bred using indigenous germplasm as parents. Resistance sources among wild *Nicotiana* species and Tobacco entries possessing useful chemical quality traits were identified*. Nicotiana* species used for production of male sterile lines and by utilizing the developed CMS lines, two CMS hybrids, CH-1 and CH-3 are released for commercial cultivation. Multiple biotic stress resistance lines developed. Eight unique germplasm lines are registered with National Bureau of Plant Genetic Resources (NBPGR), New Delhi.

b) **Inter-specific Hybridization:** After intensive systematic screening, 11 wild *Nicotiana* species having high degree of resistance/ immunity to several diseases were identified. Through pre-breeding, many useful genes viz., resistance to leaf eating caterpillar (*N. gossei and N. benthamiana*), aphids (*N. gossei*), root-knot nematodes (*N. longiflora and N. amplexicaulis*) and Black shank (*N.*

plumbaginifolia) have been incorporated into pre-breeding populations and tobacco cultivars through interspecific hybridization. Recently released FCV variety, CTRI Sulakshana is an interspecific cross derivative in which TMV resistance and tolerance to aphid are transferred from N. *gossei*.

c) Mutation Research: Several promising lines were developed through irradiation of three FCV (Siri, Kanchan and FCJ-11) and two (Banket A1 and YB-22) cultivars with different doses (300 Gy, 400 Gy and 500 Gy) of 10 MeV electron beam.

d) Biotechnological studies:

- Developed transgenic (Bt) tobacco lines toxic to leaf eating caterpillar and budworm: BT tobacco transgenic having Cry 1 A(b) (toxic to *Helicoverpa armigera*) and Cry 1 C (toxic to *Spodoptera litura*) were developed under Hema and Jayasri backgrounds.
- Seventy microsatellite markers were developed and validated their applicability in differentiating different types of tobacco and diverse cultivars of FCV tobacco, and their transferability in a wide range of *Nicotiana* species.
- Development of Mapping Population: Trait specific mapping populations were developed for important traits *viz.,* solanesol, nicotine, TSNA, high biomass, seed characters which can be exploited for development of markers through linkage and association mapping approaches.
- **Genome editing:** The work on genome editing was initiated to develop safer tobaccos with lower level of harmful substances.

e) Development of DUS guidelines: DUS guidelines were developed with 28 characteristics for registration of FCV and *bidi* varieties and were notified in the Gazette of India by PPV&FR Authority, New Delhi.

f) Basic studies in other Disciplines

1. Standardised the analytical methods for soil, water analysis, leaf quality (Nicotine, reducing sugars, chlorides), pesticide residue analysis, identification of aroma compounds, identification bioactive compounds of commercial importance *etc.*
2. Characterisation of tobacco soils for various physical, physicochemical and chemical properties
3. Identification of PGPRB in tobacco Rhizopere for their upscaling
4. Identification of suitable suckericides, seed storage, seed germination techniques
5. Nutrient dynamics and nutrient transformations
6. Deficiency symptoms of major nutrients
7. Botanical pesticides for pest control

II. Applied Research

a) High-Yielding Varieties: Developed and released 103 varieties/hybrids of different tobacco types for high yield potential/ tolerance to biotic and abiotic stresses for cultivation in rain-fed and irrigated regions during the past seven decades.

b) Production Technologies

- Tray Seedling Production Technology: Tray nursery technique developed and standardized for healthy seedling production. > 90% of the farmers are adopting the technology in NLS and KLS region.
- Good Agriculture Practices: Standardized the GAP for different tobacco types which are adopted by 90% of the tobacco farmers
- Alternative and cheaper sources of fertilizers were identified and recommended for FCV tobacco
- Fatty alcohol based suckericide (Decanol) was developed and popularized for effective management of suckers in FCV tobacco
- Integrated insect pests, diseases and nematode control modules were developed for minimising the pesticide residues.
- New-generation insecticide molecules with a low active ingredient were identified and promoted to use in nurseries and main crop against tobacco pests

- Developed novel analytical techniques for monitoring pesticide residues in post-harvest produce for exports
- Farm pond technology for harvesting run-off water and recycling for life saving irrigation was developed and popularised
- Climate resilient technologies *viz.,* mulching, soil application of hydrogel and biochar, foliar spray of gibberellic acid, potassium nitrate, dense planting are recommended for SLS and KLS regions
- Drip-irrigation and fertigation for FCV and chewing were recommended for enhancing yield and nutrient use efficiency
- Next best alternative cropping systems, Crop intensification strategies (Maize-Tobacco) identified for different tobacco zones
- Korra a pre-rabi crop was recommended in rainfed areas of Prakasam district A.P. as a crop intensification strategy for additional income

C) Resource Conservation Technologies

- Micro-sprinkler irrigation recommended to enhance the water & nutrient-use-efficiency and reduce the labour requirement
- Drip fertigation was recommended for increasing the yield and fertiliser use efficiency in FCV and Chewing tobaccos
- Developed online fertiliser recommendation software based on Soil Test Crop Response equations for FCV tobacco in Northern Light Soils region of Andhra Pradesh
- Energy conservation: Solar thermal energy based integrated barn consisting of PCRC- poly carbonate roof chamber, SHA- Solar hot Air , SHW- Solar hot water circulation for curing FCV tobacco reduced the wood consumption up to 33%
- Tobacco stem (TS) Biochar with 100% RDF was recommended as soil amendment for higher yield and nutrient use efficiency

d) Farm Mechanization Technologies

- Drudgery reducing and labour saving bale pressing machine, topping tool, poly tray medium pressing tools developed and commercialised

e) Digital Technologies

- The tobacco seed portal was developed and distributed the seed to the end user in time
- Developed user-friendly decision support system for soil and water analysis, diagnosis of nutrient deficiencies in FCV tobacco
- Developed and deployed mobile apps for advocating GAPs (Good Agricultural Practices) to FCV and Non-FCV tobacco farmers

f) Seed supply to farmers: Every year ICAR-CTRI supply ~7000 kg seed of recommended FCV tobacco seed to registered growers through revolving fund scheme. In addition, CTRI Research Stations supply burley, chewing, *motihari* and *jati* tobacco seed to farmers. The institute is supplying more than 9.0 tons of pure seed annually for all types of tobacco grown in the country to meet > 90% seed requirement of the farmers.

g) Service functions: ICAR-CTRI extends service to farmers and stakeholders for soil, water, leaf chemical quality, smoke analysis and pesticide residues.

III. Strategic Research

- **CPA Residues:** Effective low volume insecticides and pesticides were evaluated and included in the IPM schedules for reducing the residues of crop protection agents. Pre-harvest intervals of recommend pesticides were determined and recommended.
- **Farm Mechanization:** Tobacco is a labour intensive crop. In view of the non-availability of labour, development of customised farm machinery is very much essential. In this

direction ICAR-CTRI developed labour saving tools *viz.,* bale pressing tool, medium pressing tool, handheld battery operated topping tool. In addition to that prototypes were developed for tobacco transplanting and leaf stitching to reduce the labour shortage and evaluation is in progress.

- **Soil, water and nutrient use efficiency:** Iot Based Irrigation systems: Iot Based Irrigation systems is a smart irrigation system. The Automatic irrigation structure is based on IoT technology mean managing the pump for water storage of groundwater to the farmer's field and tracking the soil humidity, pressure and temperature conditions of a farm field.

  Customised fertilizers: ICAR-CTRI in collaboration with fertilizer industry is developing the customized fertilizers for FCV tobacco grown in different production zones. Research programmes are also in progress for identifying the alternate potassium sources and also the micronutrients requirement for FCV tobacco.

- **Effective suckericide:** Contact suckericides like C8-C10 fatty alcohols are recommended as suckericides in tobacco. In view of the high yielding varieties introduced and higher dose of nitrogen fertilizers recommended there is a need to develop and evaluate the systemic and semi systemic suckericides for effective control of suckers. ICAR-CTRI in public-private partnership is working vigorously in this direction

- **Increasing the alkaloid content in burley:** Contrary to the burley tobacco grown in Yeleswaram area where the alkaloid content is low, the demand for high nicotine burley grown in Vinukonda area of Guntur district is increasing. ICAR-CTRI in collaboration with industry initiated research programmes for development of hybrids and also providing the consultancy for enhancing the yield and nicotine content of burley tobacco.

- **Climate resilient technologies :** Compared to the climate prevailed in the last three decades, there was a shift in climate especially quantum and number of rainy days in crop growth. The crop is experiencing either frequent droughts or waterlogging during the crop growth, as a result the crop growth is poor consequently the yields. The institute is recommending the drought mitigation measures *viz.,* water harvesting and recycling for life saving irrigation, growing pre-rabi korra for enhancing the farmers income and dense planting technique for assured yields. Institute is also developing the drought tolerant lines for sustainable tobacco production in Southern Light Soils. In view of the unpredictable rainfall prevailed in the Southern Light Soils and Southern Black Soils it is very much essential to ensure the quality seedling supply for prolonged time to match with the occurrence of Rainfall.

- **Application of Drones:** Different prospects are offered by drones (small unmanned aerial vehicles) for the agricultural sector. Typical drone applications *viz.,* pesticide spraying, nutrient spray, real-time aerial imagery and sensor data collection *etc.* are being evaluated by the Institute.

IV. Anticipatory Research

- **Lowering the harmful substances:** In order to moderate the levels of TSNA, a harmful substance in burley tobacco, it was targeted to edit the CYP82E4 gene responsible for TSNA through CRISPR/Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats/ CRISPR-associated protein 9) genome editing tools.

- Suckerless tobacco varieties: Sucker management has become a real challenge in tobacco cultivation. By using the biotechnology tools the possibility of producing suckerless tobacco will be explored.

- Short duration tobacco varieties: The duration of FCV tobacco is about 150-160 days from the date of transplanting. In 150-160 days duration 60-70 days will be for harvesting tobacco for 9-10 times. In order to reduce the crop duration it is necessary to breed a variety with single harvest.

- Tobacco for various end uses: Tobacco is a rich source of phytochemicals. For the long term sustainability, apart from the conventional uses, research on alternative uses from tobacco is to be vigorously pursued.

RESEARCH AND TECHNOLOGY IMPACT

ICAR-CTRI apart from research has made a phenomenal contribution to technology adoption and transfer activities front which resulted in productivity and quality improvement of Tobacco. Some of the major impacts are furnished below:

I. Adoption of tobacco varieties/technologies: The institute has developed over the years a large number of improved varieties/hybrids (103), production, protection, and processing technologies for enhancing the productivity and quality of tobacco. More than 90% of the tobacco area in the country is covered by these varieties and technologies.

II. Increase in productivity of tobacco: The concerted research efforts of ICAR-CTRI have led to a significant increase in the productivity of tobacco in the country. The annual average productivity of tobacco was very low at 732 kg/ha during 1950-60 and gradually increased over the decades and reached 1718 kg/ha during 2010-2022 owing to the large-scale adoption of scientific interventions and practices developed by the Institute.

III. Productivity-led growth in Tobacco Production: The area under tobacco cultivation in the country has shown a slight increase from 374 lakh hectares during 1950-60 to 433 lakh hectares during 2010-2022. However, the average tobacco production increased by >2.5 times during the corresponding period (from 275 million kg to 758 million kg), primarily attributed to due to the technological interventions in terms of high-yielding varieties, timely supply of quality seed, sustainable production, and protection practices made available by the institute.

IV. Tobacco Exports: Scrupulous adoption of technology interventions has led to the production of quality leaves with low levels of pesticide residues and free from NTRMs. The annual tobacco exports from the country increased by 2.3 times in volume and 8.4 times in value during the past three decades i.e. from an average of 103 million kg and Rs.692 crore during 1991-01 to 291 million kg and Rs. 9740 crores during 2011-23, respectively

Tangible Research Plans for accelerating the tobacco Exports

i) Genetic Resource Management for identification of Novel sources

j) Emphasis on molecular breeding- climate smart varieties

k) Intensification of Genome editing initiatives for safer tobacco

l) Strategies on soil heath management

m) Identification of new molecules for sucker control

n) Tobacco based botanicals for pest and disease management

o) Validation of designed machinery for labour management

p) Exploration of green energy and natural gas for curing

q) Reduced levels of harmful substances, particularly CPA residue

DIVERSIFYING THE RESEARCH MANDATE

Though tobacco is known for its potential to give relatively high returns to the farmers and generate huge revenue to the government, the public perception in general is negative and is growing with time because of health risks and environmental issues associated with its production and consumption. In addition, the tobacco-control policies such as WHO-FCTC (2005), COTPA (2003) *etc.* and anti-tobacco campaigns have also contributed to prevailing uncertainty in the sector. Thus, the institute to remain relevant in the present context, there is a strong need to diversify its research mandate and change research priorities for its future sustenance. The committee constituted by ICAR under the chairmanship of Dr. H.S.Gupta, suggested to rechristen the Institute as National Institute for

Research on Commercial Agriculture and the Institute mandate suggested to broaden the Institute mandate as

- To conduct research on diverse aspects of commercial agriculture for enhancing farm income, employment, nutrition and export earnings, while ensuring sustainability of environment and agro-ecological assets
- To develop cost-cutting strategies, secondary agriculture technologies and diversified value chain models for increased profitability, competitiveness and sustainability
- To deliver front-line extension services for technology and market intelligence dissemination and organize trainings for stakeholders' capacity and competency building
- To collaborate, coordinate and liaison with producing, processing, value addition, marketing and exporting agencies for achieving its vision

Institute will strive to achieve the above mandate by focusing its research efforts on Tobacco, Chilli, Turmeric, Castor, Ashwagandha etc.

Perspective Research Plan for the Commercial crops in the proposed mandate

- Germplasm screening in Aswagandha for profiling of secondary metabolites
- Development of chemo types specific to human ailments from Aswagandha
- Classical breeding to improve the bioactive compounds in turmeric and chilli
- Development of formulations from Aswagandha for specific use
- Farmer producer organizations (FPO) to realize best market price
- Market intelligence studies -International
- Exploring organic cultivation & hydroponics
- Mechanization of production and post-harvest management
- Standardization of 2-octonol extraction protocols from castor oil
- Exploring cheaper methods for production of 2- octonol derivatives from castor oil

WAY FORWARD

- Technological innovations for genetic enhancement of commercial crops for doubling export potential
- Development of energy efficient technologies with least environmental footprints for sustainable production
- Enhancing commercial value of the mandated crops through novel post-harvest produce management and value addition approaches
- Exploring innovative extension and market intelligence approaches for efficient marketing and profit realization

Transforming to Tech - enabled High - Value Agriculture - New Paradigm to Profitability and Ecological Security

G R Chintala

Ex-Chairman, NABARD

1. High - Value Agriculture - Scenario in India

High-value agriculture plays a crucial role in the economic development of a country by enhancing farm income, creating employment opportunities and contributing to overall food security. In the context of India, a country with a predominantly agrarian economy, the promotion of high-value agriculture has become imperative to address the challenges posed by population growth, changing dietary patterns, and climate change. Innovation is more important in modern agriculture than ever before. The industry as a whole is facing huge challenges: from rising costs of supplies and labour shortages to changes in consumer preferences for transparency and sustainability. Let us explore the current scenario of high-value agriculture in India, the challenges it faces, and the potential for future growth.

1.1 Current Scenario:

High-value agriculture encompasses the cultivation of fruits, vegetables, floriculture, horticulture, and other high-yielding crops. The sector has witnessed significant growth in recent years, driven by increased consumer demand for diversified and nutritious food products. Several factors contribute to the current scenario of high-value agriculture in India:

Changing Consumer Preferences: The rising income levels and changing lifestyles have led to increased demand for fruits, vegetables, and other high-value crops. Consumers are now more conscious of their health, leading to a shift towards a diet, rich in fresh produce.

Export Opportunities: India has become a major player in the global export market for fruits, vegetables, and spices. The international demand for Indian agricultural products has opened up new avenues for farmers to earn higher incomes through exports.

Technological Advancements: The adoption of modern agricultural practices, including precision farming, greenhouse cultivation, and drip irrigation, has improved productivity and efficiency in high-value agriculture.

1.2 Challenges:

Despite the progress, high-value agriculture faces several challenges that need to be addressed for sustained growth:

Infrastructure and Logistics: Inadequate cold storage facilities, transportation, and logistics infrastructure contribute to post-harvest losses, limiting the potential of high-value crops.

Market Access and Linkages: Farmers often face challenges in accessing markets for their high-value produce. Strengthening market linkages and providing farmers with direct access to consumers can enhance their bargaining power and income.

Water Scarcity: High-value crops often require more water than traditional crops. With increasing water scarcity in many parts of the country, sustainable water management practices are crucial for the growth of this sector.

Pricing and Income Disparities: Fluctuating market prices and the dominance of middlemen in the supply chain can lead to income disparities for farmers. Implementing fair pricing mechanisms and promoting farmer-producer organizations can address this issue.

1.3 Future Prospects:

To unlock the full potential of high-value agriculture in India, a multi-pronged approach is required:

Investment in Infrastructure: The government and private sector should invest in cold storage, transportation, and market infrastructure to reduce post-harvest losses and ensure better market access for farmers.

Technology Adoption: Continued research and development in agricultural technology, coupled with the widespread adoption of precision farming practices, can further improve productivity and resource efficiency.

Policy Support: The government should formulate policies that encourage the cultivation of high-value crops, provide price stability, and support farmers through subsidies and financial incentives.

Capacity Building: Farmers need to be equipped with the knowledge and skills required for high-value crop cultivation. Training programs and extension services can play a crucial role in building their capacity.

2. Status of Adoption of Technology in India

Technology plays a pivotal role in transforming traditional agriculture into high-value agriculture by enhancing efficiency, productivity, and sustainability. In the context of India, where agriculture is a crucial sector, the adoption of technology becomes imperative to meet the challenges posed by a growing population, changing consumer preferences, and environmental concerns. Here are several technologies that can significantly contribute to high-value agriculture in India:

(i) Precision Farming:

a. Remote Sensing and GIS (Geographic Information System): These technologies help farmers collect and analyze data related to soil conditions, weather patterns, and crop health. This enables precise decision-making in terms of irrigation, fertilization, and pest control.

b. Drones and UAVs (Unmanned Aerial Vehicles): Drones equipped with sensors can provide real-time aerial imagery, allowing farmers to monitor crop health, assess field conditions, and identify potential issues such as pest infestations or nutrient deficiencies.

c. IoT (Internet of Things) Sensors: Deploying sensors in the field can provide continuous monitoring of environmental conditions, soil moisture levels, and crop growth. This data can be used to make informed decisions and optimize resource-use.

(ii) Smart Irrigation Systems:

a. Soil Moisture Sensors: Integrating sensors into the soil allows farmers to measure moisture levels and schedule irrigation based on actual crop needs, preventing over-watering and water wastage.

b. Drip Irrigation and Sprinkler Systems: These technologies help optimize water usage by delivering water directly to the root zone of plants. This is particularly crucial in water-scarce regions.

(iii) Greenhouse and Polyhouse Farming:

a. Climate Control Systems: Automated systems for temperature, humidity, and ventilation control in greenhouses and polyhouses create an optimal environment for high-value crops, enabling year-round cultivation.

b. Hydroponics and Aquaponics: These soilless cultivation methods, often employed in controlled environments, maximize resource efficiency, reduce the need for arable land, and minimize water usage.

(iv) Biotechnology and Genetic Engineering:

a. Genetically Modified (GM) Crops: Research in biotechnology can lead to the development of crops with improved resistance to pests and diseases, increased nutritional value, and enhanced tolerance to environmental stresses.

b. Marker-Assisted Breeding: This technology accelerates the traditional breeding process by identifying and selecting desirable traits more efficiently, leading to the development of high-yielding and resilient crop varieties.

(v) Post-Harvest Technologies:

a. Cold Storage and Refrigerated Transport: Infrastructure for storing and transporting perishable high-value crops, such as fruits and vegetables, helps reduce post-harvest losses and extends shelf-life.

b. Food Processing and Preservation Technologies: Processing and preserving high-value crops into value-added products contribute to the development of a more robust agri-food industry.

(vi) Digital Platforms and AgTech:

a. Farm Management Software: Platforms that offer tools for planning, monitoring, and analyzing farm activities, including crop rotation, pest management, and resource utilization.

b. Market Linkages and E-Commerce Platforms: Digital platforms connecting farmers directly to consumers or markets can help eliminate middlemen, ensuring better prices for high-value produce.

The integration of advanced technologies is crucial for the sustainable development of high-value agriculture in India. Government support, private sector investments, and farmer education and awareness programs are essential to facilitate the widespread adoption of these technologies, empowering Indian farmers to transition towards more efficient, profitable, and environmentally sustainable agricultural practices.

3. How do we make farming profitable?

Making high-value agriculture profitable for small farmers involves a combination of strategic planning, technology adoption, access to resources, and market linkages. Here are several strategies that can be employed to enhance the profitability of high-value agriculture for small-scale farmers:

(i) Diversification of Crops:

Encourage small farmers to diversify their crops to include high-value, specialty crops such as fruits, vegetables, herbs, and spices. These crops often have higher market value and demand.

(ii) Market Research and Linkages:

Facilitate access to market information and establish direct linkages between small farmers and potential buyers. This can reduce dependence on intermediaries and improve farmers' bargaining power.

(iii) Capacity Building:

Provide training and extension services to small farmers on modern agricultural practices, including the use of technology, efficient irrigation methods, and pest management. Knowledgeable farmers are better equipped to enhance productivity.

(iv) Technology Adoption:

Introduce and promote the adoption of cost-effective and suitable technologies, such as precision farming, drip irrigation, and greenhouse cultivation. These technologies can improve efficiency, reduce input costs, and increase yields.

(v) Access to Finance:

Ensure that small farmers have access to affordable credit and financial services. This can help them invest in necessary infrastructure, equipment, and inputs for high-value agriculture.

(vi) Cooperative Farming:

Encourage the formation of farmer cooperatives or producer groups. Working together allows small farmers to pool resources, share knowledge, and collectively negotiate better prices for inputs and outputs.

(vii) Value-Added Processing:

Promote on-farm processing of high-value crops to add value to the produce. This could involve activities like drying, packaging, or processing fruits and vegetables into jams, pickles, or other value-added products.

(viii) Quality Certification:

Assist small farmers in obtaining quality certifications for their produce. Certifications such as organic, fair trade, or geographical indication can open up premium markets and fetch higher prices.

(ix) Government Support and Subsidies:

Advocate for government policies that provide subsidies, incentives, and support schemes specifically targeted at small-scale farmers engaged in high-value agriculture. This can include financial support, access to technology, and infrastructure development.

(x) Community Development Projects:

Implement community-based projects that focus on improving the overall infrastructure in rural areas, such as roads, storage facilities, and marketplaces. This can create a more conducive environment for high-value agriculture.

(xi) Access to Information:

Improve access to information through digital platforms and extension services. This includes weather forecasts, market prices, and best practices in agriculture. Informed decision-making contributes to better outcomes.

(xii) Risk Mitigation Strategies:

Help small farmers implement risk mitigation strategies, such as crop insurance, to protect them from unforeseen events like crop failures or natural disasters.

(xiii) Partnerships with Agribusinesses:

Foster partnerships between small farmers and agribusinesses. This could involve contract farming arrangements or collaboration with companies that provide technical support, inputs, and assured markets.

By implementing these strategies, policymakers, agricultural extension services, and development organizations can contribute to making high-value agriculture more profitable and sustainable for small farmers. Additionally, fostering a supportive ecosystem that combines financial inclusion, knowledge dissemination, and market access is crucial for the long-term success of small-scale farmers in the high-value agriculture sector.

4. Making farming sustainable through agro-ecological practices

Sustainability in high-value agriculture in India involves balancing economic viability with environmental conservation and social equity. Here are strategies to make high-value agriculture more sustainable in the Indian context:

a. Adoption of Agro-ecological Practices: Encourage farmers to adopt agro-ecological practices that focus on natural and sustainable farming methods. This includes organic farming, crop rotation, agro-forestry, and the use of natural predators for pest control.

b. Water Conservation and Efficient Irrigation: Promote water-efficient irrigation practices such as drip irrigation and rainwater harvesting to address water scarcity issues. Encourage farmers to use water judiciously and invest in technologies that optimize water use.

c. Soil Health Management: Emphasize sustainable soil management practices, including cover cropping, organic amendments, and reduced dependence on chemical fertilizers. Healthy soils contribute to better crop resilience and long-term productivity.

d. Crop Diversity and Resilience: Promote crop diversification to enhance resilience against pests, diseases, and climate change. A diverse range of crops also contributes to a more balanced ecosystem and reduces the risk of monoculture-related issues.

e. Conservation of Biodiversity: Implement practices that preserve and enhance on-farm biodiversity. This includes maintaining natural habitats, preserving local crop varieties, and adopting techniques that minimize harm to beneficial insects.

f. Precision Farming and Technology Adoption Encourage the use of precision farming technologies to optimize resource use, reduce waste, and enhance productivity. This includes the use of sensors, drones, and other precision agriculture tools for efficient farm management.

g. Energy Efficiency: Promote the use of renewable energy sources, such as solar power, for agricultural operations. This can reduce the environmental footprint of high-value agriculture and make it more sustainable in the long run.

h. Integrated Pest Management (IPM): Advocate for the adoption of IPM strategies that minimize the use of chemical pesticides. This involves monitoring pests, using natural predators, and employing cultural practices to control pest populations.

i. Certification and Standards: Support farmers in obtaining and maintaining certifications for sustainable agriculture practices. Certifications such as organic or fair trade can open up premium markets and provide economic incentives for sustainable farming.

j. Waste Management and Recycling: Encourage the responsible management of agricultural waste through composting and recycling. This not only reduces environmental impact but also provides valuable organic matter for soil health

k. Community Involvement and Empowerment: Involve local communities in decision-making processes related to agriculture. Empower farmers with knowledge and resources, ensuring they play an active role in sustainable practices.

l. Government Policies and Incentive: Advocate for and implement policies that incentivize sustainable agriculture practices. This could include subsidies for adopting eco-friendly technologies, promoting organic farming, and supporting conservation efforts.

m. Research and Development: Invest in research and development for sustainable agriculture, focusing on developing crop varieties resistant to pests and diseases, as well as varieties adapted to changing climatic conditions.

n. Education and Awareness: Conduct educational programs and awareness campaigns to inform farmers about the benefits of sustainable agriculture. Extension services can play a vital role in disseminating knowledge on best practices.

By implementing these strategies, India can work towards making high-value agriculture not only economically viable for farmers but also environmentally and socially sustainable. A holistic and collaborative approach involving farmers, government agencies, non-governmental organizations, and the private sector is essential for achieving sustainable high-value agriculture in India.

5. Way forward

The transformation to tech-enabled high-value agriculture in India represents a new era for profitability and ecological security. By embracing precision agriculture, smart irrigation, vertical farming, blockchain, AI, and digital platforms, the agricultural landscape can evolve into a more sustainable, efficient, and resilient system. A concerted effort from all stakeholders, including farmers, policymakers, technology providers, and the private sector, is essential to usher in this new paradigm and secure a prosperous and environmentally conscious future for Indian agriculture.

New vistas in turmeric for commercial exploitation

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Introduction

Turmeric (*Curcuma longa* L.), the golden spices of India is traditionally used in medicine, cosmetic and food preparations. The 'curcumin' is an important constituent of turmeric and useful in nutraceutical industry. India produces about 85% of world production of turmeric and is cultivated in all the states in an area of 3.23 lakh ha with a production (dry) of 11.61 lakh tons with an average yield of 3594 kg ha^{-1} in 2022-23. India exports spices to more than 100 countries, during 2021-22, we exported 1.5 Lakhs tones of turmeric (14.6% of our production) valued Rs. 1534 crores. The shift from quantity of production to quality production of agricultural produce is becoming a new norm after India has achieved self-sufficiency in agricultural production. Turmeric is no exception to this. A salient point to consider in the measurement of impact of high curcumin varieties would be the change in curcumin consumption among the general population arising from availability of high curcumin varieties for common culinary purposes. Using a logical framework of domestic production scenario, curcumin content and extent of varietal spread of high curcumin varieties, the approximate monetary value of higher curcumin consumption was worked out. The magnitude of the annual value of the monetary benefits (Rs 22591 million INR) indicate the levels of returns which are often unheeded while measuring the returns from investments in agricultural research, in general and spice crop research, in particular. Quality aspects of turmeric production and post-harvest handling from a commercial perspective is briefly discussed.

The quality of the end product always depends on the hygienic practices we follow during the crop cultivation period. This can, not only lead to a quality produce, but also protects the ecosystem where crop is grown. In case of turmeric, the quality aspects can be exploited for commercial purpose at different stages.

Production aspects

- ***Selection of high-quality varieties***: Every state has its own traditional local varieties. Apart from local varieties, many improved varieties (> 50)are released for farmers by different agencies. Varieties with low curcumin, high curcumin, light yellow colour and deep orange colour types are available. These will cater needs of spice industry for different purposes, for example, high curcumin varieties are essential for industry to extract curcumin, whereas, light yellow coloured varieties destined for masala powder industries. Stable yielding varieties for specific location are evolved. Turmeric varieties like the high yielding (Suguna, Suvarna, Sudharsana) and stable high curcumin yielding varieties suitable for growing throughout India (IISR Prabha, IISR Pragati, IISR Kedaram, IISR Prathibha and IISR Alleppey Supreme) are available for adoption to farmers across the growing tracts.

- ***Production of quality planting material (disease and pest free):*** Quality planting material is of prime importance when it comes to the successful crop production. The disease and pest free planting material fetch a premium price in market. This can be assured through licensing of the turmeric varieties by authorized research agencies like ICAR-IISR and other central agencies. The quality of planting material can be viewed from the potential of the seed to yield maximum curcumin per kg of the produce. For these varieties with high quality can be given more preference as the curcumin extraction is the most potent business option from turmeric.

- ***Production of residue free turmeric with compliance to international standard:*** Like any other agricultural commodity, turmeric also possesses the risk of high amount of pesticide residues after harvest. This affects the business in the export/import market and tames the country's image for ease of doing business. This can be tackled in two ways. First, development of good agricultural practices for production of turmeric with safer limits of pesticide residue. Second, development of pesticide scheduling for residue-free production of turmeric. This can be achieved by concentrated research effort for calculating pre-harvest interval of all the chemicals used for pest/disease management in turmeric by studying its degradation kinetics using multi-location trials. The processing factor i.e., the factor by which pesticide degrades/accumulates, during processing also needs special mention during this study. This will not only help India for developing intensive production strategies for turmeric, but also provide upper edge in a global platform for safer and quality turmeric production by virtue of developing MRL for all the chemicals used in turmeric production.

- ***Production of organic turmeric:*** Along with production of residue-free produce, production of organic turmeric, which has a premium market segment needs special attention both by researchers as well as by business fraternity. There are well established packages for production of organic turmeric and suitable cultivars/varieties in a location-specific manner. Turmeric varieties IISR – Pragati, Suguna, and Sudharsana are found to be most suitable varieties for organic farming with stable rhizome yield and higher curcumin content over the years. Popularization of this technology can lead to opening of new vistas for turmeric market on a global platform. The effort will be more economically viable, if it adds a feature of traceability to the market chain.

Post-harvest aspects

Green protocol for secondary processing (powdering and blending): Quality of turmeric mainly hovers around the content and profile of essential oil (aroma component) and oleoresin (flavor component). The major drawback of conventional processing is the development of heat during the process of grinding which leads to 20-40% loss of volatile compounds and thermal degradation of active ingredients like curcumin. Therefore, advanced methods of powdering with no heat development such as cryo-grinding needs to be employed for quality assurance of the final produce. Otherwise the efforts for producing quality turmeric in field will go in vein. The removal of mud, metals from powder, which is highly ignored during processing, can add value to the powder with minimal investments.

The importance of avoiding adulteration during processing is another quality aspect in turmeric secondary processing. The unscientific market standards viz. attributing a lemon colour to a market standard (simply based on aesthetic value) is one of the reasons by which the processors are forced to adulterate with artificial coloring agents like metanil yellow. This needs to be checked with stringent testing and market monitoring interventions to safeguard the commercial interest on turmeric industry. Even though at a low level, mixing with chalk powder and cheaper starch sources to increase the bulk of the turmeric powder needs to find check measures in place for quality turmeric powder production.

- ***Green protocol for tertiary processing (extract preparation and bio-active isolation):*** The market of turmeric extractives viz. essential oil, oleoresin and purified curcumin are the major foreign exchange earners when compared to raw turmeric. The flavor profile of these depends on the protocol used for its extraction. Organic solvent-based extraction of oleoresins is now considered as one of the most environmentally hazardous industrial processes for extraction. This can be replaced with newer technologies of extraction like supercritical fluid extraction, eutectic solvent based extraction etc., which not only serves as a environment friendly option but also provides a better flavor profile of the oleoresin. As these newer methods can be fine-tuned for selective extraction of active ingredients, enriched oleoresins or essential oils can be extracted using this method. This will add market value of oils and resins from turmeric. Freeze-dried products of turmeric aqueous extracts are of prime importance as this contains more absorbable form of curcumin. This will not only increases the value of the product but also improves the shelf-life of the product as it contains moisture level of less than 2%.

- ***Novel approaches for efficient utilization of industrial wastes (spent):*** After the extraction of essential oil and oleoresin from turmeric, the spent from spice industry is rich source of starch, dietary fibre and valuable peptides with unique biological properties. This can be used for various applications. Generally, all big industries use the spice spent as fuel for the boiler unit to avoid the handling menace. However, with the advent of newer applications, the spent is being handled carefully for much better value-added product development. A possible usage of turmeric spent is as given below.

The spent from freeze-drying industry, after squeezing the aqueous content, is a good source of curcumin and all other biochemicals which are native to turmeric matrix. This can be used effectively for fortifying actual turmeric powder.

- ***Development of more absorbable form of curcumin:*** The bio-accessibility of curcumin, a matter of concern for researchers, especially in functional food segment. It needs more research efforts for maximizing the bio-availability of curcumin for tapping more international market value of turmeric.

- ***Development of Turmeric-based functional food:*** Functional food and nutraceuticals industry is flourishing especially after Covid-19 pandemic. Considering the immense immunomodulatory potential of turmeric, it holds prime position as a candidate for development of functional food to suite variety of customers ranging from vegan and non-vegetarians.

- ***Novel applications for fresh turmeric:*** Despite centuries of expertise in usage of turmeric, the use in its fresh form is still limited. The fresh turmeric can be converted to many value-added food products. Developing a customer base for such products will be a challenge for its commercial exploitation. However, the status of using fresh turmeric for commercial ventures is still at infancy.

Spice Spent	Product prepared	Optimum dosage
Turmeric	Separation of starch from turmeric spent	10%
	Management of diabetes and diabetic neuropathy	10%
	Feeding the diabetic rats with fenugreek seed mucilage and spent turmeric helps in ameliorating the diabetic state	10%
	Turmeric spent used in bioactive film production	
	Turmeric spent used for the preparation of eco-bio-pots	

Ashwagandha or Indian ginseng (*Withania somnifera*): A medicinal plant with myriad opportunities

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Ashwagandha or Indian Ginseng (*Withaniasomnifera*; Solanaceae family) is a very popular medicinal plant used in Indian system of medicine since ancient time. For Millenia, the root portion of this medicinal herb is being used as *Rasayana* (tonic) and/or *Churna* (powder) having several health benefits like- improving memory, enhancing functions of nervous system, maintaining sexual and reproductive balance, increasing resilience of body towards stress, inducing immunomodulatory effect, antioxidant activity etc.Wider acceptability of different ashwagandha based products increases the value of this crop manifold. Various secondary metabolites are primarily responsible for bioactivities such as, steroidal lactones (withanolides, withaferin A), alkaloids (cuscohygrine, tropine), polyphenols etc. Some 40 withanolides along with 12 alkaloids, and large number ofsitoindosides have been isolated from this plant so far[1]. Owing to have such diverse health promoting effects, these high value chemical compounds have immense applications in different pharmaceutical as well as nutraceutical sector including modern medicine. The root powder and its extracts are used as key ingredient in different medicines, food supplements, cosmetic products, food and beverages. Therefore, such diverse industrial applications and existing demand make this crop a profitable venture for the farmers.Ashwagandha is cultivated in about 5000 hectares of land in the country with yield of around 1600 tonnes/year. Its cultivation is abundant in Mandsaur, Neemuch, western Madhya Pradesh and Nagaur district of nearby Rajasthan. The Nagoriashwagandha has a different identity in the market due to superior quality with high starch content[2,3]. The quality produce enriched with bioactive components are always on demand for commercial usages. The global market of ashwagandha is expected to grow with CAGR of 11.6% from 2023-2030[4]. In India the demand was estimated as 7000 tonnes in last year across various industries[2]. The large gap between demand and production, makes great opportunity for the farmers to grow this crop for fetching good price in the market.Due to the wide adaptability of this crop, lesser input requirement; the cost of production is generally low and one can make good profit out of this crop (up to 6-7 times based on market price and cost of cultivation)[2]. It is possible only through proper linkage between market, intended buyersand the growers. In India, Mandsaur and Neemuch markets of Madhya Pradesh are most popularfor ashwagandha where buyers, importers, traditional practitioners, Ayurvedic and Siddha drug manufacturers horde these markets for procurement of ashwagandha roots each year.The growers need to explore such market agglomerates to get profit from their produce. Apart from root portion, the residual biomass of ashwagandha has significant therapeutic potential as the leaf and stem are rich in withaferin A, a potential anticarcinogenic and anti-inflammatory agent. The biomass also contains dietary fibres that can be converted to several value-added products like- biochar, compost, bioethanol etc. After harvest of the root, farmers can utilize the above ground portion of this plant as therapeutic agent or biorefinery via appropriate industrial interventions. Ashwagandha is such a high value medicinal plant having one of the most diverse use and applications that too attached with the ancient medicine system. This crop has every possibility to become an intriguing part of commercial agriculture with suitable agreement between growers and buyers. Although market volatility and instability are a major issue towards wider acceptability of this crop among farmers, the problem can be resolved by implementation of various government policies, intervention of government and non-government organizations and reshaping the conventional cultivation practices among growers. The changing scenario of agriculture, market dynamics and human lifestyle are creating a huge scope for this crop to become a potential alternative to conventional agroecosystem. By overcoming some of the hurdles as mentioned earlier, the ashwagandha can become one of the most important crops in Indian agriculture that can provide monetary profit to growers, product manufacturers and health and well-being to all end-users.

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Medicinal and Aromatic Crops for Diversification of Commercial Agriculture

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Traditionally, Indian agriculture has focused on food crops, certain commercial crops such as sugarcane, cotton, tea, tobacco and others. Indian agriculture needs to diversify in such directions as utilization of marginal lands, integration of new crops in the existing cropping systems, value-addition and export promotion. Medicinal and aromatic crops (MACs) could fit into the diversification scheme of Indian agriculture. In recent times, MACs such as mint, basil, chamomile, isabgol, senna, ashwagandha, opium poppy, lemongrass, palmarosa, citronella have been shown to be commercially viable crops in different parts of India. More than 7000 medicinal plants grow in India. According to the National Medicinal Plants Board (NMPB), Ministry of Ayush, Govt. of India, out of the domestic demand of nearly 2 lakh tonnes of medicinal plants, 22% are from cultivated sources (www.nmpb.nic.in). Globally, the medicinal plants business is more than US$ 62 billion, which is growing at 15% annually and is estimated to reach US$ 5 trillion by 2050 (Tripathi and Prakasa Rao, 2016). Aromatic crops which yield essential oils on steam distillation are important and viable commercial crops for diversification. India is a leading country in the world in the production of essential oils. The essential oils market in India has reached US$ 159.7 million in 2022 and it is expected to reach US$ 247.1 million by 2028 at 7.7% growth rate (CAGR) (https://www.eoai.in).

MACs produce secondary metabolites which are used as drugs, cosmetics, dyes etc. and their synthesis in plants is mediated as (Prakasa Rao, 2021):

- Pentose ➡ glycosides, polysaccharides
- Shikimic acid ➡ phenols, tannins, aromatic alkaloids
- Acetate-malonate ➡ phenols, alkaloids
- Mevalonic acid ➡ terpenes, steroids, alkaloids

Some important MACs, their active constituents and uses are listed in Table1.

It is important that delineation of suitable agro-climatic conditions has to be worked out for successful cultivation of MACs. Such a perspective is presented in Table 2.

In order to make MACs as commercial alternatives in agriculture, the following strategies are required:

1. Identification of suitable MACs for cluster cultivation
2. Demand driven cultivation - based on commodity prices, market access
3. Integration of MACs in the existing cropping/agro-forestry systems
4. *In situ* processing facilities for extraction of essential oils and medicinal principles
5. Integration of elements starting from government, farmers to the markets (Fig 1)

Thus, medicinal and aromatic plants could be prominent diversification candidates in the commercial agriculture paradigm in India. It requires customized strategies of cluster development, technology, markets and policy support.

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Table1. Some important medicinal and aromatic plants, their active constituents and uses

Plant	Active/principal constituents	Uses
Cassia angustifolia *Cassia acutifolia*	sennosides	Laxative
Plantago ovata	psyllium mucilage	-do-
Withania somnifera	withanolides	Anti-stress, hepatoprotective
Glycymhiza glabra	glycymhetiaic acid	Anti-inflammatory
Commiphora mukul	guggul sterones	-do-
Opium poppy	Opium alkaloids papavarin narcotine	Analgesic
Gloriosa superba	colchicine	gout treatment
Rauvolfia serpentina	reserpine	Hypotensive
Catharanthus roseus	vinblastine vincristine ajmalicine	Anticancer anticancer hypotensive
Taxus baccata	taxol	Anticancer
Podophyllumemodi	podophyllotoxine etoposide tenoposide	-do-
Mappia foetida	camptothecin	-do-
Digitalis lanata	digoxin, lanatoside	Cardiotonic
Berberis sp.	berberine	Antidiarrhoel
Cinchona lederiana	quinine	Antimalarial
Artemisia annua	artemisinin	-do-
Cymbopogon winterianus jowitt.	citronellal citronellol geraniol	perfumery, raw material for various aroma chemicals
Coriandrum sativum L.	linalool, linalyl acetate	flavouring food and pharmaceuticals, perfumery
Artemisia pallens Wall.	davanone, davanofurans	flavouring cakes, pasteries, tobacco, beverages high grade perfumes
Mints *Mentha arvensis* *Mentha piperita* *Mentha citrata* *Mentha spicata*	Menthol Menthol, Perperitone Linalool, Linalyl acetate Carvone	Tooth paste ,hair oils, chewing gums, pain balms, face creams, shaving lotions, perfumes, cough syrups etc.
Eucalyptus citriodora Hook.	citronellal,isopulegol,citronellol	Perfumery

Plant	Active/principal constituents	Uses
Pelargonium graveolens L. Her.ex Ait.	l-citronellol, geraniol, linalool	perfumery and flavouring
Jasminum grandiflorum L.	linalool, benzylacetate, indole, eugenol, benzyl benzoate	Perfumery
Cymbopogon flexuosus(steud) Wats.	citral	flavours, cosmetics, perfumes, manufacture of vitamin A
Bursera delpechiana Poisson ex Engl.	linalool, linalyl acetate	cosmetics, soaps
Cymbopogon martinii(Roxb.) Wats.	geraniol, geranyl acetate, linalool	Perfumery
Pogostemon cablin Benth.	patchouli alcohol, sesquiterpene hydrocarbons	Perfumery
Rosmarinus officinalis L.	1,8-cineole,linalool myrcene, camphene	Perfumery
Santalum album L.	á-santalol,â-santalol, á- & â- santalene	Perfumery

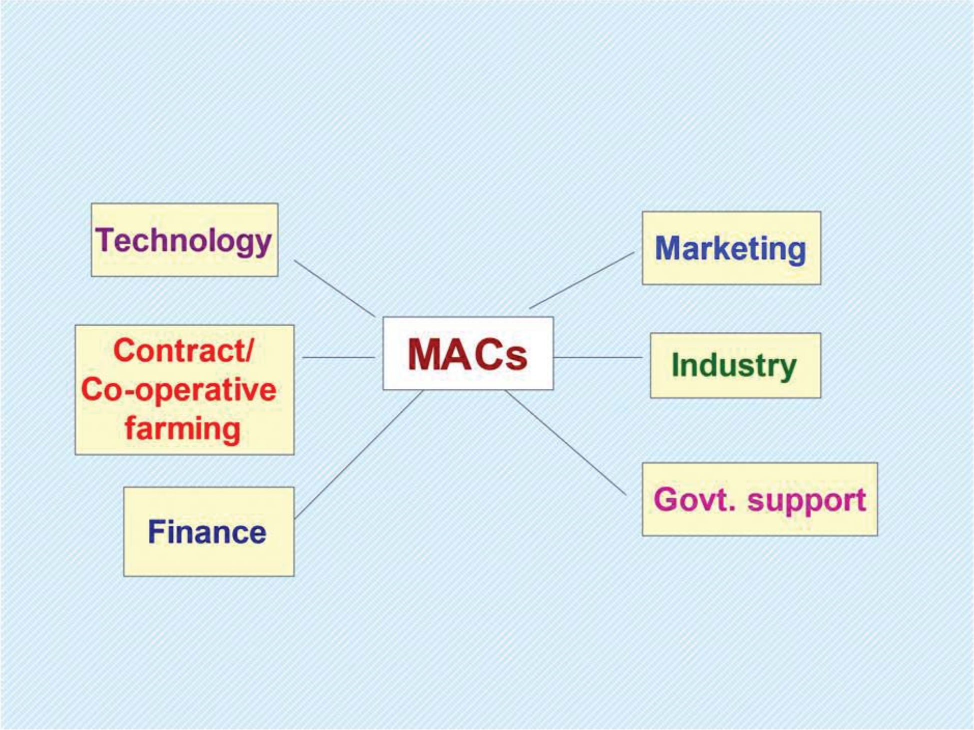

Fig.1. Integration of factors for commercial production of MACs

Table 2. Prospective MACs suitable for cultivation in different agro-climatic conditions in India (Tripathi and Prakasa Rao, 2016)

Agro-climatic zones	**Prospective MACs**
Western Himalayan region	*Valeriana jatamansi*, *Picrorrhiza kurroa*, *Swertia spp.*, *Rosa damascena*, *Lavendula angustifolia*, *Salvia sclarea*, *Pelargonium graveolens*, *Artemisia annua* *Zanthoxylum alatum*, *Terminalia bellericais*; *Phyllanthus emblica*; *Tinospora cordifolia*; *Hedychium spicatum*, *Curcuma longa*, *Zingiber officinale* and *Angelica glauca*
Eastern Himalayan region	*Picrorrhiza kurroa*, *Pogostemon cablin*, *Cymbopogon winterianus*, *C. flexuosus*; *Gingko biloba*, *Rosa damascene*, *Amomium subulatum* (Large cardamom), *Cinnamomum tamala* (Tejpatra), *Abies wbbiana*, *Eucalyptus citriodora*, *E. tereticornis*; *Origanum vulgare*, *Vanilla planifolia*
Lower Gangetic plains	*Rauvolfia serpentina*, *Asparagus racemosus*, *Bacopa monnieri*, *Mentha arvensis*, *Ocimum basilicum*, *O. sanctum*, *Vetiveria zizainoides*
Mid Gangetic plains	*Rauvolfia serpentina*, *Andrographis paniculata*, *Ocimum spp.*, *Withania somnifera*, *Mentha arvensis*; *Cymbopogon spp.*, *Vetiveria zizainoides*
Upper Gangetic plains	*Glycyrrhiza glabra*, *Cassia angustifolia*, *Rauvolfia serpentina*, *Andrographis paniculata*, *Ocimum spp*, *Mentha arvensis*; *Cymbopogon spp*, *Vetiveria zizainoides*
Trans Gangetic plains	*Cassia angustifolia*, *Rauvolfia serpentina*, *Andrographis paniculata*, *Ocimum spp*, *Mentha arvensis*; *M.piperita*, *Cymbopogon spp.*, *Vetiveria zizainoides*
Eastern plateau & hill regions	*Rauvolfia serpentina*, *Andrographis paniculata*, *Withania somnifera*, *Rosa damascena*, *Mentha arvensis*, *Cymbopogon spp.*, *Ocimum spp.*, *Vetiveria zizainoides*
Central plateau & hill regions	*Rauvolfia serpentina*, *Cassia angustifolia*, *Commiphora wightii*, *Cymbopogon spp.*
Western plateau & hill regions	*Cassia angustifolia*, *Andrographis paniculata*, *Glycyrrhiza glabra*, *Plantago ovata*, *Withania somnifera*, *Commiphora wightii*, *Cymbopogon martinii*
Southern plateau & hill regions	*Cassia angustifolia*, *Andrographis paniculata*, *Commiphora wightii* , *Withania somnifera*, *Cymbopogon flexuosus*; *Gloriosa superb*
East coast plain & hill regions	*Rauvolfia serpentina*, *Cymbopogon spp.*, *Pogostemon cablin*
West coast plains & hill regions	*Cassia angustifolia*, *Andrographis paniculata*, *Glycyrrhiza glabra*, *Plantago ovata*, *Withania somnifera*, *Commiphora wightii*, *Cymbopogon spp.*
Gujarat plains & hill regions	*Plantago ovata*, *Ocimum spp.*, *Rauvolfia serpentina*,*Rosa damascene*, *Vetiveria zizainoides*
Western dry zone	*Plantago ovata*, *Cassia angustifolia*, *Andrographis paniculata*, *Commiphora wightii*, *Withania somnifera*,*Cymbopogon martini*, *C*, *flexuous*, *Ocimum spp.*, *Vetiveria zizainoides*
The island regions	*Rauvolfia serpentina*, *Pogostemon cablin*, *Ocimum basilicum*, *Vetiveria zizainoides*, *Cymbopogon* species

New Perspectives in Chilli, Turmeric and other Herbs Cultivation for Sustainable Farming

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Indian Horticulture sector has been the mainstay of Indian Agriculture with a contribution of about 30 per cent to the agricultural GDP from about 14 per cent area and 40 per cent of total export earnings in agriculture as a whole. Horticulture production increased 13-fold from 25 million metric tons during 1950-51 to 342.30 million tonnes during 2021-22 surpassing food grain production. According to FAO (2022), amongst fruits, the country ranks first in the production of Banana, Mango, Guava & Papaya while amongst vegetables, first in producing Okra, Onion & Shallots, Chillies & Beans and second in the production of Potatoes, Tomato, Cauliflowers, Broccoli, Brinjal, Cabbages and Green peas.

India is the leading producer of several high-value commercial crops in the world. The high-value commercial crops are selected for analysis based on their potential to generate higher returns, greater scope for post-harvest processing and value-addition, and tremendous export potential to generate foreign exchange revenue to the national economy. Currently, India enjoys a pre-eminent position in the global production and exports of high-value commercial crops such as chilli and turmeric.

Curcuma longa known as yellow turmeric is an important, sacred and ancient spice of India. India is the largest producer, consumer and exporter of turmeric in the world ranking first in the production, accounts for a lion share of (85%) world production, followed by China (8%) and Myanmar (4%) recording the highest productivity in turmeric (3980 kg/ha) followed by other minor producing countries such as China (2652 kg/ha) and Myanmar (1784 kg/ha) in 2021.

Turmeric:

In the year 2022-23, an area of 3.24 lakh ha was under turmeric cultivation in India with a production of 11.61 lakh tonnes (over 75% of global turmeric production). More than 30 varieties of Turmeric are grown in India and it is grown in over 20 states in the country. Turmeric (Indian saffron), the 'Golden Spice of India', is one of the important commercial spice crops grown in India. The major states producing turmeric are Telangana (28.09%), Maharashtra (22.33%), Karnataka (11.14%), Tamil Nadu (8.13%), Andhra Pradesh (6.35%), Madhya Pradesh (5.86%) and West Bengal (3.90%). These seven states accounted for >80 % of turmeric production during the last five years. Turmeric is also cultivated in smaller pockets in other states such as Odisha, Mizoram, *etc* while highest productivity is observed in Karnataka (6100 kg/ha) followed by Telangana (5576 kg/ha).

During 2022-23, 1.534 lakh tonnes of turmeric and turmeric products valued at 207.45 million USD were exported by more than 380 exporters. India exports about 10% of turmeric per annum and 60% share in world export. The key export destinations of Indian turmeric are UAE (17%), USA (10%) Bangladesh (9%), Srilanka (7%), Japan (7%), Malaysia (6%) and UK (6%). With the focused activities of the Board, it is expected that turmeric exports will reach USD 1 Billion by 2030.

Turmeric is normally propagated by rhizomes and it requires the seed rate of 2000-2500 kg ha^{-1}. The farmer has to spend more amount on purchasing seed rhizomes. To overcome this, a study was conducted on protray technology which indicated that vertical split of mother rhizome recorded minimum number of days (20.10) for sprouting, maximum seedling vigour index (2825.33) and minimum number of days taken for final transplanting (30.10) (Chandana, 2023).

An experiment conducted on different organic manures and biofertilizers, revealed that FYM @ 45 t/ha and AMC (Arka microbial consortium) 1 litre has recorded maximum number of mother rhizomes (4.63), primary rhizomes (9.98), secondary rhizomes (16.48) with fresh rhizome yield (26.85 t ha^{-1}) and curing percentage (24.71 %). The quality of turmeric was also improved interms of curcumin content (5.75 %), oleoresin content (9.25 %) and antioxidant activity (12.01 µg/mL), (Chandana, 2022).

Application of Farm yard manure @25 t ha^{-1}, Vermicompost @5 t ha^{-1}, Neem cake @ 500 kg ha^{-1}, *Azotobacter* @ 2 kg ha^{-1}, Phosphorous solubilizing bacteria @ 2 kg ha^{-1} along with 75% RDF of NPK fertilizers has recorded higher fresh rhizome yield (29.69 t ha^{-1}), curcumin content (4.74%) and benefit cost ratio (3.66) while application of same dose of organic and bio fertilizer sources excluding RDF has recorded yield (24.23 t ha^{-1}), Curcumin content (4.54%) and benefit cost ratio (4.76) (Amala, 2019).

An experiment on different mulches studied in turmeric revealed that black plastic mulch (30 mm) recorded maximum yield (46.23 t ha^{-1}) followed by 37.86 t ha^{-1} in the case of black plastic mulch (25 mm) (TRS, SKLTSHU, Kammarapally).

The important constraints reported by turmeric growers were with respect to cultivation and marketing, non-availability of quality seed, high cost of seed, attack of rhizome fly, higher charges of commission agents and low market price. Hence innovative practices such as two budded seed rhizomes with seed treatment, planting two to three rows on raised bed method with drip irrigation, selection of high yielding and high curcumin varieties will improve the productivity in Turmeric.

Chilli:

Chilli is an important vegetable as well as spice crop mostly grown commercially all over the world adding taste, flavor, colour and pungency to the dishes. Globally, among the major producing countries, India ranks first in the production of chilli, contributing major share of (42%) of world production, followed by China (8%) and Ethiopia (7%). Globally, China topped in recording highest productivity in chilli (6728 kg/ha), followed by India (2974 kg/ha) and Ethiopia (2974 kg/ ha). Though India is the largest producer of chilli in the world, the productivity in China is almost 2.5 times greater than that of India, which is very much significant.
Andhra Pradesh is leading in chilli production with a share of 37.35% followed by Telangana (23.11 %), Madhya Pradesh (15.8%), Karnataka (9.85%) and Orissa (3.70%). Chilli production both globally and domestically is beset with many challenges. Low productivity of cultivars, climate change, improper management and utilization of genetic resources, lack of good quality seeds, increased susceptibility to major insect-pests and diseases and abiotic stresses are the major constraints and thus, chilli productivity is stagnant over several years.

India being the major producer and exporter of chilli in the world needs to emphasize more on emerging constraints which will help to cope up with deteriorating productivity of the crop. Identification and exploitation of new resistance genes remain the most important goals of hot pepper breeding programmes. Integration of molecular technologies, such as marker assisted selection and genetic transformation has become key issues in modern breeding programmes and therefore should be emphatically exercised in order to develop better products of chilli.

Developed an Integrated pest management module in chilli consisting of seedling dip with Imidacloprid 200 SL @ 0.5ml/l, spraying of Buprofezin 25 SC @ 1ml/l @25 DAT, spraying of Fipronil 5SC @ 1.5 ml/l or Fipronil 80WG @ 0.2 g/l @ 35 DAT, spraying of Verticellium lecani @ 5gm/l @ 45DAT, spraying of Chlorfenpyre 10 SC @ 1ml/l @ 55 DAT, spraying of neem oil @ 1% @ 65 DAT was found to be effective (VRS, SKLTSHU, Rajendranagar)

Evaluated different modules for the management of thrips (*Thrips parvispinus*; *Scirtothrips dorsalis*) and mites (*Polyphagotarsonemus latus*) in chilli and found that seedling dip with Imidacloprid 17.8% SL @ 1 ml/l of water; spraying of Chlorfenapyr 10% SC @ 1.5 ml/l at 25 DAT; spraying of Tolfenpyrad 10% EC @ 2 ml/l at 35 DAT; spraying of Spirotetramat 15.31% OD @ 0.8 ml/l at 45 DAT; spraying of Emamectin Benzoate 1.50 % + Fipronil 3.50 % SC @ 1.2 ml/l at 55 DAT; spraying of Fenpropathrin 30% EC @ 0.33 ml/l at 65 DAT; spraying of Cyantraniliprole 10.26% OD @1.2 ml/l at 75 DAT and subsequent need based rotation (VRS, SKLTSHU, Rajendranagar)

An innovative work conducted in Chilli at SKLTSHU was evaluation of Purdue Improved Crop Storage (PICS) based triple layer hermetic bags (PICS triple bags) for the efficacy in safe storage of dry chilli pods as aflatoxin contamination,unsafe for consumption and unfit for trade, is a major concern in dry chilli pods during storage, unsafe for consumption and unfit for trade. The results suggested that aflatoxin levels resulting from *Aspergillus flavus* infection were below detectable levels in chilli pods stored in PICS triple bags owing to the modified atmospheric conditions of hypoxia and hypercarbia conditions created inside the bags. Further, dry chilli pods stored in PICS triple bags for 2, 4 and 6 months recorded no loss in test weight (1000 seeds) and no change in moisture content. Germination percentage of the seeds from the PICS triple bags at 2, 4 and 6 month storage was highest (72%) compared to other bags (Madhusudhan *et al*., 2023).

Recently advances have been made for improvement of chilli through biotechnological tools. Use of molecular markers in isolation of resistant genes, sterility traits have proved to be of utmost significance in present day. The use of molecular marker-assisted selection can reduce the time of the conventional selection method and as well as reported to be practical, precise and rapid (Jinda *et al.*, 2023). Therefore, integration of traditional and modern molecular techniques would accelerate the identification of novel genes for improvement of chilli.

Hence, to increase the productivity in Chilli, innovative practices such as use of mulching with drip irrigation, fertigation at weekly intervals, erection of blue and yellow sticky traps to control thrips and white fly, planting of Castor and Marigold as trap crops to control lepidopteran pests and growing maize or bajra as boarder crop to reduce sucking pests are to be propagated.

Ashwagandha:

The area and production of medicinal and aromatic plants in India is 499 thousand hectares and 926 thousand tonnes, respectively (Govt. of India, 2016). The commercial medicinal crops that have potential to take up the cultivation in India such as Ashwagandha,Tulsi, Stevia, Aloe vera, Coleus, Salcia, Acorus, Andrographis, Bail, Guggal, Pachouli, and Gloriosa.

In India, Ashwagandha is extensively grown as a medicinal plant in the northwestern region of Madhya Pradesh and cultivated on more than 5000 ha of land and also grown in Rajasthan, Gujarat, Uttar Pradesh, Punjab, Haryana, Andhra Pradesh, Telangana and Maharashtra.

The global interest in ashwagandha is due to the high demand for its roots and there is ample scope to cultivate this plant on commercial scale. Other opportunities for cultivation include: present price for roots is attractive, crop gives economically remunerative returns in comparison to traditional crops, ease of cultivation under rain-fed condition, the crop can be integrated with traditional crops through crop sequencing, opportunities for marketing leaf and seed exist, by-products can be profitably utilized, value-addition can increase profits, however, current exports are limited and large scale exports of roots and value-added products need to be explored.

The challenges for Ashwagandha cultivation are *viz*., market exploitation of farmers by middlemen, price fluctuations of roots, demand-supply fluctuations of roots, limited exports, patenting by foreign companies, changing climatic conditions, long duration of the crop, low root yields, high fibre content of the roots in some locations, pests and diseases reducing yield thus resulting in plant mortality, labour problems , lack of knowledge about post-harvest technology and problems associated with long term storage of roots.

The Telangana State Medicinal Plants Board (TSMPB) implements several schemes to boost the medicinal plants production in the state. In Telangana state, over 2000 species of medicinal plants are found. The popular and commercially grown medicinal herbs in the state are Senna, Ashwagandha, Kalmegh, and Coleus (Singh and Vidyasagar, 2015).

The area and production of medicinal crops in the erstwhile Andhra Pradesh (including Telangana) is 1.88 thousand hectares and 3.5 thousand tonnes, respectively. Scientific studies on this crop need to be increased and creating awareness on imparting technical knowledge to farmers and various stake-holders is needed for large scale commercial cultivation of this crop as wide opportunities exist for large scale commercial cultivation of this crop in India.

A study conducted on integrated nutrient management in ashwagandha revealed that the maximum dry root yield (342.67 kg/ha) was recorded with application of 50% RDF & 50% of N through vermicompost followed by application of 50% RDF & 50% of N through neem cake (274.67 kg/ha) (MAPRS, SKLTSHU, Rajendranagar).

Therefore, there is a need for identifying potential area where different types of medicinal plants can be promoted. Secondly, the constraints pertaining to the medicinal plant cultivation and marketing need to be probed to formulate strategies to make medicinal plant cultivation economically viable for farmers to venture into this enterprise or the existing farmers to expand their area.

Hence, the importance of high-value commercial horticultural crops like chilli, turmeric and ashwagandha is increasing in accordance with the growing demand in both domestic and international markets. The key research thrust areas to be focused must aim at augmenting productivity, quality, processing, value addition and product diversification to enhance farmers' income and agricultural exports while ensuring the sustainability of agro-ecological conditions.

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Chilli Crop Improvement for Enhancing Commercial Value

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India is the world's largest producer, consumer and exporter of dry chillies. Chilli (hot pepper) is grown throughout the country and is one of the most important crops of India with high commercial value. Chilli belongs to the genus *Capsicum* of the family Solanaceae. The *Capsicum* genus is originated in Central America with about 35 species, of which five are domesticated for cultivation. Indian chillies have huge demand in international market. Sources said there is huge demand for chilli from UAE, USA, Saudi Arabia, UK *etc.,* and exports to these nations have gone up steadily for the past two years but the demand has surged unprecedentedly in the current season. Chillies contribute about 32.8 per cent among the total spice export from India with an economic share of Rs. 10,400 crores in fiscal year 2023. Indian spice oil and oleoresin exports also stood at 21,921 MT worth Rs 4,478 crores, in FY 2022, the highest so far; of which *Capsicum* oleoresins and paprika oleoresins have the maximum share. Due to its pungency, colour and flavor chillies have become an indispensable commodity in Indian cuisine; and are also being used in Ayurveda since ages. Fruit colour and pungency related components such as capsanthins, capsaicinoids and capsinoids are unique to *Capsicum* genus having high commercial value. They are an excellent source of health-related compounds, such as ascorbic acid (vitamin C), carotenoids (provitamin A), tocopherols (vitamin E), flavonoids and capsaicinoids; and are also being used for medicinal purposes. The crop has huge commercial applications in food, nutrition, pharmaceutical & cosmetic industries and defence.

Traditionally chilli fruits have been used as appetite stimulants, flavoring agents, and treatments for parasitic infections, rheumatism, tooth ache, muscle pain, coughs, sore throat, and wound healing. Their health benefits can be ascribed to their antioxidant properties (Carvalho *et al.,* 2015; Badia *et al.,* 2017; Takemura *et al.* 2021). Pepper is rich in diverse bioactive components and mineral nutrients, such as vitamins (especially C and E) and colored pigments (â-carotene, zeaxanthin, violaxanthin, â-cryptoxanthin, lutein, capsanthin, and capsorubin), as well as phenolic substances, such as capsaicinoids and flavonoids (Antonio *et al.* 2018; Baenas *et al.,* 2019). The concentration of these compounds in pepper can exhibit significant differences influenced by genotypes, environmental factors and cultivation practices (Carvalho *et al.,* 2015; Baenas *et al.,* 2019; Fayos *et al.,* 2019).

Breeding chilli with improved nutritional qualities will require a comprehensive understanding of biosynthetic pathway genes and their regulatory functions. Advances in molecular biology and biotechnology have facilitated the identification of genes involved in carotenoid, anthocyanin, and capsaicinoid biosynthesis, providing opportunities for the development of new chilli cultivars with tailored levels of desired metabolites. Further advances in high-throughput sequencing methods and computational analyses will allow more efficient and accurate identification and functional characterization of genes and regulatory elements participating in biosynthesis and regulation of these traits.

Capsaicinoids:

Pungency is a very important economic trait of chilli that has long been investigated. Peppers are generally grouped into pungent (hot peppers) and non-pungent (sweet peppers). Capsaicinoids, a group of secondary metabolites unique to *Capsicum*, are responsible for pungency in peppers. The concentration of capsaicinoids in hot peppers can vary widely depending on the species, cultivar, and environmental conditions (Fayos *et al.,* 2019]. Capsaicinoids comprise a variety of compounds, but capsaicin and dihydrocapsaicin make up approximately 90 per cent of the overall capsaicinoid content in hot pepper fruits (Wahyuni *et al.,* 2013). Capsaicinoids have also been shown to have potential health benefits, including pain relief, anti-inflammatory effects, and anticancer properties (Aza-Gonzalez *et al.*, 2011], making them attractive materials for the food and pharmaceutical industries. Therefore, there is significant interest in investigating the genetic and molecular mechanisms that underlie capsaicinoid biosynthesis, with the goal of producing hot pepper varieties with altered capsaicinoid contents. Indian landrace, Bhut Jolokia entered into Guinness Book of World Records for its pungency.

The capsaicinoids, a class of secondary metabolites, are responsible for conferring pungency in chillies. The phenylpropanoid pathway and branched-chain fatty acid (BCFA) pathway are the main pathways associated with capsaicinoid synthesis, in which simple amino acids and fatty acids are converted into capsaicinoids. Chilies with non-functional pAMT protein accumulate non-pungent capsaicinoid analogs called capsinoids. Capsinoids possess an ester bond between the aromatic ring and the branched fatty acid, as opposed to an amide bond of capsaicinoids, which makes them almost completely non-pungent, and are less stable in aqueous conditions compared with capsaicinoids (Tanaka *et al.,* 2010), and has various health benfits. Non-pungent capsinoids, such as capsiate, dihydrocapsiate, and nordihydrocapsiate, are naturally present in chilli fruits in very small quantities, whereas sweet peppers are a rich source of capsinoids.

The pungency levels in chilli fruit is an inherited trait determined by *Capsicum* species, variety, genotype, and environmental growth conditions (Zewdie and Bosland, 2000). *Pun1, Pun2*, and *Pun3* have been extensively studied as key players in capsaicinoid biosynthesis (Stewart Jr *et al.,* 2005; Stellari *et al.*, 2020; Han *et al.*, 2019). *Pun1* specifically functions in the last stage of capsaicinoid biosynthesis and is expressed only in the fruits (Stewart Jr *et al.,* 2005 & 2007). The *Pun2* locus, identified in *C. chacoense*, is involved in regulating pungency levels and has been found to encode the *pAMT* gene (Yi *et al.,* 2022). The *Pun3* locus, corresponding to the *Cap1/cap7.2* QTL, encodes the MYB31 TF, which is considered a master regulator of capsaicinoid biosynthesis (Arce-Rodriguez *et al.,* 2017). In addition to *Pun1, Pun2,* and *Pun3*, other genetic factors have also been reported to regulate pungency levels. A putative *KR1* gene in the BCFA biosynthesis pathway was reported to contribute to the pungency level in *C. chinense* (Koeda *et al.*, 2019). Chilli cultivars display significant variation in capsaicinoid content and pungency levels, indicating the involvement of multiple genetic factors in their regulation. Previous studies have identified at least 12 QTLs on six chromosomes that are associated with capsaicinoid regulation (Yarnes *et al.,* 2013). One of the major QTLs, *cap (Cap1/cap7.2),* has been mapped to chromosome 7 (Ben-Chaim *et al.,* 2006; Blum *et al.,* 2003) and corresponds to *Pun3* (Han *et al.,* 2019). Common QTLs have been identified on chromosomes 3, 6, and 10 in various studies. In a recent study, Park *et al.* (2019) conducted a range of genetic analyses to identify candidate genes that control capsaicinoid biosynthesis in the pericarp. They found 16 novel QTLs distributed across chromosomes 3, 6, and 11 that were associated with capsaicinoid content.

Carotenoids:

Capsicum fruits are a rich source of carotenoids, including â-carotene, lutein, â-cryptoxanthin, zeaxanthin, violaxanthin, capsorubin, and capsanthin. The accumulation profiles of carotenoids can exhibit significant differences influenced by factors, such as genotype, fruit ripening stage, and fruit color (Baenas *et al.,* 2019). â-Carotene is the predominant carotenoid compound present in nearly all pepper fruits, while capsanthin is detected only in genotypes with red fruits (Guzman *et al.,* 2010; Morales-Soriano *et al,.* 2019). The fruit color of *Capsicum* sp., either red, orange, salmon, or yellow, is determined by accumulations of distinct carotenoids (Wahyuni *et al.,* 2013). Red pepper fruits contain six primary pigments, â-carotene, â-cryptoxanthin, zeaxanthin, antheraxanthin, capsorubin, and capsanthin, at varying concentrations and lutein in a smaller amount. The orange color of pepper fruits develops from a balanced deposition of yellow and red carotenoids or from an accumulation of â-carotene or zeaxanthin, which are orange (Guzman *et al.,* 2010; Kim *et al.,* 2016). Pepper fruits that are yellow can also accumulate carotenoids, including *á*-carotene, *â*-carotene, zeaxanthin, and antheraxanthin, but they do not accumulate capsanthin or capsorubin. Instead, they accumulate high levels of violaxanthin and lutein (Wahyuni *et al.,* 2011; Shu *et al.,* 2023).

Genetically, the dominant trait for color is red over yellow and orange, and light yellow is dominant over white (Jeong *et al.,* 2020). According to Hurtado-Hernandez *et al.* (1985), the mature pepper fruit color is determined at three independent loci: *C1, C2,* and *Y*. Genetic mapping studies have shown that those loci encode the *PRR2*, *PSY1*, and *CCS* genes, respectively (Jeong *et al.,* 2020; Huh *et al.,* 2001; Lee *et al.,* 2020). To produce red fruit, a dominant allele at *Y* (CCS) is required because it is responsible for the production of capsorubin and capsanthin. In contrast, a recessive allele at this locus leads to the accumulation of violaxanthin and antheraxanthin, resulting in yellow fruit. Multiple alleles of the *CCS* gene have been found in *Capsicum* sp. (Guzman *et al.,* 2010; Rodrigez-Uribe *et al.,* 2014). Although fruit color shown to be regulated by qualitative genes, only a few studies have analyzed the associated quantitative trait loci (QTLs). Recently, Konishi et al. (2019)identified QTLs for capsanthin, including *Cst15.1* and *Cst13.1*. *Cst15.1* was detected on chromosome 9 in the context of incompletely ripe red fruit, and *Cst13.1* was located on chromosome 6 for well matured red fruit. Major effect QTLs governing the total carotenoid and capsanthin content were located on chromosomes 8 and 10, respectively (Jang *et al.,* 2022). Despite extensive research on color-determining genes, studies of regulatory genes in the carotenoid biosynthesis pathway are scarce in pepper. However, a recent study by Ma *et al.* (2022) showed that the expression levels of important carotenoid biosynthesis genes, including *PSY*, *BCH*, and *ZEP* were significantly down regulated in MYB306-silenced pepper fruits, strongly suggesting that MYB306 plays a role in regulating carotenoid biosynthesis pathway genes to control pepper fruit coloration.

Conclusions and future perspectives:

Apart from breeding chilli for enhancing yield, biotic and abiotic stress resistance, there is a need to improve fruit quality traits due to their commercial value at both national and international markets. Capsaicinoids, which possess industrial, health, and nutritional benefits, are other essential quality characteristics of chilli fruits. The food industry is also witnessing increasing demand for natural colors and flavors; hence peppers have emerged as a valuable source of those compounds. A specific research area is dedicated in developing novel pepper cultivars with increased levels of carotenoids and anthocyanins because of their manifold health advantages and high value in the food industry. Another area of research focuses in understanding the mechanisms underlying pungency in peppers, which can guide in the creation of new cultivars with desired levels of heat/ pungency. Advances in molecular biology and biotechnology have facilitated the identification of genes involved in capsaicinoid biosynthesis, providing opportunities for creating new chilli varieties with tailored levels of pungency. In recent times, metabolomics and transcriptomic studies have gained popularity as effective methods for exploring metabolite biosynthesis and the molecular mechanisms underlying it. Furthermore, advances in next-generation sequencing technologies and bioinformatics tools will enable more efficient and accurate identification and characterization of the genes and regulatory elements involved in the biosynthesis and regulation of these traits, which will facilitate the development of molecular markers for marker-assisted selection, accelerating the breeding process. Investigation on capsaicinoid accumulation in the fruit pericarp could prove advantageous for commercial capsaicinoid production. Those objectives can be achieved through traditional breeding methods, as well as genetic engineering techniques. Moreover, advances in gene editing technologies, such as CRISPR-Cas9 will enable accurate editing of specific genes for functional studies. That technology could also be used to develop new hot/ bell pepper varieties with enhanced desirable traits. A better understanding of capsaicinoid, carotenoid and anthocyanin regulation in pepper, along with technological advances, will have significant agricultural and scientific benefits. Future efforts should focus on elucidating the regulatory mechanisms of these key secondary metabolic networks to facilitate the improvement and manipulation of agronomic and economic quality in pepper crop (Venkatesh *et al.*, 2023).

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Biotechnological Breakthroughs in Commercial Crops Enabling Future Farming

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Humans first domesticated plants about 10,000 years ago, between the Tigris and Euphrates rivers in Mesopotamia. This process was based on artificially selecting plants to increase their suitability to human requirements such as taste, yield, storage, and cultivation practices. The first domesticated plants were wheat *(Triticum aestivum*), barley (*Hordeum vulgare*) and lentils (*Lens culinaris*). Other plants that were cultivated by early civilizations included maize (*Zea mays* in South America), rice (*Oryza sativa* in Asia) and potatoes (*Solanum tuberosum* in South America).

Plant breeding:

Crop improvement through systematic and scientific methods started only after Gregor Mendel's experiments with plant hybridization that led to his laws of inheritance. This work formed the basis of the new science of genetics in 1900s, which stimulated plant breeding research by many plant scientists. John Garton in England was one of the first to cross-pollinate agricultural plants and commercialize the newly created varieties in 1890.

Heterosis:

In 1908, George Shull described heterosis, also known as hybrid vigour. Heterosis describes the tendency of the progeny of a specific cross to outperform both parents. Maize was the first species where heterosis was widely used to produce hybrids.

Green revolution:

After World War II, significant breakthroughs occurred in wheat and rice production. The Green Revolution increased crop production many fold in the developing world in the 1960s. This remarkable improvement was achieved in two essential crops. First came the development of high-yielding semi-dwarf wheat by Orville Vogel who crossed Norin 10 and Brevor 14 in 1953, that formed the foundation for Norman Borlaug's efforts at CIMMYT to develop nitrogen-responsive, rust-resistant dwarf wheat varieties. Norin 10 was a semi-dwarf variety developed by Gonjoro Inazuka in Japan in 1935. Borlaug's efforts brought about green revolution in wheat, especially in the Indian sub-continent. Next came high-yielding "short statured rice" cultivars developed by Henry Beachell at IRRI by crossing Peta and DGWG in 1960. Peta was a high yielding rice variety from Indonesia and Dee-geo-woo-gen (*DGWG)* was a dwarf variety from Taiwan. Beachell and Gurdev Khush developed IR-8 that formed the basis for green revolution in rice.

Mutation Breeding:

Lewis John Stadler of the University of Missouri pioneered the use of mutations to create variability by using different forms of radiation on economically important plants like maize and barely in 1930s. X-rays, Gamma rays, UV radiation and chemicals like ethyl methane sulphonate (EMS) were widely used in mutation breeding. More than 3200 mutagenic varieties were released in various crops between 1930 and 2014.

Haploid Production:

The discovery of haploid production from pollen grains through anther culture by Guha and Maheswari (Delhi University) in 1964 opened up avenues to apply haploids in crop breeding. This is based on their potential for producing fully homozygous lines in one generation and make these more efficient through improved reliability of selection. The application of haploids in cross-pollinated crops is also based on a rapid production of Double Haploid (DH)-lines, which can be used as inbred lines for the production of hybrid varieties.

Molecular Breeding:

Application of molecular tools revolutionized plant breeding. Marker assisted selection (MAS) is an indirect selection process where a trait of interest is selected based on a marker (morphological, biochemical or DNA/RNA variation) linked to a trait of interest. In 1923, Karl Sax first reported association of a simply inherited genetic marker with a quantitative trait in plants when he observed segregation of seed size associated with segregation for a seed coat color marker in beans (*Phaseolus vulgaris* L.). Since 1980s, molecular techniques (RAPD, RFLP, AFLP, STRs, SSRs, SNPs) have been extensively used in MAS programmes. Steven Tanksley (Cornell University) first developed a DNA marker map consisting of 57 RFLP markers for tomatoes. Availability of genome sequences of major crop species after 2000 gave a great impetus to MAS.

Transgenic Crops:

Agrobacterium tumefaciens, a plant pathogenic bacterium is a natural genetic engineer that transfers a short stretch of its DNA to plants. This property was exploited by Mary Dell-Chilton (WSU), Marc van Montagu (University of Ghent), Jozef Schell (MPI for Plant Breeding) and Robert Fraley (Monsanto) in 1983 to develop a transgenic tobacco plant by introducing a gene encoding neomycin phoshotransferase enzyme. It greatly revolutionized agriculture. As of now, Transgenic crops (23 food crops and 9 non-food crops) are cultivated in 29 countries in an area of 190 mHa. 43 countries import foods and products derived from transgenic crops.

Genome Editing:

Genome editing is a method for making specific changes to the DNA of a cell or organism. It can be used to add, remove or alter DNA in the genome. Three technologies *viz.*, zinc-finger nucleases, TALE nucleases and CRISPR-Cas9 have facilitated the genome-editing revolution. First gene-edited plants were generated using zinc finger nucleases in 2010. The advent of CRISPR/Cas9 for gene-editing in 2012 was a major scientific breakthrough that revolutionized both basic and applied research in various organisms and consequently honoured with "The Nobel Prize in Chemistry, 2020" (Jennifer Daoudna and Emmanuelle Charpentier). CRISPR edited plants were developed in 2013 and since then this technology has been applied in more than 50 plant species. The first genome-edited crop (tomato expressing high levels of gamma-amino butyric acid) was commercialized in Japan in 2021.

Opportunities:

A plethora of opportunities are available in commercial crops such as tobacco, turmeric, chillies and *Withania* (*Aswagandha*) for biotechnological intervention. Molecular breeding and genome editing in these crops will help in imparting disease and pest resistance and enhancement of valuable phytochemicals useful in Human health and disease prevention.

Engineering Transcription Factors for Manipulating Specialized Metabolic Pathways using Tobacco as a Model

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As sessile organisms, plants are constantly challenged by many biotic and abiotic factors and have evolved unique strategies to combat and survive under adverse conditions. As chemical defense, plants produce array of structurally and functionally diverse specialized metabolites (SM) or natural products, which are critical for the survival of plants under adverse conditions. More than a million chemically diverse metabolites are reported to be present in the plant kingdom. Many SM are beneficial to humans because of their therapeutic properties. Archaeological findings date back to approx. 60,000 years hinted the early use of medicinal plants by modern humans. The World Health Organization (WHO) estimated that about 65% of the world's population relies on plant-derived traditional medicines for their primary health care. Nearly 70% of new drugs have originated from plant specialized metabolites over the past 30 years. Biosynthesis of SM is an energy intensive process, thus limiting the production in plants in large quantities. Chemical synthesis of many SM is expensive and, in many instances, not possible. Therefore, engineering the metabolic pathways to overproduce bioactive SM either in heterologous or native system has long been a topic of interest. However, biosynthesis of SM is complex involving multiple enzymatic steps, and manipulation of a single step does not always end-up in expected outcomes. Additionally, many metabolic pathways have not been characterized, making manipulation or engineering difficult.

Accumulating evidence suggest that SM pathways are regulated at transcriptional level. The interaction between transcription factors (TFs) and the cognate cis-regulatory motifs in the promoters of pathway genes dictate the metabolic outcomes. Transcriptional regulation of many SM biosynthetic pathways is well conserved across the species. For instance, biosynthesis of terpenoid indole alkaloids (TIAs; vinca alkaloids) in periwinkle, steroidal glycoalkaloids in tomato and potato, and nicotine biosynthesis in tobacco are regulated by a group of Apetala2/Ethylene Responsive Factors (AP2/ERFs), as well as the basic helix-loop-helix (bHLH) TF MYC2. Similarly, a well-conserved group of MYB, bHLH and WD40 TFs form the MBW complex (MYB-bHLH-WD40) to regulate anthocyanin biosynthesis in a wide range of plant species. Another characteristic of TFs is their modular nature (TFs contain multiple domains necessary protein-protein interaction, DNA binding, and transactivation or repression). The modular nature and the conserved regulatory mechanism make the TFs ideal candidates for protein engineering and manipulating SM metabolic pathways in plants. Using tobacco as model, we used two different approaches to engineer TFs for manipulation of two metabolic pathways.

Directed protein evolution is a general term used to describe various techniques for generation of protein mutants (variants) and selection for desirable functions. Directed protein evolution has emerged as a powerful technology platform in protein engineering. Using directed evolution, we have demonstrated that transactivation activities of two bHLH TFs involved in anthocyanin biosynthesis can be improved. A lysine (K) to methionine (M) substitution in the MYB-interacting region (MIR) of the perilla MYC-RP and snapdragon DELILA was identified and found to significantly increase the transactivation of both TFs in yeast and plant cells. Overexpression of the mutant, MYC-RP^{K157M}, in tobacco increased anthocyanin accumulation in tobacco flowers compared to overexpressing the wildtype TF.

In another instance, MYC2, a key regulator of nicotine biosynthesis, was used as a candidate to enhance its transcriptional activity. MYC2 is an activator while the Jasmonate ZIM-domain (JAZ) proteins are repressors of nicotine biosynthesis. MYC2 interacts with JAZ through the JAZ interaction domain (JID), resulting in suppression of MYC2 activity when endogenous jasmonic acid (JA) level is low. In the presence of JA, the JAZ proteins are degraded, leading to derepression of MYC2 and subsequent activation of downstream targets. MEDIATOR25 (MED25) is a key component of JA signaling and interacts with MYC2. We demonstrated that substitution of the conserved aspartic acid (D) to asparagine (N) in the JID of tobacco $MYC2^{D128N}$ alters the interaction with JAZ proteins, thus partially desensitizing MYC2 from JAZ repression. However, the D128N substitution does not alter MYC2 interaction with MED25. The partially desensitized MYC2 significantly increased the transactivation activity on nicotine pathway gene promoters. Furthermore, over expression of $\mathit{MYC2}^{D128N}$ in tobacco hairy roots increased nicotine pathway gene expression and nicotine accumulation compared to overexpressing wild type *MYC2*. Our approach of engineering TFs for manipulating plant metabolic pathways is useful for enhancing the production of bioactive compounds in plants.

Turmeric – New Vistas in Crop Management for Resilient Commercial Agriculture

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Introduction

Turmeric (*Curcuma longa* L.) is one of the important spices of India and World, often called as "Indian Saffron". It is traditionally used in medicine, coloring, cosmetic and food preparations. The 'curcumin' is an important constituent of turmeric and useful in pharmaceutical industry. Around 85% of world production is from India. In India, it is cultivated in all the states with an area of 2.7 Lakhs hectares, production (dry) of 10.25 lakhs tones with average yield of 3776 kg / ha (data averaged over four years 2017-18 to 2020-21)(Table 1). The data is not provided for Goa and Jharkhand, may be due to limited area of cultivation. Telangana, Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh, Madhya Pradesh, West Bengal , Orissa, Mizoram are important turmeric producing at states. The productivity is high in Telangana followed by Karnataka. India exports spices to more than 100 countries, during 2021-22, we exported 1.5 Lakhs tones of turmeric (it is only 14.6% of our turmeric production) to the value of Rs. 1534 crores. We also import turmeric, during 2021-22, imported 24,480 tons to the value of Rs. 245.77 crores.

Improved varieties

Every state has their own traditional local varieties, for example Salem turmeric variety from Tamil Nadu, which is very popular in trade has a straight long, bolder finger that is preferred for the market. Apart from local varieties, many improved varieties > 50 are released for farmers by different agencies. The varieties with different duration like short (maturing around 200 days), medium (7-8 months) and long 8-10 months) are available. Varieties with low curcumin, high curcumin, light yellow colour and deep orange colour types are

Table 1. Area and production of Turmeric in India (Area:'000 ha, Production:'000 tonnes, Yield: kg/ha)
Turmeric production in terms of dry (processed)

Sl No	State	Area	Production	Yield
1	Andhra Pradesh	27.194	73.426	2816
2	Arunachal Pradesh	0.556	3.094	5583
3	Assam	16.689	20.974	1256
4	Bihar	2.860	2.943	1029
5	Chhattisgarh	1.225	1.044	856
6	Goa	0.000	0.000	0
7	Gujarat	4.250	16.766	3944
8	Haryana	1.209	2.861	2398
9	Himachal Pradesh	0.246	0.163	657
10	Jammu& Kashmir	0.019	0.020	1091
11	Jharkhand	0.000	0.000	0
12	Karnataka	22.039	135.032	6155
13	Kerala	2.457	7.245	2943
14	Madhya Pradesh	14.672	51.528	3512
15	Maharashtra	36.225	130.622	3160
16	Manipur	2.445	5.908	2416
17	Meghalaya	2.555	3.347	1318
18	Mizoram	7.696	29.665	3855
19	Nagaland	0.677	1.894	2798
20	Orissa	27.869	43.614	1565
21	Punjab	0.957	3.454	3609
22	Rajasthan	0.290	0.398	1546
23	Sikkim	3.965	12.140	3037
24	Tamil Nadu	20.189	87.066	4341
25	Telangana	51.926	334.857	6434
26	Tripura	1.670	5.111	3065
27	Uttar Pradesh	1.638	3.446	2002
28	Uttarakhand	1.714	2.885	1685
29	West Bengal	17.686	45.376	2566
30	Pondicherry	0.008	0.022	2830
31	Andaman & Nicobar	0.088	0.244	2942
	Total	**271.009**	**1025.142**	**3776**

available. These will cater needs of spice industry for different purpose, for example, high curcumin varieties are essential for industry to extract curcumin, whereas, light yellow coloured varieties destined for masala powder industries. Stable yielding varieties for specific location is evolved. ICAR-IISR, Kozhikode, a leading spice research institute have released eight varieties, besides, many SAU's/SHU's have also released many varieties for respective states. Turmeric varieties like the high yielding (Suguna, Suvarna, Sudharsana) and stable high curcumin yielding varieties suitable for growing throughout India (IISR Prabha, IISR Pragati, IISR Kedaram, IISR Prathibha and IISR Alleppey Supreme) are available for adoption to farmers across the growing tracts.

Micro-rhizomes and Protray technology

Under precision farming methods farming under controlled condition is encouraged in crops that could be grown to increase the unit area output adopting precise technologies. For that uniform quality and disease free seeds or vegetatively propagated healthy planting units which is the base for any crop production needs to be supplied. Micro rhizomes resemble the normal rhizomes in all respect, except for their small size. The micro rhizomes consist of 1 to 6 buds and 2 to 4 nodes. They have the aromatic flavor of turmeric and resemble the normal rhizome in anatomical features in the presence of well-developed oil cells, fibres, and starch grains. *In vitro* formed rhizomes are genetically more stable when compared to micro propagated plants. Generally seed rhizome weight of micro rhizome was 2-8 g as against 20-30 g or even more in case of conventionally propagated plants. Micro rhizomes can be easily stored and transported to a long distance without much disturbance.

The budlings of turmeric can be raised in pro trays under net houses with sterilized nursery medium containing partially decomposed coir pith and vermicompost (75:25), enriched with PGPR/ Trichoderma 10 g/kg of mixture showed the conspicuous effect on budling growth. Pro-tray raised bud transplants being popularized now-a-days for planting in these the spice crops have helped to reduce seed rate considerably, suitable for mitigating the climate change and the propagules are suitable for high tech precision farming both under open and poly house conditions.

Improved Agro-technologies

In India, turmeric is grown as rainfed crop where quantum and distribution of rainfall is good, it is also grown as irrigated crop where water availability is good from river/tank/well *etc.* It is grown in different kind of soils which have more organic matter, good drainage, in wide range of soil pH from 5.0 to 8.0. In general, planting season coincides with the onset of rain or availability of water, planting is mostly between April to June, further delay will result in yield reduction. As it is a rhizomatous crop, thorough land preparation is required and planted in ridges and furrows in irrigated conditions and raised beds in rainfed situations. Mulching is a common practice adopted in rainfed conditions which offers several beneficial effects. Weeding is an important operation as its initial growth and establishment is slow for this annual crop. Two to three hand weeding is practiced in traditional farming, due to labour shortage; nowadays herbicides are very common in weed control. Inter cultivation (weed control), fertilizer application (top dressing) and earthing up are always go together.
Turmeric is highly amenable for different cropping systems and several cropping systems for different locations are evaluated and standardized for maximizing the productivity. Around 40 irrigations are needed in sandy soils whereas, in clay types soils around 20 irrigations are enough. Drip irrigation and fertigation schedules are developed and recommended under irrigated conditions for better water use efficiency and yield maximization.

Automation in the field of turmeric planters has provided opportunities for savings in labour and time required for planting operation in open field and controlled environmental structures. The advent and recent advances in planting technologies suggest ample scope of working on automated finger pickup and drop mechanisms. Such automated systems help to ease the planting operation and efficient planting by maintaining the accuracy, precision and effectiveness in planting finger with minimum human intervention.

Bio agents for residue free production

IPM technologies involving spraying of low risk green labelled insecticides for effective control of shoot borer in turmeric reduces the risk to the environment. Technologies like, Trichoderma spp. *Pochonia chlamydosporia*, a biocontrol agent against nematodes, PGPRs like *Bacillus safensis*, *B. amyloliquefaciens* have good scope for reducing the fertilizer dosages up to 25-50% as they have potential to solubilize the native P and Zn from soils. The encapsulation technology of these bio agents and its delivery through bio capsules is simple, easy for handling and transport and has long storage life at normal temperature. Besides, this encapsulation technique can be used to deliver all kinds agriculturally important microorganisms. Patent for this delivery process has been awarded and the technology has been commercialized by providing non-exclusive licenses to private companies by ICAR-IISR. Rhizome coating technology is a novel process of coating efficient strains of PGPR on seed rhizomes, with components like live PGPR, inert material and a binding agent. The coated seed rhizomes can be stored at the room temperature without deterioration in quality and seed borne disease attack. Constraints like low germination, slow initial growth and high susceptibility to diseases can be managed through this technology.

Site-specific nutrient management

Under open field conditions, there is no possibility of meeting the precise nutrient requirements of crops to express its full productivity. Therefore, a practical approach would be soil test-based site-specific fertilizer recommendations based on crop requirement. Targeted yield equations for recommending nutrient requirements for fixed yield targets for different spices in soils with varying fertility levels were standardized. Targeted yield-based fertilizer prescription models to get fixed rhizome yields in soils with varying fertility levels was standardized in turmeric. The nutrient contribution from soil was 32% for N, 187% for P_2O_5 and 40% for K_2O and from the fertilizer sources was worked out to be 76% for N, 48% for P_2O_5 and 55% for K_2O in turmeric with the nutrient uptake ratio of NPK as 0.65: 0.20:1.0. The yield increase with the fertilizer recommendations based on these established equations as compared to the blanket fertilizer recommendation was in the range of 32-43%. The economic optimum in terms of profitable response for money invested was found to be Rs. 0.65/ bed (3 m^2) for N, Rs. 0.40/ bed for P2O5 and Rs. 0.85/bed for K2O. Decision support systems are developed and made available on the public domain to get the fertilizer recommendation for the targeted yield levels.

Crop-specific micronutrient formulations

Majority of soils in the turmeric growing areas are encountering fertility issues due to acidity, nutrient imbalances and deficiencies of secondary and micronutrients that becomes yield limiting. Besides crop specific, soil pH based micronutrient mixtures for foliar application in turmeric guarantees 10 to 20% increase in yield and quality in terms of curcumin content. The technology comes at very low cost and hence is very farmer friendly. The micronutrient technologies have been licensed to several entrepreneurs for large scale production and commercialization.

Organic farming

Nutrient management plans for turmeric has been standardized for organic farming systems and organic packages have been developed integrating composts, oil cakes, biofertilizers/ PGPRs and biocontrol agents. Turmeric varieties IISR – Pragati, Suguna, and Sudharsana are found to be most suitable varieties for organic farming with stable rhizome yield and higher curcumin content over years. Adoption of these practices by the farmers in groups or clusters will ensure the supply of residue free produces that can be established in to a viable value chain model.

Vertical farming

Vertical farming of turmeric has been taken up by few companies on commercial basis where they claim to produce 10000 q of wet rhizomes yields of turmeric from an area equivalent to 1 acre by growing the crops under vertically staked systems under controlled environments. The poly houses are provided with Photosynthetically active radiations (400-700 nm) and photo periods (11-12 h) as per the crop requirement through LED lights, optimum temperature (26-32°C) and humidity (70-90%) during the crop periods under fertigated systems. The initial cost involved is very high and the systems are said to yield profit over periods as the produce is said to be uniform and contaminants free (https://www.asagriaqua.com/vertical-farming-india/index.html; accessed on October 2022). Even though farming under these systems are not economically viable for the production of turmeric as such, this may be oriented towards the production of nutraceutical compounds of turmeric and different turmeric species like black turmeric, Kasturi turmeric etc.

GIS for planning

The studies on current and future land suitability for turmeric cultivation in the humid tropical India by analyzing climatic variables for future scenario using advanced geospatial techniques using climatic scenarios of shared socioeconomic pathway (SSP) from the Intergovernmental Panel on Climate Change (IPCC) AR6 model of MIROC6 for the year 2050 (SSP 1-2.6, SSP 2-4.5, SSP 3-7.0, and SSP 5-8.5) revealed that suitable area for turmeric cultivation is declining in future scenario and this decline can be primarily attributed to fluctuations in temperature and an anticipated increase in rainfall in the year 2050. With the GIS tools, the study identified highly suitable, moderately suitable, marginally suitable, and not suitable areas of turmeric cultivation. Presently 28% of area falls under highly suitable, 41% of area falls under moderately suitable and 11 % falls under not suitable for turmeric cultivation. This reduction in area will have an impact on the productivity of the crop due to changes in temperature and rainfall patterns.

Conclusions

The major challenges confronted in the turmeric sector are,

- Climate change resulting in drought/ excess moisture, high/low temperature during critical periods, etc.
- Emergence and epidemics of pests and diseases.
- Adulteration at multiple points in the value chain
- Pesticide residues in the products and lack of MRL and ADI standards in some of the pesticides used

Our capability to address these challenges directly depend on the technological options developed in response that are to be simple, cost-effective and farmer-friendly. Nurturing and improving sound techniques, technologies and innovations in the spices sector can help in surmounting the challenges posed by competing countries and help in meeting the global market demands while ensuring a sustainable and equitable production models.

Sustainable Water Management Technologies for Enhancing Productivity of Commercial Crops

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The food security in India is mainly challenged by the diminishing water resources in agriculture coupled with ever increasing human population. Further, the changing climate further worsens the scenario. Extreme climatic events have been witnessed at higher frequency now. Owing to extreme events, the crops are subjected to either excess water stress or deficit water stress. This necessitates us to minimize the damage to agricultural sector in the backdrop of changed climate and to promote adaptive capacities and the mitigation of climate change and work towards disaster risk reduction. Water is one of the key inputs for agricultural productivity and its timely and adequate supply is directly proportionate with the economic produce. As water is becoming a limiting factor for crop production, soil and water management should be the key to the development of eco-friendly and climate smart agriculture for both irrigated as well as rainfed areas. The commercial crops like tobacco, chilli, turmeric are being grown diverse agro-ecosystems and hence water management in these areas is essential for sustaining the food production. We need to critically analyze the existing water resources of different agro-ecological regions, current water demand of commercial crops and prioritization and wide scale adoption of eco-friendly climate resilient sustainable water management techniques and integrating them in to water management policy interventions or schemes such as Pradhan Mantri Krishi Sinchayee Yojana (PMKSY).

Analysis of water resources scenario in India

Owing to increasing demand of water for sectors like domestic, industrial and energy, there is a severe constraint in the availability of water for irrigation sector / farming. It has been assessed that the utilizable water is 1123 BCM (690 BCM from surface 433 BCM ground water) only, which accounts to about 28% of the water derived from precipitation. Annual groundwater recharge is about 433 BCM, of which 212.5 BCM is used for irrigation. Out of net sown area of about 139.9 Million ha, the net irrigated area in India as on 2013-14 is 75.5 Million ha (54% of net sown area). The remaining 64.4 Million ha area is under rainfed condition (46% of net sown area). The area irrigated through other sources is 7.54 million ha. Similarly, the gross irrigated area of the country is 112.2 Million ha accounting for 53% of the gross cropped area (211.4 M ha). At the same time, the availability of water for agriculture in India is expected to decline from 84% in 2010 to 74% by 2050. Even within agriculture, the water demand for different sub-sectors or farming systems will change significantly in the coming years. The enhanced water demand in domestic, industrial and energy sectors will need additional 222 BCM water by 2050. Low water use efficiency and poor maintenance of irrigation systems are some of the major problems while managing the water resources in the country. The commercial crops have huge potential to earn foreign exchange revenue provide they are supported with advanced water management practices Hence, there is a strong need to focus on eco-friendly climate resilient and sustainable water management techniques for commercial crops. Some selected sustainable water management interventions are described here.

Sustainable water management interventions

Solar-powered soil moisture sensor-based automatic surface irrigation system

Soil moisture sensor-based automatic surface irrigation system developed by Water Technology

Centre, ICAR-Indian Agricultural Research Institute, New Delhi is breakthrough technology which enhances the water application efficiency of surface irrigation system. This system consists of an automatic check gate, soil moisture sensors, a communication system, and a web/mobile interface. The check gate is made of an aluminium sheet attached to an iron frame installed in the field inlet channel. The solar-powered capacitance soil moisture sensor installed in the field senses the real-time data and transmits it to the cloud server via the gateway. The wireless communication was established with LoRa and GSM modules. The cloud server is wirelessly connected to the check gate and mobile or web interface though GSM module. Farmers can download the mobile app from Google Play. The real-time soil moisture status can be monitored on mobile by the user/farmer and the system enables the farmers to start (open check gate) and off (close the check gate) the irrigation based on real-time soil moisture status from anywhere/remotely. The irrigation scheduling with an automatic real-time soil moisture-based system helped to save nearly 25% of water as compared to the conventional method of irrigation. It also helped to enhance water use efficiency and water productivity by 30% as compared to conventional practice. The automatic surface irrigation system has the potential to make a significant contribution in water, labor and energy saving in commercial crop cultivation.

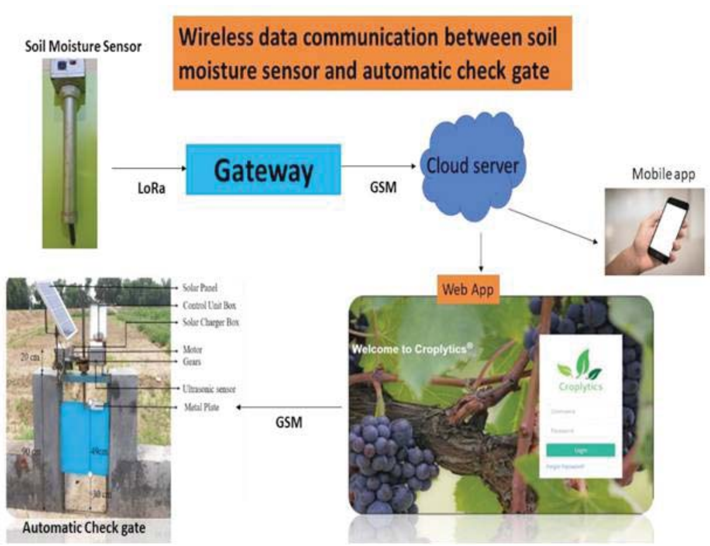
Solar-powered soil moisture sensor-based automatic surface irrigation system

Design of tank cum well system in watersheds in rainfed areas

The tank cum well system technology along the drainage line in a watershed is recommended for plateau areas having slope of 2 to 5%). The site for the technology should be selected in such a way that the area should have a well-defined valley where the runoff flows either as overland flow or channel flow. The well is constructed about 100 to 300 m downstream of the tank to tap the water that is lost by seepage from the tank. A set of 15 tanks and wells is required for a catchment area of 500 ha to irrigate 60 ha area. The technology is well suited for commercial crops like turmeric, chilli and tobacco.

ICAR-flexi rubber dams for watersheds

The installation of rubberdams in watersheds act as better drought resilience structure and it will significantly help in additional water storage, crop productivity and net economic returns to the



farmers. This technology has potential to create an additional water storage capacity of about 52,000 to 80,000m^3 for irrigating about 30-40 ha of paddy in kharif and 6 ha of pulses, oilseeds and vegetable crops / commercial crops in rabi season. It has potential to enhance the net returns of the farmers up to Rs.48,000/ha.

Drone-based Water Stress Monitoring

Huge scope exists for drone-based irrigation monitoring and identification of variable plant stress zones in India. The application of drones is more significant in identification of mechanical problems in canal operation and maintenance which may lead to sustainable water resource development. The prospects for use of drones in agricultural sector in India will be improved with the new regulations issued by Government of India. This will aid in enhancing water productivity of commercial crops like tobacco and chilli.

Conclusion

The vulnerability of different agro-ecosystems has been found to be on increasing trend due to the higher frequency and magnitude of extreme climatic risks or events in the recent years. This affects the productivity of field crops and horticultural crops including commercial crops. Hence, the efforts must be concentrated on evolving eco-friendly and climate resilient sustainable agricultural practices through best utilization of created water resources and adoption of innovative water management practices leading to higher water use efficiency and water productivity. Upscaling of the proven sustainable water management techniques suitable for climate induced excess and deficit water stress scenarios would certainly make commercial crop cultivation more viable economically thereby providing better cushion to the farming community..

Towards Sustainable Agriculture: Carbon Sequestration and Effective Policy Implementation

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Abstract

Sustainable agricultural practices play a pivotal role in ensuring that current needs are met while preserving the capacity of future generations to satisfy their own requirements. The overarching goal of sustainability in agriculture is to establish an integrated system of plant and animal production practices, strategically tailored for site-specific applications over the long term.

This holistic approach involves the tandem use of non-renewable resources and farm practices, harmonized with appropriate biological cycles, thereby contributing to long-term environmental sustainability. Beyond its role in mitigating climate change, carbon sequestration in agriculture offers multifaceted benefits. These include improving soil health, preventing soil erosion, enhancing water quality, conserving biodiversity, and creating economic opportunities for farmers.

Recognizing the challenges associated with agricultural carbon sequestration, achieving its maximum potential demands a comprehensive approach. This approach encompasses rigorous research, the integration of innovative solutions, the formulation of effective policies, and the provision of economic incentives. By addressing these aspects collectively, we can ensure that sustainable agricultural practices not only meet current needs but also pave the way for a resilient and ecologically balanced future.

1. Introduction

Sustainable agriculture refers to the practice of farming in a manner that aims to meet current food and resource needs without compromising the ability of future generations to meet their own needs. It encompasses a holistic approach that addresses environmental, economic, and social aspects, aiming for long-term viability and resilience. By persuading farmers to use sustainable agricultural practices that help with soil carbon storage, we can achieve a food system that is more sustainable, resilient, and climate friendly.

As an essential ingredient for maintaining agricultural productivity to preventing land degradation, adaptability of agricultural practices, such as crop rotation, cover cropping, and conservation tillage practices help to improve soil health, reduce soil erosion, and increase organic matter content.

Key principles and practices of sustainable agriculture include:

Environmental Stewardship: Minimizing the impact of farming activities on the environment by promoting soil health, water conservation, and biodiversity. Sustainable agriculture seeks to maintain or enhance the natural resource base on which agriculture depends. Emphasize on efficient water use and quality water safeguard practices including the adaptive use of precision irrigation,

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drought-resistant crops, and buffer zones around water bodies may help to conserve water resources and prevent pollution from agricultural runoff. Habitat creation and integrated pest management encourage the presence of beneficial insects, pollinators, and other wildlife to maintain biodiversity and healthy ecosystems.

Economic Viability: Ensuring the economic stability of farming operations by adopting practices that are financially feasible. This involves optimizing resource use, reducing input costs, and exploring diverse revenue streams.

Social Equity: Promoting fair labor practices, community engagement, and social responsibility within the agricultural system. Sustainable agriculture seeks to enhance the well-being of farmers, farm-workers, and local communities.

Resource Efficiency: Optimizing the use of natural resources such as water, soil, and energy to minimize waste and environmental impact. Sustainable agriculture aims to maximize productivity while minimizing inputs and waste.

Crop Diversity: Emphasizing the importance of crop diversity to enhance resilience to pests, diseases, and climate variations. Crop rotation and polyculture are examples of practices that contribute to maintaining a diverse agricultural landscape.

Reduced Reliance on Chemicals: Sustainable agriculture promotes the use of natural pest control methods and organic fertilizers, reducing the dependence on synthetic pesticides and fertilizers to protect water quality, biodiversity, and human health from harmful chemicals.

Climate Change Mitigation: Sustainable agricultural practices, such as carbon sequestration in soils and reducing greenhouse gas emissions from livestock, can help to mitigate climate change. Soil carbon sequestration traps carbon dioxide from the atmosphere, while reducing livestock emissions contributes to lowering methane gas, a potent greenhouse gas.

2. Carbon Sequestration and sustainable agricultural practices

To overcome the economic obstacles of eco-friendly and environmentally sustainable agricultural practices, carbon sequestration is one approach that can be utilized. Agriculture's contribution to the ongoing greenhouse effect stems from the emission of methane, carbon dioxide, and nitrous oxide (N_2O), as well as factors such as eutrophication (resulting from nitrogen and phosphorus run-off), pollution of water bodies through leaching and erosion, climate change, air pollution, and stratospheric ozone depletion.

In recognition of the urgent need to limit global warming, the Paris Agreement, established during the 21st Conference of Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCC), calls for collective efforts to curb temperature rise below 2°C, with an aspirational target of 1.5°C. To concretely achieve this objective, the "4 per 1,000 Initiative: Soils for Food Security and Climate," proposed by France, was launched. This initiative aims to increase the soil's organic carbon (SOC) by 0.4% annually, contributing to the overarching goals of food security encapsulated in the "3-Fold objective."

A. **Mitigate climate change**: Soil organic carbon acts as a carbon sink, removing carbon dioxide from the atmosphere and storing it in the soil. Sequestering an estimated 2.6 billion tonnes of carbon dioxide per year by increasing SOC stocks by 0.4 percentage points annually would be equivalent to taking about 580 million cars off the road.

B. **Improve food security**: Healthy soil is essential for crop productivity and thereby increasing food security. The improvement of soil structure, water retention, and nutrient availability can be achieved by increasing SOC stocks, which can lead to increased crop yields.

C. **Enhance soil health:** It helps to improve soil structure, water retention, nutrient availability, and biodiversity. The 4 per Thousand Initiative is a promising approach to address climate change, food security, and soil health challenges. By increasing SOC stocks, more sustainable and resilient food system for future generations can be developed under the sustainability regime.

3. Carbon Sequestration in Agriculture

Role of agriculture in carbon sequestration, emphasizing its potential to mitigate climate change. Soils are a substantial source of soil carbon stocks which can help in mitigating the significant amount of global greenhouse gas emissions (GHG). Maintaining the existing soil organic carbon stocks and enhancing its sequestration using sustainable soil management practices stems up the possible solution to offset the global emissions as well as environmental benefits. IPCC, 2019 also highlighted that SOC is one of the most cost-effective options for climate change adaptation and mitigation to combat desertification and agricultural insecurity. The rate of SOC-sequestration is evident only after a few years and is mainly dependent on the regional geography, land cover and the sustainable practices to recover SOC. Sustainable soil management practices include the cover cropping, intercropping, crop rotation, addition of organic manure for fertility and control over soil erosion from the local factors of erosion.

4. Technology Integration

The adoption of a technology-driven sustainability approach in agriculture also entails challenges that can be instrumental in facilitating the implementation of mitigation strategies.

By offering innovative solutions to improve soil health, optimize land management practices, and monitor carbon storage, emerging technologies have the potential to enhance carbon sequestration in agriculture. To improve carbon sequestration in agriculture, it is possible to integrate emerging technologies into policy frameworks. Some of the technologies/practices are presented as follows.

a. Precision Agriculture and Soil Carbon Mapping: Precision agriculture techniques can offer precise knowledge of soil conditions, carbon content, and nutrients through advanced sensors, drones, and data analytics. Integrating these technologies into policy frameworks can enable:

- **Targeted soil management practices**: Policies can incentivize the use of precision agriculture tools to identify areas with high carbon sequestration potential, allowing farmers to tailor soil management practices accordingly.
- **Carbon credit programs**: Accurate soil carbon mapping can support the development of carbon credit programs that compensate farmers for increasing soil organic carbon.

b. Improved Soil Health Practices: Emerging technologies can promote soil health practices that enhance carbon sequestration, including:

- **Biochar application**: Policies can encourage the production and utilization of biochar which is a charcoal-like material or the biomass through the pyrolysis in which the biomass is heated in an oxygen limited environment. The resulting biochar is highly porous enabling it to develop as a carbon sink. The physical stabilization of biochar through microbial decomposition leads to improvements in soil health, water retention, and nutrient availability. Biochar inoculated microbes are also one of the promising applications to contribute information of stable soil organic carbon pools.

- **Microbial amendments**: Enhancing carbon sequestration in agriculture can be achieved through this promising strategy. The role of microorganisms in soil carbon cycling is crucial, with their influence on the decomposition of organic matter and the formation of stable soil organic carbon (SOC) pools. Cover cropping can be promoted by microbial amendments, which introduce beneficial microbes into the soil and promote carbon sequestration. Several other technologies include increased microbial biomass activity as it can contribute to stable organic matter aggregates. These technologies include:

Promoting plant-microbe interactions involves the formation of symbiotic relationships with plant roots by certain microbes, such as arbuscular mycorrhizal fungi. The presence of these fungi improves plants' ability to absorb nutrients and grow, which results in more root exudate and carbon input into the soil.

- The promotion of plant growth can be achieved through the production of hormones, nitrogen fixing, phosphorus solubilization, and disease protection by Plant Growth-Promoting Bacteria (PGPB). This enhanced plant growth results in more carbon being deposited in the soil.
- Use of compost derived microbes to enhance soil health and carbon sequestration.

Policies can incentivize the adoption of cover cropping practices, which increase soil organic matter and contribute to carbon sequestration.

c. Advanced Monitoring and Verification: Technologies like remote sensing, satellites, and blockchain can provide continuous monitoring and verification of carbon sequestration activities, ensuring transparency and accountability:

- **Remote sensing**: Satellite imagery and aerial photography can track changes in land use, vegetation cover, and soil carbon levels over time.
- **Blockchain technology**: Blockchain can be used to create secure and verifiable records of carbon sequestration activities, facilitating carbon credit transactions, and ensuring compliance with policy standards.

d. Policy Incentives and Market Mechanisms: Creating supportive policy incentives and market mechanisms can further encourage the adoption of carbon sequestration practices in agriculture:

- ***Carbon pricing:*** Policies that put a price on carbon emissions can incentivize farmers to implement carbon sequestration practices to offset their emissions or generate carbon credits.
- ***Cost-share programs:*** Government cost-share programs can provide financial assistance to farmers adopting carbon sequestration practices, reducing the upfront costs, and increasing adoption rates.
- ***Market-based incentives:*** Policies can create markets for carbon sequestration services, allowing farmers to generate income from enhancing carbon storage on their land.

Revolutionizing agriculture's contribution to mitigating climate change is possible by incorporating emerging technologies into policy frameworks. Policymakers, through the strategic use of technology, can empower farmers to actively engage in carbon sequestration, thus playing a significant role in shaping a more sustainable and carbon-neutral future.

e. Community Engagement: Highlight the importance of involving local communities in the implementation of policies, emphasizing the social aspects of sustainable agriculture. Effective and sustainable agricultural policies can be developed with the valuable knowledge and experience of local communities on their environment and agricultural practices.

The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), India's premier employment program, has a considerable potential to help reduce carbon emissions and has supported the country's Nationally Determined Contributions (NDC) targets under the Paris Agreement. The enhancement of carbon sinks and mitigation of climate change can be achieved through MGNREGA's NRM activities, which include afforestation, tree planting, and soil conservation measures.

- By establishing new tree covers and enhancing biomass production, afforestation and tree planting activities directly enhance carbon sequestration. Carbon dioxide is absorbed by trees, which store it in their trunks, branches, and leaves as carbon sinks.
- Bunding, terracing, and contour farming can improve soil health and reduce soil erosion, which can indirectly contribute to carbon sequestration. Reducing erosion prevents carbon loss from the soil, as healthy soil has a greater capacity to store carbon.
- The Paris Agreement stipulates that India's NDC will create an extra 2.5 to 3 billion tons of CO_2e sink by 2030 by afforestation and reforestation. MGNREGA's NRM activities can have a significant impact on achieving this objective.

- According to studies, MGNREGA's NRM activities can store an average of 102.2 million tons of CO_2 annually. By 2030, this figure will reach 249 million tons of CO_2- emission, which will greatly contribute to India's NDC target. This integration can involve:
  - Targeting NRM activities in areas with high carbon sequestration potential.
  - Promoting efficient tree species selection and planting techniques.
  - Ensuring long-term maintenance and monitoring of planted trees.
  - Developing carbon credit schemes to incentivize carbon sequestration under MGNREGA.

5. Monitoring and Evaluation

Crucial for evaluating the effectiveness of sustainable agriculture and carbon sequestering policies over time, robust monitoring and evaluation (M&E) mechanisms play a pivotal role. Through tracking progress, pinpointing successes and shortcomings, and adapting strategies accordingly, M&E ensures that policies not only meet their intended outcomes but also actively contribute to the overarching goals of sustainable development.

Significance of Monitoring and its Key Components

Robust monitoring and its systemic evaluation entail the measures for effective policies to attain carbon sequestration, improved soil health, enhanced crop yields, and reduced greenhouse gas emissions objectives. There are several tools and approaches which can be adopted for the dissemination of effective policy monitoring and evaluation of the sustainable approach of agriculture-based sustainability. The approach includes:

a) Field based measurements of soil carbon content, plant biomass and crop yield productivity

b) Remote sensing, agri-drone technology for regular crop monitoring of land use changes, vegetation cover and soil moisture analysis to enable the large-scale monitoring of carbon sequestration and sustainable land use management.

c) Modelling and simulation of collected data obtained can also help in stimulating the impact of different policies for implementation of carbon sequestration strategies in agriculture.

6. Capacity Building and Education

Crucial in empowering farmers and stakeholders to embrace sustainable practices are capacity-building programs and educational initiatives. These initiatives provide the necessary knowledge, skills, and informed resources that enable individuals to make decisions geared toward improved and sustainable environmental outcomes. Capacity-building programs are particularly effective in closing knowledge gaps that farmers may have in the context of contemporary and smart skill evolution.

Notable examples of successful initiatives include workshops and training programs that offer practical guidance on sustainable practices such as composting, cover cropping, and agroforestry uses of farm byproducts. By investing in these programs and educational initiatives, governments and organizations have the opportunity to cultivate a cadre of farmers and stakeholders equipped to serve as stewards of sustainable agriculture, contributing to the establishment of a resilient and sustainable carbon economy.

7. Adaptability and Flexibility of Sustainable policy frameworks

The long-term sustainability of food systems and the environment is dependent on flexible policy frameworks that can respond to complex and evolving agricultural and environmental challenges. As climatic conditions change, technologies evolve, and societal demands change, rigid policy frameworks can become obsolete and unproductive.

- Adapting to changing circumstances can be accomplished by flexible policy frameworks, which enable policymakers to respond proactively and effectively to emerging trends and challenges. Benefits of flexible policy framework can be adjusted using the adaptive approach of changing environmental and agricultural demands.
- Incorporating scientific knowledge, technological advancement, and the evolution of social and economic outcomes is part of a flexible policy approach. Such flexible policy framework can become the route map by identification and adaptation of best management practice approaches with a low

carbon footprint without impacting the crop yield and productivity.

8. Potential Barriers and Solutions:

Effective policy implementation is crucial to address the desired outcomes, especially in sustainability and to attain the targets of sustainable development goals.

- In case of local obstacles which need a sound address, such obstacles can be addressed using the local solutions for the appropriate policy coherence mechanism with the institutions.

9. Success Stories and Best Practices:

Region/Country	Policy Initiatives	Statistical Data	Technological Regimes
· Costa Rica	Payments for Environmental Services (PES) program	· Deforestation reduced by over 50% between 1996 and 2010 · Forest cover increased from 26% in 1996 to 53% in 2020 · These methods are estimated to sequester around 3 million tons of carbon dioxide equivalent (CO_2e) per year	Monitoring forest cover and deforestation rates using remote sensing and GIS while utilizing precision agriculture techniques to optimize resource use and minimize environmental impact.
· Ethiopia	Sustainable Land Management Program (SLMP)	· Crop yields increased by 10-20% · Soil erosion reduced by 50% · Soil organic matter content increased by 2% between 2010 and 2020. · Estimated to sequester around 60 million tons of CO_2e per year	· Integrated pest management (IPM) to reduce reliance on pesticides. · Use of drought-resistant and climate-resilient crop varieties- Soil conservation practices like terracing and hillside planting
· China	· Subsidies for organic farming · Support for research and development- Restrictions on the use of pesticides and fertilizers	· Organic farming practices · Precision agriculture techniques · Use of renewable energy sources in agricultural production	The amount of forest cover rose from 16.6% in 1990 to 21.7% in 2020, and it is predicted to trap roughly 800 million tons of CO2 annually
· Finland	· Sustainable forestry practices · Harvest levels aligned with annual forest growth. · Certification schemes for sustainably sourced wood products	· Advanced forest management practices · Use of forest biomass for energy production - Carbon accounting and monitoring systems	The forest biomass has grown by 40% since 1922 and is thought to sequester approximately 30 million tons of carbon dioxide annually
· Sweden	· Subsidies for organic farming - Reduction in fertilizer use. · Support for research and development	· Organic farming practices · Precision agriculture techniques · Use of renewable energy sources in agricultural production	· Between 1995 and 2020, the amount of organic farmland grew by 20-fold while the amount of fertilizer used decreased by 30%. · It is estimated to sequester approximately 40 million tons of CO_2 annually

- Addressing the weak institutional capacity within the implementing agencies can also divert the map of policy translation by selecting appropriate stakeholders for engagement and collaboration.
- Financial constraints can inadvertently impede the policy roles to address the sustainability based agricultural objectives and inter institutional resource allocation along with the necessary infrastructural collaboration can help in addressing this challenge.
- Stakeholder engagement in an effective and beneficial manner along with the public -private partnership (ppp) model of resourceful collaboration can help in contemplating the farmer and market gap to reduce agriculture-based carbon emissions.

10. The Role of Stakeholders

Enhancing stakeholder management is essential for farmers to concurrently manage resource sustainability and capitalize on the advantages of economic liberalization, as well as stronger local and meta-level institutions. Achieving efficiency gains in sustainable agriculture requires the outsourcing of public services and infrastructure provision to private firms, NGOs, and universities. The active involvement of local grassroots farmers' groups is crucial in promoting farmer engagement and enhancing skill sets for maintaining sustainable agricultural practices, contributing to carbon sequestration efforts, and requiring substantial support from meta-level institutions.

Ensuring the successful promotion of sustainable agriculture practices involves the stabilization of meta-level institutions and the high-value input from local participation of grassroots farmers. Additionally, managing research priorities, including budget considerations, can be facilitated through competitive bidding and public-private cost-sharing arrangements among stakeholders. This strategic approach not only maximizes the benefits of trade liberalization and market development but also helps alleviate externalities, fostering sustainable management in agriculture and promoting the adoption of sustainability practices in agroforestry.

11. Long-term Vision for Policy Adoption

Navigating the dynamic landscape of agricultural sustainability and its application in sustainable farming systems poses a challenge for farmers, extension services, agribusiness, and policymakers. The long-term vision for policy adoption may encompass:

- Create long-term strategies for generating and distributing agricultural information.
- Provide comprehensive, system-oriented agricultural training.
- Encourage vocational education for jobs outside of farmland and in urban areas.
- Encourage the participation of the private sector, particularly small businesses.
- Establish an environment that fosters market development.
- Ensure that trade liberalization is a mutually beneficial process.
- Concentrate small-scale producers on cash crops that require significant labor or are specialized.
- To expand carbon sinks, it is crucial to increase the use of Agri-silviculture or Agri-horticulture systems for food and fruit production. Planting along the boundaries and contours to safeguard against wind and soil damage. A system that combines agriculture and forestry to produce crops and conserve soil and water.
- Plantation of biofuels having sustainably grown biofuels for the fuels and biofuel and oil from the tree borne oilseeds can delay the release of carbon from fossil fuel as long as the fuels remain unused. Renewable agroforest-based wood matter from natural forests will also promote the slow release of carbon emission.

12. Policy Impact Assessment:

A comprehensive approach that considers a variety of methodologies and data sources is necessary to evaluate the impact of policies on carbon sequestration and overall sustainability in agriculture. Here are some commonly used methodologies:

- **Carbon Accounting**
    - To quantify the impact of policies on carbon sequestration, carbon accounting entails measuring and tracking carbon fluxes in agricultural systems using soil sampling, vegetation inventories, and modeling are all methods that can be utilized for this task.
- **Life Cycle Assessment (LCA)**
    - LCA, in its broadest form, evaluates the environmental impact of a product or process throughout its entire life cycle, from the extraction of raw materials to its final disposal. The carbon footprint and overall sustainability of agricultural practices and policies can be assessed using LCA in the context of agriculture.
- **Eco-system Services Assessment**:
    - Food production, water purification, and climate regulation are examples of ecosystem services that humans derive from ecosystems. The assessment of ecosystem services considers the impact of policies on providing these services, with a particular emphasis on carbon sequestration.
- **Socio-economic Analysis**:
    - Socioeconomic analysis is dedicated to evaluating the social and economic effects of policies, including their impact on farmer livelihoods, food security, and rural development. To ensure positive social and economic outcomes, it is important to ensure that policies that promote carbon sequestration and sustainability also result.
- **Monitoring and Evaluation**:
    - To track the effects of policies and identify areas for improvement, monitoring and evaluation involve collecting data over time. Adaptive management requires ensuring that policies are effective and can be adjusted as necessary, which is a crucial aspect. The impact of policies on carbon sequestration and sustainability in agriculture can be assessed by using various data sources in addition to these methodologies. These include:
- **Agricultural production data**:
    - The impact of policies on agricultural productivity and greenhouse gas emissions can be evaluated using data on crop yields, livestock production, and fertilizer use.
- **Soil data**:
    - The impact of policies on soil health and carbon sequestration can be assessed by using soil data, such as soil organic matter content and soil nutrient levels.
- **Land use data**:
    - The impact of policies on deforestation and carbon sequestration can be evaluated using land use data, which includes forest cover and land management practices.
- **Climate data**:
    - The impact of policies on climate change adaptation and mitigation can be assessed using climate data, such as temperature and precipitation records.
    - A comprehensive understanding of how policies affect carbon sequestration and sustainability in agriculture can be obtained by policymakers and researchers by utilizing a combination of methodologies and data sources. By using this information, policy decisions can be informed, and agricultural practices can be ensured to contribute towards a more sustainable future.
- **Timeframe**
    - It is possible for policies to have a delayed impact. When making assessments, it's crucial to take into account the long-term effects of policies.
    - Measurement and assessment of carbon sequestration and sustainability in agriculture are subject to uncertainty. This uncertainty should be considered when making policy decisions.

13. Challenges in Policy Implementation:

Identify challenges and barriers hindering the effective implementation of policies aimed at promoting carbon sequestration in agriculture.

- Agriculture's dependence on weather and climatic conditions makes it especially vulnerable to climate change. Higher temperatures, increased rainfall variability, invasive pests, and greater frequency of extreme weather events are all negative impacts that climate change is already causing.
- The production and land use change caused by agricultural expansion lead to on-farm emissions, which in turn are a major source of global greenhouse gas (GHG) emissions. Without taking matching action, agricultural emissions are predicted to continue to increase and the sector's contribution to total emissions will increase as other sectors accelerate their efforts to decarbonize.
- Agriculture's contribution to reducing emissions is positive, unlike many other emissions-intensive sectors, as it removes carbon from the atmosphere by sequestering carbon in biomass and soils. By implementing productive practices like conservation, agriculture and the restoration of degraded agricultural lands, this can be accomplished. Both processes are intended to reduce direct emissions and prevent further indirect emissions caused by land use changes.
- Addressing GHG emissions in agriculture comes with specific challenges. The sector is governed by a variety of government policies, which include significant support policies in OECD countries. The primary concern is whether current policies are helpful or unhelpful in addressing climate change in agriculture. It is equally significant to examine the kinds of mitigation policies that governments have implemented or are contemplating to combat agricultural emissions.
- The main sources of direct emissions from agriculture across the globe are enteric fermentation and manure management from livestock, which needs to be taken into account. Many of these emissions (42% of direct agricultural emissions) are due to Enteric fermentation, which is a digestion process of cattle, sheep, goats, and other ruminant livestock that produce methane.

14. Economic Considerations

Analyze the economic implications of sustainable agriculture practices and the role of policies in supporting financially viable initiatives.

- The farming sector's interaction with the rest of the economy is expected to change because of the shift towards sustainable practices. The shift in purchasing and selling patterns should be reflected when analyzing the differences between farming types, such as conventional and sustainable farming.
- Despite the fact that sustainable agriculture practices may cost more initially, sustainable practices can often save money in the long run by reducing the need for chemicals and expensive machinery.
- The adoption of sustainable agriculture practices can greatly enhance food security by creating and giving way to alternative food options. By creating a food system that is more efficient, stable, and resilient than traditional farming practices, it can be a successful approach to meeting the global food demand. The result of this can bring significant reduction in global poverty and food insecurity, and it remains a major contributor to growth in many regions of the world.
- Environmental, social, and economic sustainability is supported by sustainable agricultural productivity growth, which involves improving ecosystem services, better educated and healthier workforces, and stable markets and communities.

15. International Collaboration:

International collaboration and cooperation are crucial for developing and implementing effective policies for sustainable agriculture and carbon sequestration. Here are some examples of country-based international collaborations in this area:

- **United States and China**: The US and China, the world's two largest emitters of greenhouse gases, have established a Joint Working Group on Climate Change and Environmental Cooperation. This group has facilitated collaboration on a range of issues, including sustainable agriculture and carbon sequestration. For instance, the two countries have partnered on initiatives to promote conservation tillage practices and develop climate-resilient crop varieties.

- **Brazil and Germany**: Brazil, a major agricultural producer, has collaborated with Germany, a leader in renewable energy technology, to develop and implement sustainable agriculture practices. This collaboration has focused on reducing deforestation, promoting reforestation, and improving soil management techniques. One notable example is the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) project in the Amazon rainforest, which is funded by Germany and other developed countries.
- **Australia and Indonesia:** Australia and Indonesia, two countries with significant agricultural sectors, have partnered to promote sustainable agricultural practices and carbon sequestration. Their collaboration has included research on climate-smart agriculture, development of carbon accounting methodologies, and capacity building for farmers and policy makers.
- **Kenya and Norway**: Kenya, a country highly vulnerable to climate change impacts, has collaborated with Norway, a leading donor in climate finance, to develop and implement climate-resilient agriculture practices. This collaboration has focused on promoting drought-tolerant crops, improving water management systems, and enhancing soil conservation techniques.
- **European Union and African countries**: The European Union (EU) has established various partnerships with African countries to promote sustainable agriculture and carbon sequestration in Africa. These partnerships have focused on areas such as improving soil health, developing agroforestry systems, and supporting climate-smart agriculture initiatives.

These examples illustrate the diverse range of country-based international collaborations that are advancing sustainable agriculture and carbon sequestration practices worldwide. By working together, countries can share knowledge, resources, and best practices to address the shared challenges of climate change and food security.

16. India International partnership:

- **India-France Climate and Environment Partnership**:

In 2018, this partnership was established to encourage collaboration on various climate and environmental concerns, including sustainable agriculture and carbon sequestration. The partnership has concentrated on promoting renewable energy and increasing energy efficiency through the development of climate-resilient agriculture practices.

- **India-Brazil Agricultural Cooperation Agreement**:

The purpose of this agreement was to promote cooperation on multiple agricultural issues, such as sustainable agriculture and carbon sequestration. The agreement has centered its efforts on developing farming practices that can withstand climate change, supporting biofuels, and enhancing techniques for conserving soil.

- **India-African Union Climate Action and Sustainable Development Partnership**:

The launch of this partnership in 2021 was designed to promote collaboration on multiple climate action and sustainable development issues, including sustainable agriculture and carbon sequestration. Development of climate-resilient agriculture practices, promotion of renewable energy, and improvement of energy efficiency in Africa have been the focus of the partnership.

17. Public Awareness and Advocacy:

Highlight the role of public awareness campaigns and advocacy efforts in garnering support for policies promoting sustainable agriculture.

- Public awareness campaigns can increase consumers' comprehension of the benefits of consuming local products by informing them about the value of local agriculture. It has the potential to help them make intelligent decisions that aid local farmers and contribute to the development of vibrant, resilient local food systems.
- Local farming practices are analyzed through campaigns that provide insight into both organic and sustainable methods, crop rotation, integrated pest management, and animal welfare practices. By demonstrating how local farmers are committed to environmentally friendly and responsible farming, consumers can gain a deeper appreciation for the quality and integrity of local agricultural products.

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Climate Change and Sustainable Tobacco Crop Production

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Introduction:

Sustainability in leaf production aims at long-term farming which ensures consistent supplies optimising input use, quality and profitability of the crop while protecting environment and supporting community well-being.

Climate Change and impact on Agriculture:

Weather plays a critical role in a successful crop production. There has been a volatile and unpredictable weather pattern, leading to extreme weather events hitting all parts of the world. Never the impact was so devastating, as it happened in the past few years. World Meteorological Organisation's (WMO)[1] provisional state of the Global Climate report confirmed that 2023 is the warmest year so far. Similarly, February 2023 in India was the warmest month on record since 1901[2]. Wildfires in California, El-Nino phenomenon, Wildfires in Hawaii[3], Freddy cyclone[4] devastating Malawi, Mozambique and Madagascar, earlier this year are all as a consequence of rapidly transforming climate, making farming activity challenging. Consequently, direct impact is reflected in the form of physiological and phenotypic changes, depletion in soil fertility, declining water availability for irrigation, frequent flooding and occurrence of drought, leading to a significant damage to agricultural ecosystems and disruptions in supply and prices of Agri produce.

Addressing Climate Change:

As a response, the global community evolved a mechanism to initiate processes to mitigate the deteriorating situation arising due to climate change. The broad frameworkwas designed to address the emerging requirements through Global goals and principles, Regulations/Standards (Carbon Tax, Science based Targets, Business and Global Biodiversity Framework etc), Reporting Frameworks (CDP, TCFD, TNFD) and Global Goals (Sustainable Development Goals, UN Global Compact, Green House Gas Protocols, UN Paris Climate Agreement etc.). These facilitate driving Science Based Climate actions, promote sustainable & responsible business practices and improve transparency & accountability for the companies. Green House Gas Emissions (GHG) are considered to be the primary reason for global warming and several countries are adopting laws, implementing policies and timed pledges to reduce carbon footprint. Recent endorsement of the declaration on Sustainable Agriculture, Resilient Food Systems and Climate Action during COP28 UAE[5], will help in strengthening the food systems, building resilience to climate change, reducing global emissions, and thus contributing to the global fight against hunger, which is in alignment with the UN Sustainable Development Goals (SDGs)[6].

Sustainable Tobacco Production in the face of Climate Change:

Global Tobacco production is no exception and is impacted by Climate change, impacting Tobacco production in major Tobacco producing countries including India, leading to a drop in productivity, a substantial shift in quality, and demand supply imbalance. Occurrence of two seasons of drought followed by equal number of wet weather seasons brought down the production of Indian AP Traditional Flue cured crop to sub optimal levels of 74-87 m kg from a potential of more than 120 m kg. Mysore region also experienced the impact of climate change resulting in production of about 60 m kg in 2022 against an authorised crop of 100 m kg.

Strategies for ensuring Sustainable Production of Tobacco:

In this challenging and complex backdrop, for ensuring sustainable tobacco production and regain a preeminent position as a formidable supply source, innovative plans are to be evolved and implemented over a shortand long-time horizon. Several measures which can be broadly classified under adaptation and mitigation measures implemented across various agricultural production systems, involving development of products and technologies need to be identified and customised to Tobacco farming.

A broad framework for implementation covering strategic long-term initiatives and short-term mitigation measures aid in developing Weather Resilience across the leaf tobacco value chain:

a. Short Term:

- Damage recovery measures – Servicing seedling demand through contingency plan, access to other crop inputs
- Explore and establish commercial nurseries as buffer zones.
- Informed decisions for calibrated operations – weather forecast based crop advisory.
- Rain/Drought hot spot mapping
- Staggered and extended planting window
- Climate specific production practices (Dry/Wet)
- New technologies like drones for sprayingfor ensuring quick & widespread coverage.

b. Long Term:

- Evolving Varieties/Hybrids with tolerance to abiotic (Water Use Efficiency) and biotic stress (*Fusarium* and *Orobanche*) and niche traits such as stay green &holdability, Nitrogen use efficiency etc.
- Maintaining an inventory of seed for 2 years
- Development of Micro region-specific crop production practices
- Use of Novel crop inputs to achieve resource use efficiency – Customised Fertilisers
- Weather based growing models – extensive use of contemporary tools such as AI and Data Analytics.
- Watershed management approach in Tobacco growing regions and adopting water use efficient technologies for irrigation.
- Promote nature positive tobacco cultivation through Regenerative production practices and conservation of natural resources and habitats
- Embrace future digital technologies such as Autonomous farming machines, Robotics, Bigdata, AI & IOT, Smart crop monitoring through Drones / Satellites (Remote Sensing)and Digital Crop Advisory

In addition to the above actions, achieving Low Carbon Footprint in crop production through Science Based Targets is of paramount importance, since the global industry and major economies were mandated to advance their Net Zero Targets by 2050 during the G7 Meet in May 2023 in Japan[7]. Through an internal study, it was identified that there is anopportunity to reduce Carbon emissions in Tobacco production chain by addressing three major sources – Fertilisers (especially Nitrogen), Curing and Mechanisation.

Role of Stakeholders in achieving Sustainability in Tobacco Production:

Alignment of all stakeholders involved directly or indirectly towards achieving weather resilience is critical for preparing the farming community to face the imminent threat of climate change. Formulation and enablement of favourable policy environment to mitigate climate change is important. Tobacco Industry has to forge R&D Collaborations, facilitate technology transfer and provide financial support for promoting low carbon technologies. Tobacco Board has a key role informulation and enablement of favourable policy framework to mitigate the impact of climate change and deployment of climate resilient production practices. In addition, extending financial support to farmers in transitioning to new technologies and dissemination of advanced practices will certainly provide much needed impetus to achieve the objective. Central Tobacco Research Institute (CTRI), being an apex scientific body for research on tobacco mayspearhead fast tracking the process for release of varieties / Hybrids with biotic and abiotic stress tolerance and provide timely recommendations for deploying frontier technologies.

It is certain that execution of above actions, with a strong process orientation, goal directed approach and enabling policy, results in achieving supply stability ofIndian Tobacco that is laced with Product quality, compliance, price competitiveness topped with ESG and Sustainability features, making India, **A Compelling and Must Buy Destination**.

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ESG: AOI Approach & Possible Impacts on Tobacco Supply Chain

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Introduction to AOI:

Alliance One International, LLC (AOI) is a leading independent leaf tobacco supplier and a wholly-owned subsidiary of Pyxus International, being a global tobacco leaf merchant company with 150 years of experience. Headquartered in Morrisville, North Carolina, Our core business has been - purchasing, processing, packing, storing and shipping tobacco to manufacturers of cigarettes and other consumer tobacco products throughout the world.
AOI has over 300,000 farmer relationship across the globe, covering five continents, in 20 countries around the world. Our agronomists maintain frequent contact with our contracted farmers prior to and during the growing and curing seasons to provide technical assistance to improve the quality and yield of the crop. AOI is well recognized for producing sustainable and traceable leaf tobacco.

Sustainability:

AOI since its inception has sustainability as core of its business, developing programs to supporting farmers, environmental and CSR projects, with focus on customer programs compliance and internal programs.

ESG addition, has helped to identify, organize, analyze, prioritize, and guide decisions on various business risks. Setting the ambition: Goals, mile stones and achievements. Thought its governance, provides a framework to measurable and verify our achievements, which are reported publicly annually.

ESG Initiatives:

Introduction of AOI initiates per country, covering key ESG developments.
Living income: AOI approach to collect data from 100% of its farmers to bench mark farmer living income by segmentation of scale and providing GAP training to all farmers with the goal to maximize farmer's income.

Importance of ESG

Brief discussion on the importance of ESG adoption and possible consequences for the stakeholders.

Closing message with AOI position and the path forward.

Futuristic Processing Technologies in Value-addition to High-value Commercial Crops Alternate to Tobacco

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ABSTRACT

Promoting alternative crops to tobacco cultivation is crucial to diversify agricultural practices and reduce the negative impact of tobacco farming on health, the environment, and local economies. Keeping these things in view, the Government has been making conscious efforts to promote alternate crops such as chilli, turmeric, castor and aswagandha keeping their scope for enhancing productivity, processing, value-addition, and export promotion of these crops. The above commercial crops are known for their diverse bioactive components, each with potential health benefits. Researchers often combine multiple techniques to comprehensively extract, detect, and characterize bio-active compounds for various applications, including pharmaceuticals, nutraceuticals, and functional foods. Value-addition can take various forms, including the creation of convenient foods, therapeutic products, and shelf-stable foods. Value-added products of selected commercial crops, potential application of their active ingredients, novel characterization and processing technologies have been presented in this paper.

1.Introduction

Agriculture is currently viewed as an agribusiness enterprise with the overarching goal of enhancing farm returns, profitability, value-addition, and exports. The commercial agriculture plays a major role in its contribution in boosting economic growth of the farmers. Promoting alternative crops to tobacco cultivation is crucial to diversify agricultural practices and reduce the negative impact of tobacco farming on health, the environment, and local economies. The Indian Government has been making conscious efforts to promote alternate crops such as chilli, turmeric, castor and aswagandha keeping their scope for enhancing productivity, processing, value-addition, and export promotion of these crops. Presently, India is the world leader in the export of chilli (56%, Rs.8582 crores), turmeric (76%, 1784 crores), castor (87%, Rs.7805 crores), and second position in tobacco (9%, 6306 crores) at the global level generating export value of Rs.24,477 crores (FAOSTAT, 2022).

2. Value-added Products of Commercial crops

Chillies, turmeric, castor, and ashwagandha are plants that are known for their diverse bio-active components, each with potential health benefits. Here are some of the key bio-active components present in each of these plants:

1. Chillies (*Capsicum annuum*):

- **Capsaicin:** This is the primary bio-active compound responsible for the spiciness or heat of chillies. Capsaicin has been studied for its potential health benefits, including pain relief, anti-inflammatory properties, and metabolism-boosting effects. Capsanthin is a colour component with diversified uses in food product manufacture.

Key words: Curcumin, Capsaicin, Pulsed electric field assisted extraction, Super critical fluid extraction, Ultrasound assisted extraction, Fluorescence spectroscopy, Surface Plasmon resonance, Mass spectroscopy imaging, metabolomics.

2. Turmeric (*Curcuma longa*):

- **Curcumin:** Turmeric contains curcumin, a well-known bio-active compound with anti-inflammatory and antioxidant properties. Curcumin has been studied for its potential benefits in managing various health conditions, including arthritis, cardiovascular disease, and certain types of cancer.

3. Castor (*Ricinus communis*):

- **Ricinoleic Acid:** Castor oil, derived from the seeds of the castor plant, is rich in ricinoleic acid. This fatty acid is known for its anti-inflammatory and anti-microbial properties. Castor oil is commonly used in traditional medicine and skincare products.

4. Ashwagandha (*Withania somnifera*):

- **Withanolides:** Ashwagandha contains bioactive compounds known as withanolides, which have adaptogenic properties. Adaptogens are substances that may help the body adapt to stress and promote overall well-being. Withanolides are believed to contribute to the anti-stress and anti-anxiety effects of ashwagandha.

It's important to note that the presence and concentration of bio-active components can vary based on factors such as the plant variety, growing conditions, and processing methods. These bio-active compounds contribute to the medicinal and therapeutic properties associated with these plants.

Table 1. Potential applications of select commercial crops

Crop	Potential applications
Chillies	· **Culinary Use:** Chillies add heat and flavor to a wide range of dishes globally. They are a crucial ingredient in many cuisines, providing various levels of spiciness. · **Pharmaceutical Industry:** Capsaicin, the compound responsible for the heat in chillies, is used in the pharmaceutical industry for pain relief and as an ingredient in topical creams. · **Export Industry:** Chillies are a significant agricultural export commodity, contributing to international trade and economies.
Turmeric	· **Medicinal Use:** Turmeric contains curcumin, a compound with anti-inflammatory and antioxidant properties. It is used in traditional medicine for various health benefits and has gained popularity in the health and wellness industry. · **Culinary Use:** Turmeric is a key ingredient in many cuisines, providing flavor and color to dishes. It is a staple spice in Indian and Southeast Asian cooking. · **Cosmetic Industry:** Turmeric is used in cosmetic products for its skin-brightening and anti-inflammatory properties. · **Dyeing Industry:** Turmeric has been traditionally used as a natural dye for fabrics.
Castor	**Industrial Uses:** Castor oil has various industrial applications. It is used in the production of bio-diesel, lubricants, paints, plastics, and cosmetics. · **Pharmaceutical Use:** Castor oil is used in the pharmaceutical industry as a laxative and in certain medications. · **Agricultural Benefits:** Castor plants are grown for their oil-rich seeds, and the oil cake left after oil extraction is used as a fertilizer.
Aswagandha	· **Traditional Medicine:** Ashwagandha is an adaptogenic herb used in traditional Ayurvedic medicine to reduce stress, improve energy levels, and enhance overall well-being. · **Pharmaceutical Industry:** Ashwagandha extracts are used in the production of herbal supplements and formulations for stress management, immune support, and various health benefits. · **Nutraceuticals:** Ashwagandha is increasingly used in the formulation of nutraceutical products, contributing to the growing market for natural health supplements.

However, it's also crucial to exercise caution and seek professional advice before using these plants or their derivatives for therapeutic purposes, as individual responses can vary, and interactions with medications may occur. These bio-active components can be infused in various value-added products using various processing technologies.

Value-addition can take various forms, including the creation of convenient foods, therapeutic products, and shelf-stable foods. Additionally, they often align with current trends in the food industry, such as the demand for functional foods, healthy snacks, and time-saving meal solutions. It's worth noting that the development of value-added products requires careful consideration of consumer needs, market trends, and regulatory requirements.

3. Novel processing extraction technologies of active ingredients

The field of bio-active compound research is dynamic, and continuous advancements are likely to occur. There are many novel processing technologies used for extraction of various bio-active components of commercial crops viz., Chillies (Capsaicin), Turmeric (Curcumin), Aswagandha (Withanolides) (Table.3).

Table 2. Various value-added forms of commercial crops

Crop	Shelf stable products	Convenient products	Therapeutic/ Nutraceutical foods/ Products	Personal care and beautyand industrial products
Chillies (Jalgaonkar, 2022)	Chilli powder Chilli flakes Chilli sauces Dehydrated chilli chips or snack mixes	Gourmet chilli oils Spicy cold-pressed juices, chilli-infused sodas cocktail mixers with unique flavor profiles Chilli based food colours	Capsaicin extract	Chilli-infused lotions, creams, or masks for potential antioxidant and anti-inflammatory benefits
Turmeric (Sasikumar, 2012)	Turmeric-infused yogurt, milk, ice cream Turmeric-infused pet treats or pet food	Turmeric-infused functional beverages with added flavors and nutrient Turmeric-flavored, extruded snacks Instant turmeric latte mixes	Curcumin extract Enteric-coated turmeric capsules that release curcumin	Turmeric-infused creams, serums, and masks
Castor (Kaur and Bhaskar, 2020)	Castor oil	Castor oil capsule	Laxative, Dietary supplements Castor oil capsule	Lubricants, Polyurathene foam (PUF), Castor wax in form of lip balm, cream and lotion, Biodiesel Fertilizers Feed stock for biochemicals
Aswa Gandha (Singh *et al*., 2014)	Aswagandha extract	Aswagandha infused beverages, Aswagandha enriched tea blends Ashwagandha-infused snacks like bars, trail mixes	Aswagandha enhanced foods such as granola, cereals or dairy products	Aswagandha infused creams, skin care products, serum, masks

4. Novel detection and characterization techniques for bio-active components of commercial crops

Various novel technologies have emerged for the precise detection of bio-active compounds from natural sources (Fu *et al*., 2019). The following methods play a crucial role in characterization and used in sectors such as pharmaceuticals, food and beverages, environmental monitoring, and healthcare.

a. High-Performance Liquid Chromatography (HPLC) with Mass Spectrometry (MS):

- **Detection and Characterization:** HPLC coupled with MS is a powerful technique for separating, detecting, and characterizing bioactive compounds. It provides high sensitivity and selectivity.

Table 3. Novel processing extraction technologies

Technology	Principle	Process	Advantages
Super Critical Fluid extraction (SCFE) (Khanam, 2018; Leal, *et al*., 2003)	Utilizes supercritical carbon dioxide (CO_2) as a solvent under specific temperature and pressure.	Raw material is exposed to supercritical CO_2, which acts as a solvent to extract active ingredient (a.i). The CO_2 is then separated, leaving behind the a.i extract.	Selective extraction, minimal thermal degradation, and no residual solvent in the final product.
Microwave assisted extraction (MAE) (Sagarika and Prince, 2016)	Applies microwave radiation to enhance the extraction process by promoting the movement of molecules	Raw material is combined with a suitable solvent, and microwave energy is applied to facilitate the extraction of active ingredient	Reduced extraction time, increased efficiency, and preservation of thermolabile compounds
Ultrasound assisted extraction (UAE) (Teng *et al.,* 2019; Rao *et al.,* 2021))	Uses ultrasound waves to create cavitation, promoting the release of compounds from plant materials	Raw material is immersed in a solvent, and ultrasound waves are applied to disrupt cell walls and enhance the release of active ingredient	Accelerated extraction, increased yield, and improved mass transfer.
Hydrodynamic cavitation assisted extraction (HCAE) (Preece *et al.,* 2017)	A technique that utilizes the phenomenon of cavitation induced by high-pressure fluid flow to enhance the extraction of bio-active compounds, such as oleoresins, from plant materials.	Raw material is subjected to hydrodynamic cavitation in the presence of a solvent, facilitating the extraction of active ingredient	Improved mass transfer, reduced extraction time, and enhanced yield
Enzyme assisted extraction (EAE) (Das *et al*., 2021)	Involves the use of enzymes to break down cell walls and release bio-active compounds	Enzymes, such as cellulose or hemicellulose (Ex., for turmeric) are added to the slurry in specific concentrations and ratios and further processed.	Enhanced selectivity, improved extraction efficiency, and reduced solvent usage
Pulsed Electric Field Extraction (PEF) (Barbosa-Pereira *et al*., 2018)	Applies short bursts of high-voltage electric fields to disrupt cell membranes and enhance extraction	Raw material is exposed to pulsed electric fields in the presence of a solvent, facilitating the extraction of curcumin	Increased mass transfer, reduced extraction time, and improved overall extraction efficiency
Ionic Liquid based Extraction (Dinh *et al*., 2018)	Uses ionic liquids as solvents to dissolve and extract active ingredient from raw material	Raw material is mixed with an ionic liquid, and active ingredient is extracted through dissolution	High selectivity, reduced environmental impact, and the potential for recycling ionic liquids.

b. **Gas Chromatography-Mass Spectrometry (GC-MS):**

- **Detection and Characterization:** GC-MS is commonly used for volatile compound analysis. It separates and identifies compounds based on their mass-to-charge ratio, providing detailed information about the composition of complex mixtures.

c. **Nuclear Magnetic Resonance (NMR) Spectroscopy:**

- **Characterization:** NMR spectroscopy is a non-destructive technique that provides structural information about bio-active compounds. Advances in NMR technology have improved resolution and sensitivity.

d. **Matrix-Assisted Laser Desorption/Ionization Mass Spectrometry (MALDI-MS):**

- **Detection and Characterization:** MALDI-MS is particularly useful for analyzing large biomolecules. It allows the analysis of intact bio-active compounds, preserving their structural integrity.

e. **Metabolomics and Metabolite Profiling:**

- **Characterization:** Metabolomics involves the systematic study of small molecules (metabolites) within cells, tissues, or organisms. It provides a holistic view of the metabolites and is used to understand the bio-active compounds present.

f. **Biosensors and Nanosensors:**

- **Detection:** Biosensors, including those based on nanotechnology, offer rapid and specific detection of bioactive compounds. They often use biological elements like enzymes or antibodies for recognition.

g. **Mass Spectrometry Imaging (MSI):**

- **Characterization:** MSI allows the spatial mapping of bio-active compounds within a sample. It provides information about the distribution of compounds, enabling researchers to visualize their localization.

h. **Surface Plasmon Resonance (SPR):**

- **SPR Biosensors for detection:** SPR allows the real-time monitoring of biomolecular interactions. Bio-active compounds can be immobilized on a sensor surface, and binding events are detected based on changes in refractive index

i. **Fluorescence Spectroscopy:**

- **Fluorescence Resonance Energy Transfer (FRET) for detection:** FRET is used to study molecular interactions. Fluorescent labels on bio-active compounds emit signals when close to specific biomolecules, allowing for detection.

j. **Electrochemical Sensors:**

- **Voltammetry and Amperometry:** These electrochemical techniques measure changes in current or voltage resulting from the electrochemical reactions of bio-active compounds, providing a rapid and sensitive detection method.

k. **Microfluidic Devices:**

- **Lab-on-a-Chip Technology:** Microfluidic devices integrate multiple analytical processes on a small chip. They enable rapid and efficient detection of bioactive compounds with minimal sample volume.

l. **Laser-Induced Breakdown Spectroscopy (LIBS):**

- **LIBS for Elemental Analysis:** LIBS uses a laser to create a plasma, and the emitted light is analyzed to determine the elemental composition of a sample, including bio-active compounds.

Conclusions

In recent times, the commercial crop sector has experienced a significant upswing as agriculture transforms into a thriving agribusiness industry within the country. Despite India's prominence in exporting value-added products derived from these crops, the proportion of exports in relation to production remains relatively modest, standing at less than 35%. This suggests a pressing necessity for a more export-oriented approach, involving the exploration of new international markets, diversification of products, and the implementation of processing and value-addition strategies. Modern consumers have elevated expectations for food products, seeking attributes such as convenience, variety, extended shelf-life, appropriate caloric content, affordability, and eco-friendly. Meeting these expectations necessitates the implementation of strategies that involve adjusting existing food processing methods and embracing innovative processing technologies. To deliver high-quality food products that align with consumer demands, it is essential to comprehend the fundamental principles of food processing. Moreover, recognizing emerging opportunities and employing integrated strategies becomes crucial.

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Post-harvest Interventions and Value-addition in Turmeric (*Curcuma longa*)

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Turmeric, scientifically known as *Curcuma longa*, is a flowering plant belonging to the ginger family, Zingiberaceae. For thousands of years, this plant has been cultivated in the Indian subcontinent and Southeast Asia and is considered a native species. One of the most active compounds in turmeric is curcumin, which is responsible for its distinctive color and many health benefits. Curcumin is known for its anti-inflammatory, antioxidant, and antimicrobial properties. Due to these properties, turmeric has been a staple in traditional medicine systems, such as Ayurveda and traditional Chinese medicine, for centuries. Turmeric has gained widespread popularity in recent years for its potential health benefits and has become the focus of numerous studies exploring its role in supporting overall well-being.

India is the world's largest producer, consumer, and exporter of turmeric. India grows more than 30 different types of turmeric, which are planted in more than 20 states. The largest producing states of Turmeric are Maharashtra, Telangana, Karnataka, and Tamil Nadu. The processing of turmeric involves several unit steps to transform the raw rhizomes into the familiar yellow spice used in cooking and traditional medicine (Figure 1). It is important to note that the process can vary, and some producers may skip specific steps or utilize alternative methods. In addition, growth circumstances, harvesting techniques, and storage also have an impact on the quality of turmeric. Strong aroma, savory taste, and bright yellow color are characteristics of premium turmeric.

The major issues of turmeric after harvest are the storage losses and quality specifications. Postharvest interventions like polishing, coloring, and grading the rhizomes are required to minimize post-harvest loss. For value-addition, new updated technologies like spray-drying, supercritical CO_2 extraction of curcuminoids and turmerones, and microwave-assisted extraction technique of curcuminoids needs to be adopted. Some value additions of turmeric rhizome are oleoresin, essential oils, and curry powder with high market value.

The Government of India has launched several schemes to promote small enterprises to promote turmeric processing through the Prime-Minister Formalization of Microprocessing Enterprises (PMFME) and the national turmeric mission. PMFME scheme supports all turmeric and other commodity growers to establish primary and secondary processing units. The National Turmeric Board focuses on developing and growing turmeric and turmeric products. The board is expected to enhance the turmeric export to 1 billion USD in 2030 from 207 USD reported during 2022-23.

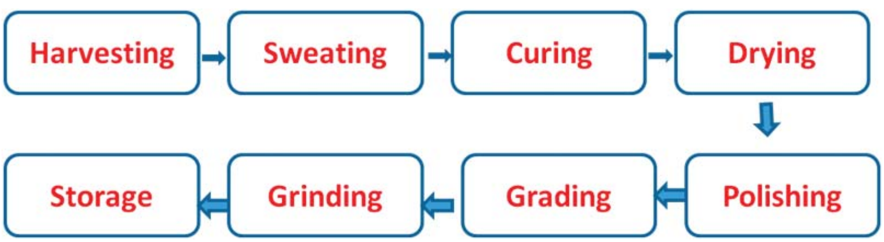

Figure 1: Different unit operations used in Turmeric Processing

Exploring and Exploiting *Curcuma* spp. for Ensuring Quality and Enhancing Trade of Turmeric

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Significance of turmeric

The present knowledge and utilization of turmeric (*Curcuma* spp.) can be summarized in one statement: a lot is known but the vast remains yet to be known, which is the prompt for the title of this presentation. The use of turmeric popularly known as 'Indian Saffron' in religious ceremonies as substance of auspiciousness and in culinary as a colourant and spice dates back to the Vedic culture of India. Its medicinal benefits have found mention in Susruta's ayurvedic pharmacopoeia. All systems of medicine including the modern medicine now acknowledge the array of its applications in treating a range of ailments. COVID 19 has reinforced its recognition as an immunity booster.

Owing to its huge trade potential, turmeric was at the centre of a patenting controversy between India and the United States of America which, however, was justly settled in favour of India, thanks to the pugnacious efforts of the Council of Scientific and Industrial Research of India under the leadership of Dr. R. A. Mashelkar.

Diversity in *Curcuma* genus and *C. longa*

Turmeric is the commodity from *Curcuma* spp. Nearly 130 species of *Curcuma* have been described worldwide. The most investigated and capitalized species has been *C. longa,* which is considered as the type species of the genus. The other species of commercial value are *C. amada* (Mango Ginger), *C. angustifolia* (Wild Arrowroot), *C. aromatica* (Wild Turmeric), *C. zedoaria* (zedoary or white turmeric) and *C. caesia* (black turmeric). Many accessions of different *Curcuma* spp have been collected and described and some have been exploited. Explorations in North East India which is considered a rich hub for origin of *Curcuma* diversity and other regions may lead to discovery of distinct genotypes for commercial utilization.

Considerable variation among *C. longa* genotypes with regard to morphological traits, crop duration, reaction to foliar diseases, curing recovery and biochemical composition has been identified. Turmeric cultivars displayed distinct variability with regard to their duration based on which they have been classified in to three groups *viz*. long duration (CLL types, eight months), intermediary duration cultivars (CLI types, seven months) and short duration (six months). Cultivars also have exhibited differences for yield and rhizome characters besides biochemical constituents. The identified variability for traits is handy in selection of the cultivar that fits in a given cropping system, yields high with the desired biochemical constituent composition. Variability in *Curcuma* spp. with regards to reaction to the two foliar diseases was reported and that the diseases are mutually exclusive, that a cultivar is susceptible to only one disease and remains resistant to the other disease which helps in the choice of resistant cultivar for the disease endemic to a given area.

Variability in *Curcuma* genus and *C. longa* in particular with the help of molecular markers was also identified. With the sequencing of the *C. longa* (2n=3x=63) genome (Chakraborty *et al.*, 2021), now it is possible to identify the genes that code for enzymes involved in the synthesis of secondary metabolites, fighting biotic and abiotic stresses. The genome sequence also revealed the distinct evolutionary features in the form of seven unique enzymes in the phenyl pathways of curcuminoid and terpenoid backbone synthesis (for essential oils). These insights provided by the complete reference genome are expected to lead further advances in commercial exploitation of curcuminoids and essential oils.

Composition of turmeric

Abundance of secondary metabolism pathways lead to the synthesis of an array of secondary metabolites in *Curcuma* spp.that assist in disease resistance and stress tolerance. Curcuminoids and essential oils are the chief secondary metabolites unique to *Curcuma* spp which have found value in human usage. These are synthesized in rhizomes, roots and leaves of the plants though rhizomes are mostly used for commercial extraction because of higher concentrations. Turmeric powder is the main form of usage. Solvent extracted oleoresin from turmeric powder (12%) contains curcuminoids imparting colour and essential oils responsible for aroma. The essential oils from different *Curcuma* spp. were found to possess specific medicinal properties. Type and concentrations of curcuminoids and essential oils were found to vary with *Curcuma* spp, cultivar, geographical area, agro-climatic conditions, method of extraction, etc. which gives scope for manipulating the cultivation, curing of rhizomes and extraction processes for either increasing their content or adjusting their proportion.

Since the gene structures of the curcuminoid genes are revealed, it may now be possible to direct differential expression of these genes for altering the content of curcuminoids as per a desired proportion. Elicitor molecules for exogeneous application that selectively regulate expression of these genes need to be identified. A Study on the differential expression of *CURS* genes and curcumin content revealed that *C. zanthorrhiza*, a wild relative of *C. longa*¸ produces more curcumin. In addition to that is present in rhizomes and bulbs, curcuminoid contents in roots and leaves of various *Curcuma* spp. have to be realised to raise the total curcumin yield potential.

Essential oils (EO) are usually a byproduct of curcumin extraction from turmeric powder. Extraction of the volatile and solvent free EO needs refinement of processes. Solid phase microextraction is an alternative method now employed to prevent loss or chemical modification of EO. Turmeric EO are predominantly a wide variety of volatile sesquiterpenes and monoterpenes and other aromatic compounds that have great therapeutic value in human medicine. Various chemotypes and concentration of the EO from different species of *Curcuma* and their medicinal applications have been reported. Innumerable proven health and therapeutic benefits of these EO have been listed. EO of *C. zedoary* showed selective inhibition of cancer cells without any effect on normal epithelial cells. This target-specific effect of zedoary EO holds promise in treatment of several cancers. The understudied species of *Curcuma* deserve to be investigated for a treasure of such beneficial compounds. The root EO were also found to vary with the *Curcuma* sp. Detailed investigations for determining their content and chemotypes with therapeutic effects would widen the range of medical options.

Turmeric trade

Turmeric dried rhizomes and powder are the commodities of commerce mostly from *C. longa.* India is the prime producer and consumer of turmeric in the world, and is also a net exporter of turmeric with some imports from Vietnam, Indonesia, Myanmar, Ethiopia, Nigeria, Cambodia, etc. Technological and government's promotional interventions ensured that production and productivity of turmeric has shown an upward trend over the last three decades. The seasonal volatility in yield of turmeric is mainly influenced by the rainfall and other climatic factors.

The chief markets for turmeric trade in India are Alleppey and Madras. The turmeric from Alleppey is mostly exported to USA while from Madras it is mostly exported to UK which indicates the importing country's preference of quality of turmeric. The Lakadong type of turmeric from NE India is rich in quality but a poor yielder.

The production trends point to the demand for turmeric which needs to be exploited and the exports/imports indicate possible competition from some countries which challenge must be faced with appropriate policy for turmeric production and export promotion so as to sustain the top position.

Blockchain technology is being extended to facilitate traceability of turmeric consignments as a measure of enhancing credibility of the produce of particular origin.

GAP (Good Agricultural Practices) for turmeric

GAP has been the primary principle of international trade of any agricultural commodity including turmeric. The Indian Institute of Spices Research and All India Coordinated Research Project of the Indian Council of Agricultural Research have jointly standardized and published GAP for turmeric which serves as a guide for turmeric cultivation from selection of site, variety, planting to harvest and processing for increasing yield of quality turmeric that meets national and international standards. Due to lack of awareness of scientific approach and tradition-bound cultivation besides other factors like availability of quality planting material, proper and timely market intelligence, the technology adoption has still not reached a satisfactory level. Technology adoption in the NE states of India is very low as turmeric is organically grown by tradition. Technology adoption in NE India needs to be promoted through special packages as there is a lot of turmeric diversity with high curcumin and EO contents remaining unexploited in this region.

Quality planting of the recommended varieties in required quantity is a major limiting factor in GAP compliance. The traditional planting material in turmeric is mother rhizomes and finger rhizomes. Since number of mother rhizomes is small, finger rhizomes are the predominant planting material. Storage methods and conditions play crucial role in maintaining the health and vigour of the seed rhizomes. Raising turmeric crop exclusively for seed purpose in high tunnels, single bud sprouts in portrays hydroponics, aeroponics and tissue culture need to be promoted and supported either directly by government or through farmer producer organisations sponsored by National Bank for Agriculture and Rural Development.

Critical stages of fertilizer application and soil moisture maintenance have been determined. Iron chlorosis has been the most important nutrient deficiency affecting turmeric crop particularly at tillering stage. Correcting this deficiency helps maintain the initial vigour of the plants. Application of neem cake and biocontrol agents (*Trichoderma asperellum* and *Pseudomonas fluorescens*) is found an effective practice to manage rhizome rot as well as rhizome fly. Non-availability of quality neem cake at affordable price is a serious impediment being faced by the farmers. Fungicidal management of both leaf spot and leaf blotch have been standardized but wide gap in adoption exists. Demonstrations to convince the growers of proper dose, method and time of application of application of the recommended fungicides should be conducted. The important pest affecting turmeric is root-knot nematode (*Meloidogyne* spp.). Managing the nematode requires a lot of planning in cropping sequence besides cultural practices. Rice, marigold, sugarcane etc. are crops that do not allow nematode build up in the field. Nematicides application as far as possible is best avoided for residue problems.

Harvesting at the right maturity and appropriate soil moisture results in intact rhizomes with very little soil adhering to them. Designing and fabricating harvesting machinery for turmeric is imperative to tide over shortage of labour at peak harvesting period. Improvements in cooking, drying, grading and packaging without loss in curcumin and EO remains an important aspect for meeting the standards specified by national and international agencies.

Organic turmeric

Owing to its culinary and medicinal properties turmeric is considered an ideal commodity for organic production. Turmeric production in some traditional turmeric producing areas in Orissa, Andhra Pradesh and the NE India is inherently organic. The principles of organic production by IFOAM (International Federation of Organic Agriculture Movements) are generally broad. Several countries have their own organic production guidelines for production and certification. Harmonized organic production systems that are acceptable to many countries helps enhance organic turmeric trade worldwide.

Quality specifications for turmeric

Ayurvedic Pharmacopoeia of India (API) American Spice Trade Association (ASTA), European

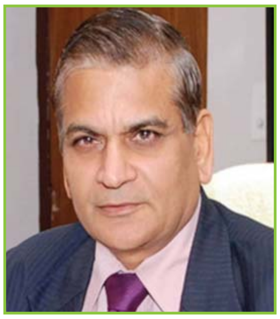
Spice Association (ESA) and East African Standards for East African Community have set specifications for turmeric imports while Agmark and Food Safety Standards Authority of India (FSSAI) have specified the guidelines for Indian markets. These specifications are operative at the traders' level but not percolated to the farm level. Bridging this gap by creating awareness among farmers and farm workers would lead to better compliance with the specifications.

Aspergillus, Salmonella, Escherichia coli, etc. are the important harmful microflora in turmeric rhizomes and powder. Aflatoxin B1 and total aflatoxin maximum permissible levels have been kept at 5 ppb and 10 ppb, respectively while no allowance is made for *Salmonella* and *E. coli.*

Heavy metals are important toxicity indicators along with insecticide residues in turmeric trade. Maximum residue limits (MRL) for some insecticides and upper limits for heavy metals *viz*. lead, arsenic, cadmium, copper and zinc that contaminate turmeric have been specified.

Way forward for turmeric production and trade

- Detailed investigations for determining the phytochemical constituents and their beneficial effects of the understudied *Curcuma* spp.
- Construction of predictive models for turmeric yield based on rainfall and climatic factors for major turmeric growing areas, and market demand at national and international levels.
- Harnessing frontier technologies like internet of things and artificial intelligence to facilitate farmers in turmeric cultivation and marketing.
- Organizing seed rhizome production adopting modern methods through seed village concept or Farmer Producer Organizations.
- Standardizing location-specific organic production modules for turmeric and supporting certification process.
- Instituting nodal agency exclusively for turmeric like the proposed Turmeric Board to coordinate all stakeholders in turmeric production for coordinating all stakeholders for promoting turmeric cultivation and trade.



Nematodes as Reliable and Convenient Bioindicators of Regional and Global Climate Change and Relevance to Agriculture

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Nematodes are a diverse group of multicellular microscopic organisms that play crucial roles in soil ecosystems. Many nematode species are despised as serious parasites of all kinds of plants and animals, including humans. Often ignored is the fact that over 80% of the nematode species are not harmful to agriculture but are vital to nutrient cycling, decomposition, and maintaining soil health. Nematodes are an integral part of a complex food web. Due to their small size, countable large numbers, short life cycles, ontogeny, organ systems and physiology nearly similar to other animals, their quick responses to the changes in the environment in their vicinity, and absence of ethical restrictions regarding them, nematodes can serve as near perfect biological models. Nematodes have served this role in much of biotechnological and pharmacology research. They can also serve as very useful ecological model organisms to understand, measure and forecast the impact of climate change.

The intricate interplay between nematodes and climate change has significant implications for soil ecology, agriculture, and overall ecosystem stability. Nematodes being ectothermic organisms, climate change impacts nematodes through alterations in temperature and precipitation patterns. As global temperatures rise due to climate change, soil temperatures are also affected. Thus, warming can have profound effects on nematode physiology, behaviour, and life cycles. There is a diversity among nematode species regarding their temperature, moisture and osmotic preferences. The rates of various metabolic processes, rates of development, duration of life cycle, fecundity, survival and thus their numerical abundance are closely dependent upon how suitable the temperature, moisture, gaseous composition, and rates of chemical and biochemical reactions in their habitats. This can have cascading effects on the entire soil food web, impacting other organisms that depend on nematodes for food.

Changes in precipitation patterns associated with climate change can also influence nematode populations. Nematodes are highly dependent on soil moisture for their survival and movement. Altered precipitation patterns, including more intense rainfall events or prolonged droughts, can directly impact nematode habitats. Some nematode species may be more resilient to changes in soil moisture, while others may struggle to adapt, leading to shifts in community composition. Soil moisture content and osmotic pressure are interrelated.

The relationship between nematodes and climate change becomes even more complex when considering their role in nutrient cycling. Nematodes contribute to the decomposition of organic matter in soils, releasing nutrients that are essential for plant growth. As climate change affects the rate of organic matter decomposition, the balance between nutrient availability and demand in ecosystems may be disrupted.

In agricultural systems, nematodes are both beneficial and detrimental. Changes in climate conditions also influence the prevalence and impact of these plant-parasitic nematodes. On the contrary, certain nematode species contribute to natural pest control by parasitizing insects and other harmful organisms. Understanding how climate change influences the delicate balance between beneficial and harmful nematodes is crucial for sustainable agricultural practices.

Opportunities and challenges related to the use of plant resistance in IPM

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There is an urgent need to reduce the environmental impact of insect pest management without sacrificing effectiveness. The use of crop varieties possessing inherent resistance to insect pests is one management tactic that can help meet this need, but host-plant resistance has historically been an under-utilized tactic. There are many reasons for this, including overreliance on cheap and easy-to-use insecticides, difficulties in breeding for insect resistance, and lack of research specifically focused on using resistant varieties in management programs. The use of plant resistance against the rice water weevil (*Lissorhoptrus oryzophilus*), an important early season pest of rice in the U.S., illustrates some of the challenges of using host-plant resistance in pest management. Despite intensive efforts to identify resistant genotypes, no genotypes with high levels of resistance to the weevil have been identified, although varieties possessing low levels of resistance can be used in conjunction with seed treatment insecticides. Furthermore, some varieties (particularly hybrids) have been identified with greater tolerance to rice water weevil injury. In addition, amendment of soils with mycorrhizal fungi can increase tolerance of rice to weevil injury, and treating seeds with methyl jasmonate can increase plant resistance. The potential of using varieties resistant to the Mexican rice borer (*Eoreuma loftini*), an invasive pest of rice in the U.S., appear to be much greater, and future efforts will focus on developing a management program centered on the use of borer-resistant varieties.

Role of Artificial Intelligence in Agriculture

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Artificial Intelligence is machine's ability to perform the cognitive functions we associate with human minds, such as perceiving, reasoning, learning, interacting with an environment, problem solving, and even exercising creativity. There are many instances where machines can perform things faster and accurately than a human being. Decades ago, example is calculator. Yesterday's example was Computer. Today's example is anything that is AI enabled. Please note that there is a huge difference between calculations and AI enabled actions. There are many branches of AI. Some of them are Machine Learning, Deep Learning, Computer Vision, Expert Systems, Natural Language Processing, Robotics, Reinforcement Learning, Artificial Neural Networks, Fuzzy Logic, Cognitive Computing, and Pattern Recognition.

AI can play a major role in agriculture. The industry is turning to Artificial Intelligence technologies to help yield healthier crops, control pests, monitor soil, and growing conditions, organize data for farmers, help with the workload, and improve a wide range of agriculture-related tasks in the entire food supply chain. PEAT, a German digital start-up, has created Plantix, an AI-based application that can detect nutrient deficits in soil, as well as plant pests and diseases, and provide farmers advice on how to apply fertilizer to increase harvest quality. Image recognition technology is used in this app. Smart phones may be used by the farmer to photograph plants. Trace Genomics, meanwhile, is a machine learning-based startup that assists farmers with soil analyses. Farmers may use such an app to track the quality of their soil and crops, resulting in healthier, more productive harvests. Agriculture AI applications have produced apps and tools that assist farmers in performing correct and regulated farming by offering suitable advise on water management, crop rotation, timely harvesting, kind of crop to be cultivated, optimum planting, insect assaults, and nutrition management. AI enabled technologies predict weather conditions, analyze crop sustainability, and evaluate farms for the presence of diseases or pests, as well as poor plant nutrition, using data such as temperature, precipitation, wind speed, and solar radiation in conjunction with machine learning algorithms and images captured by satellites and drones. Farmers who don't have access to the internet may profit from AI right now using basic technologies like an SMS-enabled phone and the Sowing App. Meanwhile, farmers with Wi-Fi connectivity may utilize AI programmes to acquire an AI-customized plan for their farms on a continuous basis. Blue River Technology combines AI, computer vision and robotics to save costs and reduce the quantity of pesticides. The computer vision defines each plant separately, machine learning determines how the characteristics of each should be observed and allows the robot to intelligently control the farm machinery and takes suitable actions. AI companies are developing robots that can easily perform multiple tasks in farming fields. This type of robot is trained to control weeds and harvest crops at a faster pace with higher volumes compared to humans. These types of robots are trained to check the quality of crops and detect weed with picking and packing of crops at the same time. These robots are also capable to fight with challenges faced by agricultural force labor.

AI systems use satellite images and compare them with historical data using AI algorithms and detect if any insect has landed and which type of insect has landed like the locust, grasshopper, etc. And send alerts to farmers to their smart phones so that farmers can take required precautions and use required pest control. Thus, AI helps farmers to fight against pests. Jiva bhumi is creating a "Smart" Agricultural Market place for optimizing the supply and demand for agricultural products, which is often inadequate. It is an innovative food aggregation solution that integrates agricultural products, e-marketplace services and innovation. It uses technologies such as block chain to collect information about products at various stages of the supply chain. Drone technology had a lasting effect on the productivity of India's agriculture sector. The companies like Equinox Drones provide farmers with drone-powered solutions to boost productivity in a variety of farming operations, including precision farming, livestock management, pesticide application, crop stress identification, treatment planning, plant growth monitoring, and scouting. AI can simplify crop selection and help farmers determine which crops will be most profitable. Using forecasting and predictive analytics, farmers can reduce errors in their processes and minimize the risk of crop failures.AI can collect data on plant growth to develop crops that are more resistant to diseases and better suited to weather conditions. AI systems can analyze soil chemically and provide accurate estimates of nutrient deficiencies. AI can monitor plant health, detect diseases, identify and remove weeds, and suggest effective pest control methods. AI can determine optimal irrigation schedules, and nutrient application timings, and recommend suitable agronomic products. With the assistance of AI, harvesting can be automated and the best time for harvest can be predicted. Overall, Agribusinesses must recognize that AI is not a cure-all solution. Nevertheless, it can provide tangible advantages by simplifying farmers' lives and enhancing everyday farming tasks. By harnessing the power of AI, we can enable sustainable farming practices and effectively address the current challenges faced in agriculture.

Market Intelligence and Value Chains for Commercial Farming

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In India, the Green Revolution improved food grain production but was not reflected in a proportional improvement in the farming society's standard of living. The time has come to concentrate more on agricultural marketing policies and programmes rather than agricultural production policies. It should also be recognized that land is a natural resource and fixed in its supply. Many initiatives have been taken up both at the state and national level to improve the condition of farmers, both technology-wise and in input and output marketing. The efforts in production could be converted into income only if a reasonable price is realized by growers. It could be made possible if the producers are empowered by providing information on the marketing of their products and inputs as well. It is evident that there exist excess intermediaries in the marketing channel, which makes the supply chain longer than optimal, especially in commercial crops. This has led to system inefficiencies, providing less income to the farmers, and becoming more costlier to the consumer. To solve these problems, there is a need for clear market information both market news and intelligence, so as to provide knowledge and information to the farmers and also to the consumers. It was noticed that, in all sectors, market intelligence gained importance, but in agriculture at a slow pace.

Market Intelligence System in India:

In view of its importance in agricultural sector, the Agricultural Prices Enquiry Committee (1954) recommends the Directorate of Economics and Statistics, Ministry of Agriculture (DESMOA) to set up 14 Market Intelligence Units (MIU) in the capitals of Andhra Pradesh, Assam, Bihar, Delhi, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal (desagri.gov.in). These market intelligence units are intended to assist the DESMOA in the formulation, implementation, and review of the agricultural price policy relating to procurement, marketing, storage, transportation, imports, exports, credit, etc. The units furnish regular reports on market arrivals, off-takes, stocks, crop prospects, and the outlook of market prices. They are also required to give their appraisal of the production of various *kharif* and *rabi* crops at regular intervals to help prepare crop forecasts. Though the data to be supplied by the MIUs is of great utility, the units have ceased to be effective in discharging their functions, mainly due to a lack of proper direction and control of their activities (mospi.gov.in).

Agricultural Market Intelligence helps in ensuring that produce goes to markets where there is a demand for it. It shortens marketing channels cuts down on transport costs, and helps ensure that each marketing transaction is a fair one and that all participants share the risks and benefits. The consumption requirements of the Indian population were satisfactorily met with the increased production of crops after the Green Revolution and further technological improvements. The small farmer-producers should be assured of a fair price for their produce, failing which they may lose the incentive to increase agricultural production (Reardon et al, 2011). To realise the remunerative returns and to prevent the ill effects of volatile prices farmers must be aware of the price behaviour of major agricultural commodities. Market information and intelligence are important to enable farmers to join the possible value chains to reap the benefits of a dynamic marketing system. The different sources of present market information sharing are shown in Figure 1.

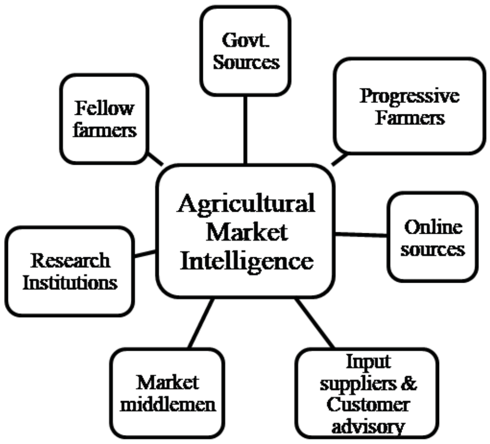

Fig 1: Different Sources of Market Intelligence

Changing Dynamics in Market Intelligence:

In the dynamic world trade environment, the dissemination of trade-related information and intelligence is crucial. However, agricultural marketing in the country, with a particular focus on market intelligence, has not received adequate attention. The wide fluctuation in prices for agricultural commodities within a season and between markets are the routine risks faced by farmers. These fluctuations have some regular patterns: seasonal, cyclical, and secular, but every year they depart from these patterns quite erratically. The seasonal indices analysis of various crops revealed that turmeric prices were high in the months of January and February, whereas arrivals were high in the months of May and June. In the case of chilli, prices were high in the months of October and November, whereas arrivals were high in the month of February. Over time, it has become a fact that irrespective of crop, prices and market arrivals show an indirect relationship. Most of the price forecasts could not cover all factors responsible for price fluctuations, including those determining erratic behaviour. The broad policy reforms in terms of the modified APMC Act in 2003 and e-NAM in 2015 have not paid adequate attention to improving market intelligence. Furthermore, market developments with a specific focus on farmer-producer organizations is still in the nascent stage which needs immediate attention for their self-reliance. Also, the potential benefits of machine learning techniques, artificial intelligence, and satellite data have hardly been reaped. There are many questions that need to be addressed in agricultural market intelligence:

- To what extent has the available marketing intelligence been used by the farmers?
- What market intelligence the traders use for discovering prices?
- How important is market intelligence for the agricultural sector?
- What will make the farmers to gain knowledge about marketing?

To answer these questions, there is a need for research at the gross root level and government involvement in developing the institutional base.

Commercial Farming:

Commercial farming, an important pillar of modern agriculture, is critical to supplying worldwide demand for food, raw resources, and exports. It can be defined as farming that focuses on producing agricultural products for sale in the market rather than solely for subsistence purposes. The need for an increase in productivity and incomes of small holdings and the promotion of non-farm activities for these farmers is obvious (B Swaminathan, K C Sivabalan, 2016). Commercial farmers optimise productivity and contribute to economies of scale by focusing on farming a single crop across large regions aiming comparative advantage principle. In general, commercial crops are in high demand because they are exported to other countries as well and domestic companies use it as raw ingredients to produce local culinary items.

In commercial farming, the Indian farmer uses high quantities of fertilizers, pesticides, and insecticides to boost crop yield. Depending on the crop, it varies among areas. For instance, rice is a subsistence crop in Orissa, but it is a commercial crop in Haryana, Punjab, and West Bengal. Chilli, turmeric, coffee, cotton, raw jute, sugarcane, tea, tobacco, soybean etc., are some of the major commercial crops of India.

The production of commercial crops has increased with the use of hybrid/high-yielding variety seeds, proper use of fertilizer and intensive use of plant protection chemicals in Andhra Pradesh.

AP is one of the major producers of commercial crops on account of its diverse climatic conditions and the production of commercial crops has increased in recent years (P Naveen and A Bharathi Devi, 2022). Nowadays, there has been a transformation in agriculture from the stage of subsistence to market-oriented due to the changes in the economy and the changed farm households' requirements other than fulfilling the need for food (S Angles and M Chinnadurai, 2018). Today's agriculture has been metamorphosised into market-led agriculture rather than the production-oriented. Market-led agriculture needs an entirely different approach, where market-led research and market-led extension are two eyes of it. In agriculture, pioneering institutes like ANGR Agricultural University some other state agricultural universities and a few private institutions have initiated basic work on market intelligence and providing required information to the farmers. The results are reaching the farmers and creating a positive effect in achieving the objective of better profit and improvement in the livelihood status of the farmers but at a slow pace. However, there are many hurdles in developing the estimates under the market intelligence for crops which makes it tedious and affects the effectiveness of the market/price-related communications. The major problems faced were the non-availability of the data, improper maintenance of the secondary data available, large variations in the quality of produce, price quotes in the forward markets, non-availability of international prices etc.

AMIC at ANGRAU:

Agricultural Market Intelligence Centre (AMIC) was an initiative by ANGR Agricultural University, Guntur, AP, which aims to forecast the price information of principal agricultural crops and disseminate the market information to the stakeholders of the state. By using superior time-series models (ARIMA, VAR) and machine learning algorithms (ANN) the centre estimates the future market prices and then standardizes these values to minimum errors by considering influential factors like sowing area, market arrivals, and the primary data from market intermediaries. The released forecast bulletins were uploaded to *angrau.ac.in* and University monthly magazine Vyavasayam, Rythu Bharosa magazine of Govt of AP displayed in 10776 RBKs at village level, phone calls, news dailies, TV & Radio broadcasts, voice message services by Reliance Foundation *etc.* The price forecasts released by the centre were evaluated through impact assessment on a regular basis. When compared to the real market prices, the accuracy of the estimates for the agricultural crops under research ranged from 86.54 to 96.38%. Farmers were taking advice by calling to the AMIC centre and to other institutes of ANGRAU. The growers who adopted the advice were studied for the economic impact of AMIC advice followed regularly. The study conducted during 2022-23 revealed that turmeric and chillies farmers who adopted the AMIC advice benefited with an amount of Rs. 1276 and Rs. 1568 per quintal of sale proceeds (Table 1).

Table 1: Profit/loss attained to farmer by following the AMIC advice

Name of the Crop	No. of farmers Provided the AMIC advise	No. of farmers followed the AMIC advise	Total Acreage of the farmers (in Ha.)	Average Yield (in quintals /Ha.)	Total yield of follower farmers	Total sale proceeds (in Rs)	Profit/ loss of the follower farmers (Rs/qtl/ farmer)	Net profit of sale proceeds of follower farmer (in Rs.)
Ground nut	61	42 (69 %)	32.86	32.82	1078.47	7321700.24	851	917773.89
Blackgram	89	55 (62 %)	48.63	15.56	756.68	5432982.50	796	602319.51
Turmeric	62	44 (71 %)	22.36	47.86	1070.15	6482966.28	1276	1365510.89
Chilli	101	51 (50 %)	65.25	18.69	1219.52	25483142.16	1568	1912211.28
Bengalgram	53	29 (55 %)	30.25	14.75	446.19	2050677.75	226	100838.38
Greengram	68	41 (60 %)	22.59	10.98	248.04	1981577.18	512	126995.56
Redgram	52	39 (75 %)	19.68	8.16	160.59	1218226.64	1101	176808.27
Total/Average	**486**	**301 (62 %)**	**265.76**	**148.82**	**4979.63**	**49971272.75**	**904.29**	**4503012.43**

As a part of AMIC, fact sheets/crop outlook reports were prepared by AMIC regularly about recent information about area, production, productivity particulars of world, India, Andhra Pradesh, and its districts; export and import scenario, procurement and consumption pattern, price behaviour of crops and they were uploaded to ANGRAU portal. The chilli and turmeric crop outlook reports can be viewed at *angrau.ac.in* website.

Market Price Forecasting Methodology:

Agricultural product price forecasting uses scientific methods to estimate or judge the trend and level of agricultural product price changes over a period of time in the future based on historical data and current information. Traditional methods like regression analysis and grey model prediction methods were initially used as they are relatively simple and easy to understand and implement, but the prediction effect is poor for nonlinear, non-smooth, and high-dimensional data, and they require more a priori knowledge and assumptions. In the mid-nineties, the univariate time series analysis, which refers to a statistical method of modelling and analysing agricultural commodity prices based on the regularity presented by the price itself over time, and extrapolating future data from existing data, was used. Presently, time series models like Auto Regressive Moving Average (ARMA), Autoregressive Integrated Moving Average (ARIMA), Seasonal Auto-Regressive Integrated Moving Average (SARIMA), Auto-Regressive Conditional Heteroskedasticity (ARCH), Generalized Auto Regressive Conditional Heteroskedasticity (GARCH), etc are noteworthy.

'Univariate' Box-Jenkins models, also referred to as ARIMA models. Univariate or single series means that forecasts are based only on past values of the variable being forecast, they are not based on any other data series (Brockwell and Davis, 2011). The ARIMA methodology is carried out in three stages, viz. identification, estimation, and diagnostic checking (Figure 2). Parameters of the tentatively selected ARIMA model at the identification stage are estimated and the adequacy of the tentatively selected model is tested at the diagnostic checking stage. If the model is found to be inadequate, the three stages are repeated until a satisfactory ARIMA model is selected for the time series under consideration. Most of the standard software packages, like SAS, SPSS, R and e-Views contain programs for fitting of ARIMA models. For price forecasting in AMIC, ARIMA and SARIMA models were employed for the data.

Nowadays, due to advancements in science and technology, intelligent methods are employed to forecast for highly accurate values. These methods handle complex data with high accuracy and generalization, but require large amounts of data and computational resources, but sometimes lack interpretability and stability. Therefore, understanding the characteristics of each forecasting method and choosing the appropriate algorithm to build a price forecasting model is a key issue to be solved for good agricultural price forecasting

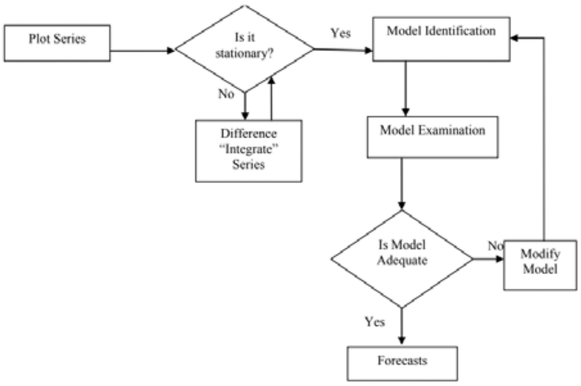

Fig 2: Box-Jenkins methodology for ARIMA model

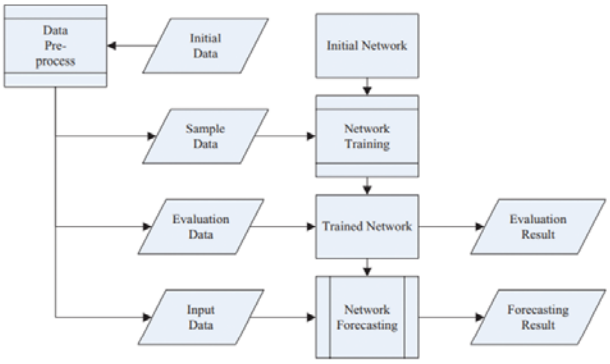

Fig 3: Process of Network Training and Forecasting

research. The AMIC centre also employs machine learning techniques like Artificial Neural Network (ANN) and Support Vector Machine (SVM) approaches for forecasting. The process of Network Training and Forecasting is presented in Fig 3. ANN is a multivariate non-linear non-parametric data-driven self-adaptive statistical method. The main advantage of the neural network is its flexible functional form and universal functional approximator (Haykin, 1999; Jha et al., 2009). With ANN, there is no need to specify a particular model form for a given data set.

The ANN, structure for a particular problem in time series prediction includes the determination of the number of layers and the total number of nodes in each layer. It is usually determined through experimentation as there is no theoretical basis for determining these parameters. The time series data can be modelled using ANN by providing the implicit functional representation of time, whereby a static neural network like a multilayer perceptron is bestowed with dynamic properties. A neural network can be made dynamic by embedding either long-term or short-term memory, depending on the retention time, into the structure of a static network. It has been proved that neural networks with one hidden layer can approximate any non-linear function given enough nodes at the hidden layer and adequate data points for training.

These are machine-generated estimates which will mostly consider the previous price data, which provides the direction for price forecast estimates decision. The validity of these estimates should be coupled with the current Intelligence of the other stakeholders in the market. The need-based information on the realistic expectations of the intermediaries in the trade is being used and finally, the forecast estimates will be released after the validation by an agricultural statistician.

Supply Chain and Value Chains:

Supply chains are primarily concerned with the flow of products and information between supply chain member organizations—procurement of materials, transformation of materials into finished products, and distribution of those products to end customers. Around 90 per cent of produce is traded in the market by way of retailers and wholesalers and only 10 per cent within the village (Samshimastung and Giribabu 2016).

Some of the common supply chains in agriculture are below

Channel I Producer '! Village Merchant '! Commission agent '! Wholesaler '! Secondary Wholesaler '! Cold Storage '! Retailer '! Consumer

Channel II Producer '! Commission Agent '! Wholesaler/ Processor '! Dealer '! Retailer '! Consumer

Channel III Producer '! Village Merchant '! Whole seller Cold Storage '! Exporter '! Overseas Buyer '! Consumer

A value chain, on the other hand, refers to the process of producing or adding value to the ultimate product at every stage, from production to distribution (Fig 4). With rising incomes, the demand for high-value agricultural crops in India has increased over the years. Therefore, it is essential to develop value chains that can handle the pre and post-harvest requirements of such commodities.

A value chain is a series of interconnected activities that aim to increase the value of a product; it comprises actors and actions that improve a product while connecting commodities producers to ultimate consumers and markets. Participation in agro-food value chains benefits the agricultural and food industries by enhancing returns to farmers and food manufacturers throughout the value chain. Indian agriculture is gradually transitioning away from traditional farming and towards high-value horticulture and livestock production (poultry, dairy, and fisheries).

As the population urbanises, earnings grow, and consumer patterns change, there is an increase in demand for fresh and processed products of all sorts. The development of an effective value chain network from “farm to fork” can help reduce agricultural production spoilage while also assisting farmers in capturing value as products preserve quality and give additional advantages to consumers. The value-added products of chilli include chilli powder, sauces,

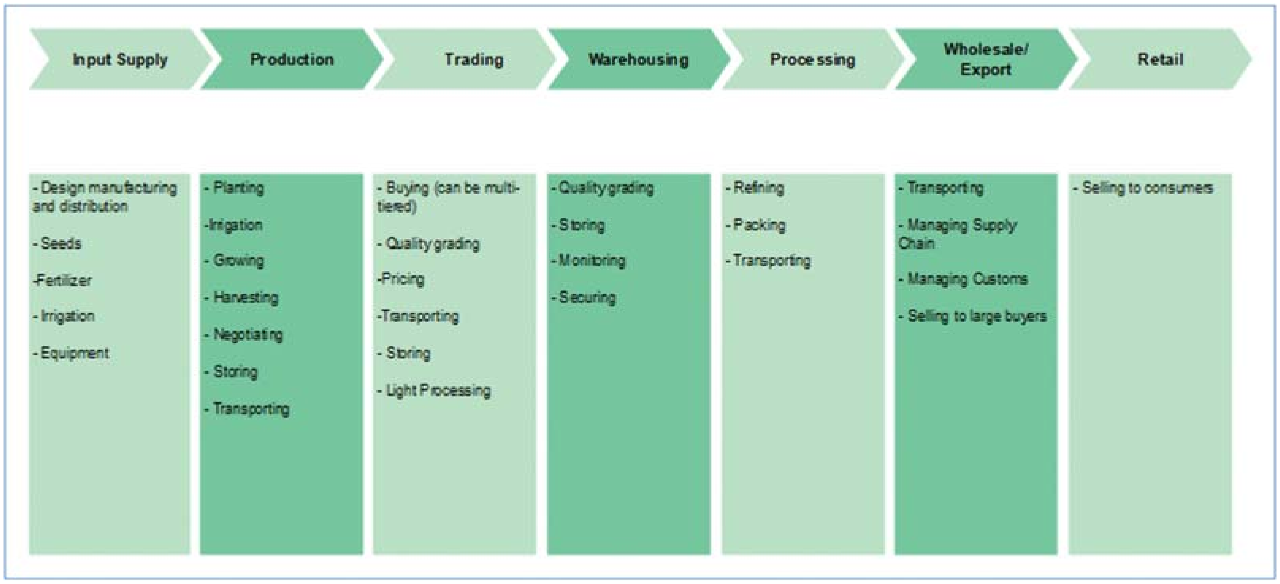

Fig 4: Representation of agricultural value chain

paste, pickles etc., whereas value-added products of turmeric include Oleoresin/Extract, Haldi Drops, Curcumin Powder, Turmeric Milk etc.

The value chains should be competitive financially and environmentally sustainable. The value chains should be inclusive to ensure the participation of marginal and small farmers. Awareness needs to be created among farmers that exporting value-added products is more beneficial than merely participant of the supply chain. The proper value chain can identify the requirement of the product form at the consumer level so that it can lead in the direction of product development research, and technology modification in production and processing. A massive thrust to food processing and other agro-based industries will add value to the product thereby increasing the income of farmers, creating employment opportunities, and diversifying the rural economy and faster rural industrialization (Raj Bala Grewal, 2015).

Linkage of Market Intelligence with supply/ value chain:

Market Intelligence is important for the management of a competitive supply chain. The monopoly of intermediaries can be reduced with a better market intelligence system. If a proper supply chain is established, farmers will think of value chains. Bombarding of product market intelligence is vital for the creation of competition in trade and can lead to the development of new value chains with growers' voluntary involvement.

Agriculture transformation scenario:

Agricultural transformation is the process of increasing agricultural production, commercialising farming, and building linkages with other sectors of the economy. In the process of development, Indian farmers change from the subsistence level to a marketable surplus level and finally, it's time to adapt value addition with commercial farming. Commercial agriculture is essential, otherwise, we might all be obliged to live in the countryside and devote all of our time and energy to traditional/ subsistence farming. Today, it is essential to adopt sustainable technology that not only boosts agricultural output but also guarantees social and environmental impact at every level. Many owned farmers were unable to cultivate their own lands, hence looking for better tenancy services. Tenant farmers will not continue farming if they incur continuous losses. If not commercialized with market information & and value chain building, sustainability of production systems at the gross root level will pose a lot of challenges and continuation of production with economies of scale with suitable products in a specific region will be affected.

Conclusion:

There are many studies which showed the potential to increase the profit of the farmers through the provision of market intelligence to the needy farming community. Thus, there is a need for intensive initiatives in the research and investment in the market intelligence aspects to help the millions of farmers and to make them continue farming.

Agricultural Market Intelligence is an important and useful instrument, and it should be strengthened and extended to all the states. The MIUs established by GoI apparently have not been able to function in the manner envisaged. Their operations and staff requirements should be re-evaluated and appropriate measures shall be taken to streamline the units. The aim of MI is not only for information dissemination but also can restructuring/developing the supply chain leading to the streamlining of present channels.

Way Forward:

- Dynamics in the process of forward linkages should be stabilized to develop confidence at the gross root level to produce commercial crops.
- Proper value chains at the farmers' level can only be developed with the help of FPO. Need-based development of agribusiness enterprises with proper infrastructure and logistics for distinct markets must be improved.
- The marketing opportunities need to be identified prior to the production of commercial crops. The situation is in such a way that marketing is being searched after the production of commodities which is a vice-versa process and policy needs to be developed in a proper way.
- The real commercialization of farming can be achieved by the integration of farmers into the value chain of respective agricultural commodities through clusters to ensure better incomes with a larger share of the consumer's rupee.
- Corporates in agricultural commodity retail chains can play a crucial role along with public sector agencies to connect the growers and make them part of the value chain by creating awareness and providing technical support.
- Development of specific clusters for commercial agriculture with specialized farming systems coupled with continuous market intelligence can pave the way to create profitable value chains for the growers possibly through Public-Private partnerships.
- Voluntary participation by the growers by realizing the benefits of commercial value chains can motivate the farmers to form groups so that a strong FPO mode of development is possible.
- Even though different sources of price-related knowledge are available, the scientific, authentic, procedural, and authentic dissemination of the required market information is necessary to adopt the improved technologies and realize better net returns by the farmers.

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Mastering Market Dynamics: The Role of Market Intelligence

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Background

The volatility in agricultural commodity prices has been a major concern for policy makers in India as it significantly affects the gains to farmers (Saxena and Chand, 2017). The volatility in the agricultural prices has a catastrophic effect on all the stakeholders involved in the production, marketing and consumption of the food commodities. Prices of some of the horticulture commodities especially onion and potato continue to remain highly volatile. The Government's price policy for agricultural commodities seeks to ensure remunerative prices to the growers for their produce with a view to encourage higher investment and production. The price policy also seeks to evolve a balanced and integrated price structure.

Globally, continuous efforts are being made to capture the trends in prices and commodity outlook/ projections to gain from the market dynamics in terms of demand-supply interplay. Esteemed organizations such as the Organization for Economic Cooperation and Development (OECD), Food and Agricultural Organization (FAO), Food and Agricultural Policy Research Institute (FAPRI), and the US Department for Agriculture (USDA) are at the forefront of this endeavour. Through their agricultural outlook exercises, these entities provide annual and medium-term projections for selected agricultural commodities on a global scale, offering a compass for navigating the supply and demand dynamics. In essence, the challenge of agricultural price volatility is not confined to national borders; it resonates globally. The quest for stability and foresight in this sector necessitates a collaborative effort, where nations and organizations work in tandem to decipher the intricate patterns that govern the ebb and flow of agricultural commodity prices.

Box 1 depicts the trajectory of market intelligence efforts in India. The market intelligence activities are now being given strong emphasis by the Government of India and efforts are being made to institutionalize the capacity within the institutions to carry out the efforts in long run.

Prevalent Modelling Approach for Price Forecasting

Market intelligence efforts aimed at providing the short term forecasts to farmers at an appropriate

Early efforts on MI	•Started in 1954 on the recommendation of the Agricultural Prices Enquiry Committee.
Market Intelligence Units (MIU)	•Directorate of Economics and Statistics, 14 MIU in different states
AGMARKNET	•Mega initiative launched by GOI for providing market information
NAIP Project on Market Intelligence	•Started in Tamil Nadu Agricultural University in 2004 to disseminate commodity price forecasts for the benefits of farmers
Network Project on Market Intelligence	•Started during 12th Plan (2013) for the plan period (till 2017) to provide short term price advisories.

Box 1. Trajectory of Market Intelligence in India

time for effective decision making. Appropriate forecast models were developed to capture the price trends of selected commodities. Most widely used technique for the analysis of time-series data is the Box Jenkins' Autoregressive Integrated Moving Average (ARIMA) methodology, as these models are found to be more flexible in handling different patterns of time series data. ARIMA models place greater emphasis on the recent past rather than the distant past. In extremely volatile commodities like onion, potato and few other; ARIMA family could not provide robust solutions. Thus, the framework relied on the models belonging to Autoregressive Conditional Heteroscedasticity (ARCH)/Generalized Autoregressive Conditional Heteroskedasticity (GARCH) family. These models assume non-linearity in mean and also non-linearity in variance. The most promising parametric nonlinear time series models are ARCH and GARCH models. The exponential GARCH or EGARCH model was first developed by Nelson (1991). Forecasts of a GARCH model can be obtained using methods similar to those of an ARMA model. GARCH models are mean reverting and conditionally heteroscedastic, but have a constant unconditional variance. It was observed that prices of horticultural commodities, especially, that of vegetables were the most volatile. ARIMA, SARIMA, GARCH, VAR, E-GARCH and ARCH-GARCH models are mostly used for forecasting of major horticultural crops in India. Hybrid models, artificial neural network, autoregressive neural network and space-time auto-regressive moving average (STARMA) model are recently in trend due to its higher forecasting efficiency.

Recent Developments in Modelling Approach

The forecasting of crop yield and agricultural prices, incidence of disease and pests in agricultural field, along with predicting meteorological variables such as rainfall and air temperature has evolved through the application of machine learning methods (Ganapathy et al. 2022; Haq 2022; Paul et al., 2022; Paul et al. 2023a; Satpathi et al. 2023). Traditional econometric methods such as the vector autoregressive model (VAR), the generalized autoregressive conditional heteroskedasticity model (GARCH), and the autoregressive integrated moving average model (ARIMA) were found to adhere to strong linear assumptions, limiting their effectiveness in predicting the non-linear characteristics of prices of agricultural commodities. In response to the non-linear and volatile nature of agri-commodities, machine learning methods have been continuously optimized, leveraging the computational power to capture non-linear information.

Several studies in recent years have focused on the application of machine learning models for forecasting agricultural commodities and crude oil prices. Xiong *et al*. (2018) introduced a novel hybrid approach that combines seasonal-trend decomposition procedures based on loess (STL) and extreme learning machines (ELMs) for short-, medium-, and long-term forecasting of seasonal vegetable prices. Xu and Zhang (2022) addressed forecasting issues in datasets spanning fifty years for soybean and soybean oil, employing nonlinear autoregressive neural network (NARNN) and NARNN with exogenous inputs (NARNN–X). Guo *et al.* (2023) used machine learning to process historical information, volatility and non-linear features, observing the forecasting effects of recurrent neural networks (RNN), support vector machines (SVM) and multilayer perceptron (MLP), long short-term memory (LSTM), gated recurrent unit (GRU), convolutional neural network (CNN) and back propagation (BP) models on China crude oil futures. Furthermore, Mati *et al.* (2023) made a significant contribution by employing an evidential neural network based on Gaussian random fuzzy numbers (GRFNs) to predict crude oil prices. Evidential neural networks are a recently developed machine learning technique that has shown promising results in various fields, including finance, engineering, and environmental studies. The capacity of artificial intelligence (AI) to analyze market patterns and historical pricing data allows for the forecast of agricultural commodity future prices, supporting farmers and stakeholders in making educated choices (Paul and Garai 2021, 2022; Paul et al. 2022, 2023a; Yeasin and Paul 2023). This analytical capability extends to the global market, allowing exporters to anticipate commodity price variations and make strategic choices based on market insights (Singla *et al.*, 2021; Paul *et al.,* 2023b).

Way Forward

Effective price forecasting relies not only on the strength of the models employed but also on the precision of the underlying data. The intricacies involved in this process become apparent when considering the various factors that influence the accuracy of price predictions.

One recurrent challenge stems from the existence of disparities in data obtained from diverse sources. This arises due to the inherent variability in data collection and reporting methodologies across different platforms. To address these discrepancies, it becomes imperative to synchronize the data compilation and dissemination efforts among relevant organizations. Achieving harmonization in these processes is crucial for ensuring a cohesive and reliable dataset.

Beyond the idiosyncrasies of data sources, the multifaceted nature of price determination involves a multitude of external elements, including climatic conditions and policy variables. Integrating these critical factors into forecasting models is paramount for simulating real-world scenarios and enhancing the effectiveness of market intelligence efforts. The modelling framework must extend its reach to encapsulate the influences of climate aberrations, such as rainfall and temperature. Obtaining real-time data on these dimensions remains a challenge.

Moreover, a comprehensive understanding of market dynamics necessitates focused regional and commodity studies. These studies serve the dual purpose of shedding light on updated market conditions and providing valuable insights for policymakers. In this context, having accurate, up-to-date information becomes pivotal for policymakers to make informed decisions and implement preventive or corrective actions when required. Thus, a nuanced approach to data integration and analysis, coupled with targeted studies, emerges as the cornerstone for refining price forecasting precision in the ever-evolving landscape of economic variables.

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Revolutionizing Agricultural Markets and Trade for Commercial Crops: Exploring the Potential and Impact of Blockchain Technology

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Agriculture supply and value chains are undergoing significant structural transformations in the modern era of the Internet of Things (IoT) and globalization. In response to the challenges encountered in the agri-food system due to the global transition, Distributed Ledger Technology (DLT), commonly known as "Blockchain Technology," has emerged to revolutionize the agricultural markets and trade. Blockchain Technology (BCT) provides a secure digital database for recording agri-business transactions, minimizing uncertainty in trade, expediting transactions from one stakeholder to another, reducing transaction costs at each stage of the value chain, and offering accessibility to all stakeholders in the network.

Agricultural commodities, in general, 'commercial crops' in particular, are characterized by a complex network of value chains with less transparency from plough to plate (having enormous scope for domestic marketing and international trade), adversely affecting the chain actors, especially the producers, processors, and consumers. Strengthening the relationships between input supply firms, farmers, markets, traders, and consumers is crucial to maintaining transparency, promoting economic growth and development, and generating employment. Blockchain has the potential to integrate commercial crop value chains, ensure market system transparency, enhance market player efficiency, improve food safety and quality control, increase legal certainty for land ownership, and simplify agricultural finance measures. This allows agribusiness firms to leverage DLT applications, making the value chains more traceable and transparent. The BCT is of significant importance for commercial crop value chains, and through its application, the existing drawbacks in the value chains, like product traceability, security of product information, and trust building across value chain actors, including the customers for a superior quality product, are addressed.

Blockchain Technology: *Modus Operandi*

The BCT is a modern, cutting-edge technological innovation that increasingly favors networking and utilizes a peer-to-peer validation network to achieve a comprehensive, transparent, and optimized business network. It establishes a fully decentralized system for recording and authenticating all business transactions, ensuring accessibility for all value chain actors. From a core perspective, BCT serves as a decentralized digital transaction ledger maintained by a network of computer applications, eliminating the need for third-party involvement. Each transaction in the value chain, referred to as a "block," is documented within a software platform, enabling data transmission from one stage to another, processing, storage, modification, and, finally, access by all actors involved in the value chain. Every 'block' contains the recorded transactions along the value chain, including a timestamped header and a link to the previous block. Additionally, each block possesses a hash pointing to its successive block's header, allowing value chain actors (stakeholders) to verify data integrity across each block. The BCT is considered a revolutionary technology in agri-business owing to its multiple benefits. The potential applications of BCT are vast in the agricultural sector, particularly in commercial crops with immense trade potential. In the case of commercial crops, the BCT simplifies and integrates the value chain activities. It generates more reliable and secure market information and paves the way for enhanced market access through traceability, trust building, and consumer satisfaction.

The BCT facilitates secure and transparent end-to-end transactions between the chain actors, ensuring that agri-business transactions are conducted without market intermediaries, such as banks or other middlemen. Besides agriculture, BCT has witnessed significant success across various sectors and organizations, attributing its achievements to its fault tolerance and problem-solving capabilities, which establish trust among key actors in the value chain. The agricultural value chain, being critical and prioritizing areas for a specific commodity group like the 'commercial crops' that have more potential for international trade, confronts several challenges in upholding the food safety and quality standards within the agri-food system. Blockchain is a dependable means of tracing all transactions among the chain actors, mitigating malfunctions, and fostering transparency in the value chain. It enables the recording of every step in the product's value chain, for instance, from tobacco production (including the input supply) to final consumption, offering substantial value in fortifying the 'commercial crop' sector against potential threats and enhancing its intelligence in the era of the IoT and globalization. Precisely, at each stage of product movement, diverse information is encrypted in the blocks using various technologies, hence the name 'Blockchain Technology.' The five features of BCT are decentralization, immutability, peer verification, cryptography, transparency, and anonymity.

Blockchain Technology: Advantages for the Commercial Crop Sector

The utilization of BCT in agricultural marketing and trade of commercial crops yields various positive outcomes and is briefly described below.

- ***Building trust and transparency in marketing and trade*:** BCT ensures transparent marketing and trade of commercial crops, enabling stakeholders to operate in a secure and integrated system. The transparency provided by BCT supports immutability, security, and the establishment of trust within the value chain.
- ***Direct trade with less or no intermediaries*:** Agricultural marketing and trade heavily rely on intermediaries, and traditionally, agribusinesses attracted customers through information intermediaries. In the case of BCT, it bypasses intermediaries, fostering stronger relationships among core value chain actors. Disintermediation involves eliminating intermediaries, resulting in enhanced efficiency, reduced transaction costs, and stronger relationships between customers and products like premium tobacco.
- ***Smart contract combats fraudulent activities*:** BCT establishes a 'smart contract' through a transparent and trustworthy digital platform to mitigate the risks. A collaborative platform is operated in an integrated, immutable, and credible environment, allowing customers to trace products and obtain reliable data.
- ***Protecting data privacy and security*:** BCT addresses the customers' concerns about the confidentiality of their transactions and the misuse of personal information. The blockchain platform employs "privacy-by-design" technology (decentralized and cryptographic), encrypting stakeholder credentials for safe and secure transactions. Once encrypted, tampering and altering the data is complex, thereby ensuring data integrity.
- ***Improving product traceability along the value chain*:** BCT ensures a secure and decentralized method for business transactions in commercial crop value chains, connecting all core actors from production to consumption. This unique mechanism enhances the traceability of the products in the commercial crops value chain.
- ***Streamlining market access and compliance*:** BCT provides a standardized and transparent platform to meet commercial crop value chains' regulatory requirements and quality standards, facilitating better market access and trade compliance. Since BCT offers details of all operations along the value chain and more accurate market information, it empowers stakeholders to make informed marketing decisions.

Blockchain Technology: Issues and Challenges for the Commercial Crops Sector

Despite significant opportunities for the commercial crops sector, its adoption may encounter various issues and challenges, which are briefed below.

- ***Challenges in adoption*:** BCT has to be adopted on a wide scale across the commercial crops value chain. If only a few actors participate due to cost, technical barriers, and resistance to change, the benefits are restricted.

- ***Digital gap***: The Indian agricultural sector comprises largely small and marginal landholders (~85%) with a considerable knowledge gap regarding high-end technologies. Hence, efforts are needed to train and enroll producers to take advantage of the BCT.

- ***Governance***: Increased automation may reduce human intervention across the value chain, turning blockchain into a deskilling technology and causing the loss of skilled jobs. In addition, with an increased volume of data, the network may experience delays and increased costs, which may have implications for real-time value chain operations.

- ***Uncertainty in regulation***: The regulatory environment can be uncertain in commercial crops like tobacco, as navigating regulatory frameworks may pose challenges if the guidelines for trade (export and import) via BCT are still under development.

- ***Technical challenges***: The BCT records all business transactions in a common ledger accessible to all stakeholders in the value chain network. However, ensuring the stakeholders' privacy, especially in competitive mode, can be a significant operational and technical challenge. Though several blockchains have been tested on a limited scale in a controlled environment, the concern arises when value chain actors accidentally lose private keys, rendering them unable to manage their accounts. Also, in the case of a public blockchain, sensitive data may be visible to all stakeholders, which warrants careful consideration of their privacy.

Conclusion and Way Forward

Enhancing market efficiency and establishing a trusted, transparent environment for a sustainable distribution network integrating all key commercial crop value chain actors requires technological innovation and intervention. Blockchain technology is touted to be a promising innovation in scaling up the business by revolutionizing the existing practices in agricultural marketing and trade. Despite BCT's promise of many benefits, its adoption faces numerous barriers and challenges. Developing policies that promote the growth and integration of blockchain techniques in the commercial crops value chain is imperative, ensuring sustainability and promoting competitiveness among the chain actors. However, certain limitations related to governance, regulation, data privacy, technical challenges, and stakeholder relationships warrant attention. Increased investment in research and education is necessary to address the existing challenges and highlight the technology's potential benefits. Future research efforts should focus on developing a comprehensive legislative framework to position blockchain as an innovative and cutting-edge technology for sustainable and smart agricultural development.

Exploration of Nanotechnology in Agro ecosystems and Rapid Sensor Development

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The United Nations Food and Agriculture Organization (FAO) have predicted that the world population will approach 10 billion by 2050. As a result, various government agencies and organizations are calling for more innovations to address the food-energy-water (FEW) nexus. Nanotechnology innovations showing the promising results in protecting the agro-ecosystem, scope for precision farming and sustainable agricultural productivity. In this direction, some recently developed nanomaterials based products like nanofertilizers, abiotic stress tolerance, plants diseases combating potentials, nanopesticides, nanoherbicides, photocatalytics and nanobiosensors, etc are already been commercialized to meet the environmental safety and food security challenges. But, there is a huge demand for many inventions in view of future agro-ecosystem challenges. The nanoparticles viz., having size 1–100 nanometre (nm) in any dimension showing a greater surface area to volume ratio, quantum size effects, tunable physical, chemical and biological properties are hence responsible for its wide variety of applications. Various nanostructured materials like inorganic, carbon-based, organic, biological and nanocomposites can be synthesized using via top-down or bottom – up approach methods in the tunable dimensions [i.e., 0D (nanoparticles & quantum dots), 1D (nanorods, nanofibers, nanopillars & nanowires), 2D (nanosheets, nanoplates, nanopores) & 3D nanomaterials (nanocomposites and complex hierarchical structures)] to exploit the specific applications. It is reported that, polymer, carbon nanotubes (CNTs), metals and metal oxides nanomaterials (Au, SiO_2, ZnO, CeO_2 and TiO_2) can contribute in enhancing the plants needed elements up-taking, nutrients amelioration, environmental contaminants absorption and increasing soil remediation capacity, etc in farming. However, the real impact of nanomaterials on plants depends on their composition, concentration, size, surface charge, and physical chemical properties, besides the susceptibility of the plant species. Nanoparticles in plant uptake and translocation may takes place through foliar application or root exposure treatment. Nanoparticles are typically sprayed onto the leaf surface are subsequently absorbed by plants through either the cuticle or stomata(generally size of 10–100 ìm) on leaf surface then transported to different parts of the plant via the phloem. The plant root surface has negative charges; making nanoparticles with positive charges are more likely to accumulate in the root and be easily to be absorbed on the root surface. Several other transport methods are still under research and development. Recently, in June 2021, Indian Farmers Fertiliser Cooperative Limited (IFFCO) launched the world's first nano urea (NU, about 20-50 nm particle size), fertilizer, while nano DAP in April 2023. It claims that instead of using a regular 45 kg bag of urea (45 kg urea or 20.7 kg of nitrogen), farmers can now use a 500 ml bottle with 4% nano urea (43 g urea or 20 g of nitrogen) and expect higher yields. This NU initiation expected to save fertilizer fund upto "Rs 15,000-20,000 crore annually. IFFCO Nano DAP (Liquid, less than 100 nm) enter easily inside the plant system leads to higher seed vigor, more chlorophyll, photosynthetic efficiency, better quality and increase in crop yields without harming the environment or releasing green house gases.

The nanomaterial based sensors have unique surface chemistry, distinct thermal, electrical and optical properties useful to design the user friendly device with enhance sensitivities, improve detection limits, and can be used in multiplexed systems. In agro food sector, during 2022–23, India exported close to $4 billion worth of spices registering an increase of 4.74 % compared to 2021–22. Fruits and Vegetables exports increase by 18.94%, Oil Seeds by 32.83%, Oil Meals by 34.24%, Rice by 5.38% in July 2023 over July 2022. Safety and quality are key issues for the food industry and should follow the government notified regulatory standards. Consequently, there is growing demand in agro-food sector for detecting harmful contaminants, allergens, adulterations, pathogens, smart and intelligent packaging to protect the consumers health. Recently, agro farming, food and environmental sectors are utilizing the android/ digital technologies for onsite detection and sharing the data. In the next evolutionary step, the rapid nanosensor networks will be the decision support systems in ensuring global agro-food security.

Agriculture for Smallholder Farmers is a product of the UNDP Global Centre for Technology, Innovation and Sustainable Development; Singapore recognized that Agric-food systems are at the heart of the 2030 agenda and impacting all the other 17 sustainable global development goals. This UNDP's Strategic Plan 2022-25 envisages that the digitalization data is essential for precision agriculture for maximizing the development impact. Advances in digital technologies like mobile phones, satellites sensing, Drone Technology, Internet of Things (IoT), artificial intelligence (AI), and cloud computing applications will be accessible for smallholder farmers in the developing countries. Indeed, considerable progresses in the nanofabrication techniques and novel functional materials giving the hope for viable sensor systems. Introduction of biological probes (enzyme, antibodies, aptamers, peptides), or nanocomposites are often used to optimize the signal transduction with a remarkable selectivity and sensitivity. Recently, the demand for 3D Printed Biosensors in the food & beverage, agricultural, medical and healthcare sectors is highly progressing. According to the report published by Virtue market research, the global 3D Printed Biosensors market was valued at USD 4.67 Billion and is projected to reach a market size of USD 9.39 Billion by the end of 2030. Similarly, the flexible / paper printed sensor techniques are growing, and are considered as an environmentally-friendly approach.

Besides the nanoparicle's advantage the toxic nature of these materials is also a big debate issue. Metaloxide nanoparticles may also have some disadvantages, in particular the possibility of releasing metal ions into the environment, which affects their cytotoxicity. Nanoparticle toxicity is also influenced by its solubility. Some soluble compounds of nickel have been identified as carcinogens. Therefore, a good understanding of the biological activities and toxicity of nanoparticles must be put into consideration while using nanotechnology in the food industry and associated industries. Green methods for synthesizing nanoparticles with plant extracts are advantageous as it is simple, eco-friendly and require less reaction time. Surface coating, surface chemistry modifications by altering charge density and hydrophobicity, methods that modify their structure, can be used to reduce the potential toxicity of metal-based NPs.

The multidisciplinary nature of nanotechnology and its rapidly increasing scope for development of commercially viable applications pose a huge challenge to regulatory bodies across the globe. Research initiative by the Government of India through DBT, DST, ICAR etc along with other institutes collaborations has laid a strong foundation to accelerate the novel nano-based agriculture and agro-food sector sensors innovations not only for commercialization but also to enhance the environmental and human safety.

Necessity of ISO Standards on Tobacco : An Overview

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Bureau of Indian Standards

Standards contribute in making the development, manufacturing, supply and trade of products and services efficient and safe. They provide government with a technical base for health, safety and environmental legislations.

Today when the world has become a global market place, there is increasing demand to prevent needless duplication, or even multiple tests and inspections in order to achieve a situation where the principle "tested once, recognized all over the world" apply. In the context of International trade, global standards play a very important and crucial role. In this world of standards, Bureau of Indian Standards (BIS), the National Standards body of India shoulders the enviable responsibility of safeguarding India's technological interests at international level, through its active participation in International Organization for Standardization (ISO). A sizeable number of Indian Standards have been harmonized with ISO standards to facilitate acceptance of Indian products in the international market.

Tobacco is one of the most economically significant agricultural crops in the world. India is one of the leading exporters of tobacco and occupies second place after Brazil. FCV, Bidi, Hookah, Chewing, Cigar-wrapper, Cheroot, Burley, Oriental, etc. are the different types of tobacco grown in the country. India enjoys an edge over the leading tobacco producing countries in terms of low production cost, average farm and export prices. Standards play an important role in positioning India high in international trade.

Tobacco product regulation is a rapidly emerging area in tobacco control. Scientists, policy makers, and international public health organizations have called for comprehensive regulation of tobacco products with the aim of protecting public health. Many countries have already adopted legislation requiring reporting and testing of tobacco product contents and emissions. In this scenario, the standard testing methods address the quantification of analytes and allow for the comparison of their levels under standardized test conditions.

ISO is a recognized international standardization organization which comprises of national standards bodies as members. In the development of standards at International level, the interests of various countries are represented through their National Standards bodies. Developing ISO standards is a consensus-based approach and comments from all stakeholders are taken into account.

The ISO technical committee on Tobacco and Tobacco Products, ISO/TC 126 formulates international standards on Tobacco and Tobacco products has the following scope:

"Standardization of terminology and test methods for unmanufactured tobacco, all types of tobacco products, materials used for manufacturing tobacco products and tobacco smoke including environmental tobacco smoke aspects; specifications and questions of handling, storage, packaging and transport are included as appropriate.

At the present time, ISO/ TC 126 has developed 97 international standards (including revisions) relating to the testing of tobacco and tobacco products. CORESTA (Cooperation Centre for Scientific Research Relative to Tobacco), European Commission (EC), United Nations Economic Commission for Europe (UNECE), World Health Organization (WHO) are some of the many international bodies that work in liaison with ISO/ TC 126.

BIS represents India in ISO/ TC 126 as 'Participating member' and has been protecting the interests of Indian Stakeholders at international level in development of international standards.

Tobacco and Tobacco Products Sectional Committee, FAD 4 of BIS is the National Mirror Committee for ISO/TC 126. BIS through its team of experts from FAD 4, participates in the process of development of international standards in ISO. This ensures that Indian viewpoints and concerns get appropriately addressed while international standards are being developed. This makes adoption of standards better in the Indian context. As on date, 30 ISO standards under ISO/ TC 126 are identically adopted as Indian Standards. Some of the important ISO standards in tobacco sector, adopted as Indian standards are as follows:

Historically, ISO standards have been developed to specify the requirements of analytical cigarette smoking machines and their use for the quantitative determination of a number of cigarette smoke constituents [such as total particulate matter, nicotine-free dry particulate matter, water, nicotine or benzo[a]pyrene] with a unique standard smoking regime. Later, requirements to provide smoke constituents data with an intense smoking regime, originated from different countries and the Conferences of the Parties to the Framework Convention on Tobacco Control, resulting in a need to specify the conditions for the use of the intense smoking regime on analytical cigarette-smoking machines. Standardized procedures have been developed for the reproducible generation of cigarette-smoke samples and the representative collection of constituents of cigarette smoke. Cigarette-smoking machines deliver a reproducible puff of defined volume and peak shape. However, because of the range of human smoking behaviour, no regime can be considered representative of human smoking. Machine smoking testing, still remains useful to characterize cigarette emissions for design and regulatory purposes and the smoke emission data from machine measurements may be used as inputs for product hazard assessment.
Development of International standards on "Test method for Smokeless Tobacco" is one important area where a lot work needs to be done and where India's participation is vital. In this context. a working group WG 24 'Nicotine Pouches' has recently been constituted under ISO/ TC 126 for development of international standards on the following new areas where India is a member:

- ISO/AWI 21109, Nicotine pouches — Test method for pH
- ISO/AWI 21114, Nicotine pouches — Test method for nicotine content

As a member of the International committee, India (BIS) can also propose new subjects for development of International standards and contribute towards the international standard setting process. This will not only ensure development of international standards on subjects relevant to us but will also provide an excellent opportunity to lead the development of international standards in this sector.

IS 12942:2018 / ISO 8243: 2013	Cigarettes — Sampling (Third Revision)
IS 16023: 2021/ISO 4387 : 2019	Cigarettes —Determination of total and nicotine-free dry particulate matter using a routine analytical smoking machine
IS 16024:2013/ISO 8454: 2007	Cigarettes — Determination of carbon monoxide in the vapour phase of cigarette smoke — NDIR method
IS 16025:2022/ISO 10315 : 2021	Cigarettes — Determination of nicotine in total particulate matter from the mainstream smoke Gas-chromatographic method
IS 16121:2013/ISO 3402 : 1999	Tobacco and tobacco products — Atmosphere for conditioning and testing
IS 16308:2022/ISO 16632: 2021	Tobacco and tobacco products determination of water content gas-chromatographic method
IS 17778:2022/ISO 17175: 2017	Bidis — Determination of total and nicotine-free dry particulate matter using a linear routine analytical smoking machine

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Dr. M. Kumerasan
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Sri T. Ramesh

Session-1: ***Genetics and genomic strategies for enhancing commercial value(which includes Poster Session & panel discussion on that day)***

Dr. K. Sarala
Dr. K. Gangadhara Rao
Dr. C. Nanda
Dr. Partha Saha

Session-2: ***New Vistas in Crop Management for resilient commercial agriculture (which includes Poster Session & panel discussion on that day)***

Dr. K. Rajasekhara Rao
Dr. S. Ramakrishnan
Dr. S.K. Dam
Mrs. B. Sailaja Jayasekharan

Session-3***: New perspectives in post-harvest technology and value addition(which includes Poster Session & panel discussion on that day)***

Dr. J.Poorna Bindu
Dr. Anindita Pal
Smt. B. Krishnakumari
Sri N. Johnson

Session-4: ***Next generation technologies for information dissemination and digital agriculture.(which includes Poster Session & panel discussion on that day)***

Dr. Y. Subbaiah
Dr. K. Suman Kalyani
Dr. B. Hema

Session-5: ***Innovative market interventions for commercial agriculture(which includes Poster Session & panel discussion on that day)***

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Dr. P.Manivel
Dr. JJ Rajappa
Mrs. J. Vasanthi

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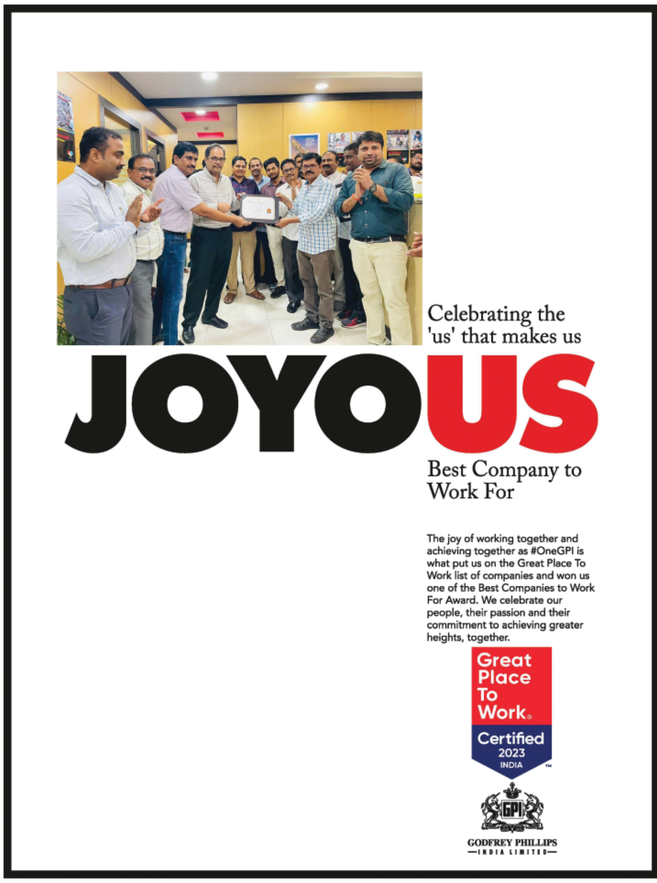
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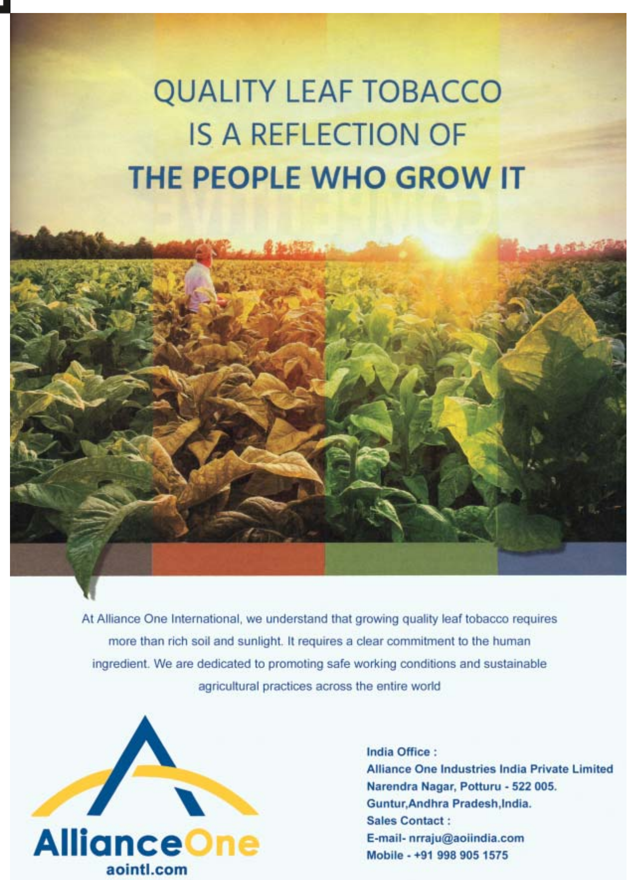
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పోషక్ బ్రాండ్
✦ పొటాషియం సల్ఫేట్
భూమిలో చల్లుటకు, డ్రిప్ ద్వారా ఇవ్వటానికి, ఆకులపై స్ప్రే చేయుటకు లభ్యమగును. ✦ పోషక్ పూర్తిగా సల్ఫేట్ రూపంలో ఉన్న ఎరువు ✦ పొటాష్ కిరణజన్య క్రియకు, నత్రజని ఉపయోగించుటకు, పంట నాణ్యత, రంగు, రుచికి అత్యంత అవశ్యకమైన ప్రధాన పోషకం. ✦ గంధకం ప్రోటీన్ల తయారికి, మొక్క సమగ్ర ఎదుగుదలకు, రోగ నిరోధక శక్తికి తోడ్పడును. ✦ అన్ని ఉద్యాన వన పంటలకు మరియు ద్రాక్ష, పొగాకు పంటలకు అత్యవసరమైన ఎరువు.
వర్ధన్ బ్రాండ్
✦ పొటాషియం షియోనైట్
భూమిలో చల్లుటకు, డ్రిప్ ద్వారా ఇవ్వటానికి, ఆకులపై స్ప్రే చేయుటకు లభ్యమగును. ✦ వర్ధన్ - పొటాష్, గంధకం, మెగ్నీషియం కలిగివున్న ఎరువు ✦ పొటాష్ గంధకంతో వున్నప్పుడు ఎక్కువ పత్రహరితం జరగటానికి తోడ్పడుతుంది. ✦ గంధకంతో కలిసియున్న పొటాష్ వల్ల పండ్ల నిల్వ, రుచి పెరిగి ఆమ్ల గుణం తగ్గుతుంది. ✦ మెగ్నీషియం వుండడం వల్ల క్లోరోఫిల్ ఎక్కువ లభ్యమగును. ✦ మొక్కలు ఏపుగా పెరుగుటకు, ఆకుల నాణ్యతకు తోడ్పడును. ✦ అన్ని ఉద్యానవన పంటలకు, ముఖ్యంగా నూనె గింజల పంటలైన ఆయిల్‌ఫామ్ వేరుశనగ, మొక్కజొన్న మొదలగు పంటలకు అత్యంత అవశ్యకం.
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