Souvenir

for

4th National Conference

Supported by NABARD

Society of Krishi Vigyan, Forum of KVK & AICRP

Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur, MP

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Souvenir

for

4th National Conference

AGRICULTURE IN 2050

Technology Development and Dissemination

March 01-03, 2024

Supported by NABARD

Organized by

Society of Krishi Vigyan, Forum of KVK & AICRP
Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur, MP

SOUVENIR FOR 4th NATIONAL CONFERENCE

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Message

The 4th SKV National Conference 2024 on Agriculture in 2050: Technology Development is being jointly organized by the Society of Krishi Vigyan, Amritsar, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Forum of KVK & AICRP, Jorhat Assam, National Bank for Agriculture and Rural Development (NABARD) and Indian Farmers Fertilizer Cooperative Limited (IFFCO), New Delhi in Collaboration with Vivek Krishi Kendra, Jabalpur, UCO Bank, Bhoodhan Agriventures Pvt. Ltd, Chandok Machinery Agro Division and Om Shanti Jeevan Jyoti Education Society. The conference will be hosted from 01 to 03 March 2024 at JNKVV Jabalpur.

I extend my warm greetings and felicitations to the organizing committee members and delegates of the conference. The success of this conference will be the result of meaningful teamwork, with an eye toward more productive future collaboration for the good of our agriculture.

It gives me immense pleasure to welcome Agricultural scientists from all over India who will present their research work in the conference and the subject experts who will deliberate on the issues of national importance which are being confronted by the farming fraternity and agriculturists.

It would be beneficial to the whole community and the nation as a whole if fruitful recommendations are forwarded to the policy makers which may be incorporated in the future developmental programmes.

My best wishes for all success of the event

(Pramod Kumar Mishra)

नानाजी देशमुख पशु चिकित्सा विज्ञान विश्वविद्यालय

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Message

I am happy to learn that a three days National Conference on "**Agriculture in 2050**: **Technology Development and Dissemination**" is being jointly organized by the Society of Krishi Vigyan Kendra, Amritsar, Punjab and Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 1st to 3rd March 2024. The theme chosen for the conference is of topical interest like Farm production; from sustenance to sustainability, Crop protection; towards ecological succession, Farm economics; from microto micro to macro economy, Technology transmission challenges and Nano fertilizers, AI and biotechnology in agriculture, aspects will certainly stimulate in effective decision-making process.

The Souvenir of invited papers and conference proceedings of 3 days national conference is meticulously brought out document. I congratulate the organizers for providing a platform for this interaction through this conference.

I have no doubt that the suggestions made by the speakers will be well taken and implemented by the concerned authorities.

I wish the Conference a great success.

Dated: 29th February, 2024

(Vice-Chancellor)

भाकृअनुप-कृषि प्रौद्योगिकी अनुप्रयोग अनुसंधान संस्थान, क्षेत्र-9
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Message

The agricultural sector is changing drastically. Its transition must be in line with sustainability in all its forms, including social, economic, and environmental sustainability. Agricultural systems that are currently gaining a lot of attention is Vision of Agriculture in 2050. The quick decline in soil fertility due the overuse of chemical fertilizers and pesticides poses presents a serious risk to long-term food security. Deeply ingrained in Indian custom, the chemical-free agricultural technique has been enhanced by contemporary knowledge of ecology, resource recycling, and on-farm resource efficiency. Functional biodiversity is integrated with crops, trees, and livestock. On-farm biomass recycling, mulching, and the use of cow dung-urine formulations are prioritized, while synthetic chemical inputs are avoided.

It is a matter of great pleasure that National Conference on "Agriculture in 2050: Technology Development and Dissemination" is being organized at JNKVV, Jabalpur from 1-3 March 2024.

Besides the oral and poster presentations from delegates and an important panel discussion will be highly useful for future policy formulations to promote technology development and dissemination process among the farmers and all other stakeholders.

I extend my best wishes for successful organization of this National Conference and publication of Souvenir for the same.

Dated: 28/02/2024
Place: Jabalpur

(S. R. K. Singh)

डॉ. दिनकर प्रसाद शर्मा
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Message

The Souvenir of invited papers and conference proceedings of the three days national conference on "Agriculture in 2050: Technology Development and Dissemination" jointly organized by the Society of Krishi Vigyan Kendra, Amritsar, Punjab and Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 1st to 3rd March 2024 is meticulously brought out document.

The conference themes chosen like Farm production; from sustenance to sustainability, Crop protection; towards ecological succession, Farm economics; from micro to micro to macro economy, Technology transmission challenges and Nano fertilizers, AI and biotechnology in agriculture, aspects will certainly stimulate in effective decision-making process.

The crispy content on varied sub sectors of agriculture may help in sketching a pathway towards achieving targets set for Vikshit Bharat 2047.

Date: 29/02/2024

(Director Extension Services)

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TECHNICAL SESSION PROCEEDINGS
of
4th SKV NATIONAL CONFERENCE 2024
AGRICULTURE IN 2050: TECHNOLOGY DEVELOPMENT AND DISSEMINATION

Technical Session I: Farm production; from sustenance to sustainability

Chair : Dr. S.R.K. Singh, Director, ICAR-ATARI, Zone-IX, Jabalpur
Co-Chair : Dr. Manoj Sharma, President, Forum of KVK & AICRP
Co-Chair : Dr. Sunil Nayak, DES, NDVSU, Jabalpur,
Convener : Dr. Harish M.N., Scientist, ICAR-ATARI, Zone-IX, Jabalpur
Rapporteur : Dr. S.K.Pandey, Senior Scientist & Head, KVK Anuppur, Dr. R.L.Raut, Senior Scientist, KVK Balaghat and Dr. Uttam Kumar Tripathi, SMS, KVK Ganeeva, Chitrakoot

The technical session-I held in Kautiliya hall, IABM, JNKVV, Jabalpur dated on 01.03.2024 in the chairmanship of Dr. S.R.K. Singh, Director ICAR-ATARI, Zone-IX, Jabalpur. Three lead papers presented during the session. First lead paper was presented by Dr. Tarunendra Singh from IFFCO. He presented on nano fertilizers for better soil health of eco-friendly agriculture. In his lecture, he very nicely presented fertilizer demand, supply and the supply gap and international scenario of fertilizers. He included how nano fertilizers works and details about uses and results to the forum. He discussed challenges of future agriculture and fertilizers. He presented scientific background of nano fertilizers their absorption through stomata and result on crop in farmers' field. It was very nice presentation for researchers, academicians as well as farmers.

Second lead speaker of the session was Dr. K.B. Singh, Director PAMETI, PAU Campus, Ludhiana who delivered his lecture on natural resource conservation. He discussed all aspects of natural resource management, various practices, their effect and adoption among farmers. He very precisely presented different water conservation practices, drought mitigation, varietal improvement, crop and variety selection, etc. for water conservation. He also presented soil conservation practices with higher production of crops. He also elaborated various harmful effects of various farm practices on soil, human & environmental health.

Third lead paper was presented by Dr. S.R.K. Singh, Director, ATARI, Zone IX, ICAR, Jabalpur. He very nicely presented the present scenario of KVK, their working and importance of KVK's in Indian agriculture. He discussed various land marks of KVK's in dissemination of modern technologies to the farmers, in the present scenario and vision for 2050. He also presented various flagship programmes of GoI implemented by KVKs like NICRA, ARYA, Farmers First, VATIKA, Nutri Smart Village and other programmes, their implementation and success stories.

In the above technical session, ten papers out of 47 listed, were presented by the delegates during the session. Dr. A.K. Singh presented his study on Impact of microbial inoculants on in-situ and ex-situ wheat residue decomposition. He mentioned that the residue completely decomposed in 52 days after use of microbial inoculants over traditional decomposition practices (95 days) with greater organic carbon and NPK contents under ex-situ decomposition. The results of the in-situ decomposition of wheat residue using microbial inoculants and residue burnt (RB) fields showed that the organic carbon, available N, P, and K status decreased by 11.48, 27, 13.62, and 16.55 percent in the soil of RB fields, respectively. Dr. H.S. Garud presented his research paper on Role of cluster frontline demonstration in enhancing production and productivity of chickpea. He very nicely presented farmer's field data on yield and yield attributing parameter of economic gain to the farmers in terms of Gross, Net return and B:C ratio. Dr. Somya Patel presented her research on greengram titled 'Assessing morphological diversity in Green gram varieties - ADUS descriptor approach'. She presented

various phenotypic character of comp which governs yield and quality of green pea and helpful on identification of varieties. Dr. K.S. Yadav presented his research paper on 'Organic based impact assessment on yield and socio-economic analysis of Okra'. He presented very nicely on effect of organic farming ingredients on yield of okra and elaborated various socio-economic factors of farmers. Dr. P. P. Shalke presented their study on 'Impact of KVK interventions on doubling the farmers income'. He presented various activities initiated by KVK on adopted villages and their role in increasing farmers income in manifold. Dr. T.R. Shahoo presented his research paper on 'Cultivation of broccoli as a substitute crop for sustainability and economic stability'. He presented yield potential of broccoli in farmer's field and various yield parameters with analysis of economic traits. Dr. Tejindar Kaur presented her study on 'Effect of different cropping system on soil hydraulic properties in north-western India'. She presented effect of different cropping systems on various soil parameters like infiltration, hydraulic conductivity, water retention and available water capacity of soil. Dr. Bijeta presented her research on garlic titled 'Effect of biofertilizer and NPK on the growth and yield of garlic in Chamoli district of Uttarakhand'. She presented various treatment combination of biofertilizers with varying NPK dose on growth and yield attributing traits of garlic. Dr. G.M Vinay presented his research on 'Introduction of Yard Long bean (Arka Mangala) variety and double the farmers income'. He presented the analyzed data of yard long bean performance, gross return, net return and B:C ratio for the economic impact on farmers income. Dr. Uma Barmaiya very nicely presented her research titled 'Impact of integrated, nutrient management for enhancing the nutrition and productivity of sesame'. She presented the observation of various NPK doses on yield and yield attributing characters of sesame.

At the end of session, the Chairperson & Co-Chairman of the session remarked that all presenters have nicely and precisely presented their studies under 'Farm production; from sustenance to sustainability'. Offered thanks to all participants and other who's present in the session.

Technical Session-II: Crop Protection towards ecological succession

Chair : Dr. (Smt.) Om Gupta, Former DES, JNKVV, Jabalpur
Co-Chair : Dr. Jayant Bhatt, Professor & Head, Plant Pathology, CoA, JNKVV, Jabalpur
Convener : Dr. Sanjay Singh, Scientist (Plant Breeding & Genetics), CoA, JNKVV, Jabalpur
Rapporteurs : Dr. Ashutosh Sharma, Scientist, KVK Narsinghpur, Dr. S.K. Singh, Scientist, KVK Tikamgarh

The technical session 2nd started in Kautiliya hall, IABM, JNKVV, Jabalpur dated on 02.03.2024 in the chairmanship of Dr. (Smt.) Om Gupta, Former DES, JNKVV, Jabalpur. Four lead papers presented during the session. First paper was presented by Dr. (Smt.) Om Gupta, Former, DES, JNKVV, Jabalpur, where as 2nd, 3rd and 4th paper was presented by Dr. Jasbir Kaur, Professor of Ocular Biochemistry, Dr. Rajendra Prasad Centre for Ophthalmic Sciences, AIIMS, New Delhi, Dr. A. K. Jain, Professor, Plant Pathology, CoA, JNKVV, Jabalpur and Dr. Nirmala Bhatt, Professor, Plant Pathology, GBPAU&T, Pant Nagar respectively.

In the above technical session, 7 papers out of 18 research paper listed, were presented by the scientists during the session. As we all know crop protection ecology, crop management practices and synergistic relationship in diverse cropping systems can increase beneficial insects, diseases and manage pests in perennial grains. The mission of the crop protection ecology is to determine how different crop management practices, synergistic and managing pest problems to make healthy crops and environment.

First research paper was presented by Dr. Manish Kumar to emphasized reduce microbial loss and increase efficiency of foliar spray and sprayer should be operated at minimum possible operating pressure with large size orifice. Second paper was presented by Dr. Pawan Kumar Amrite on new combinations of seed dressers and bio inoculants solution of

multiple stresses in soybean. Soybean crop is sensitive and humorous insect, pest, disease affect the area under production and productivity in major soybean growing areas. In the present investigation, a cambo fungicide with multiple mode of action insecticides and bio agents were evaluated as seed dressers on soybean variety JS 335 in *kharif* season. After experiment seed was found significantly superior over other combinations. Third Research paper presented by Y. Venkanna on bio intensive module for the management of trips in spices crop of Chilli. This new invasive species is mainly colonizing in part of flowers and causing huge damage reported from A.P., Karnataka and Telangana especially in Chilli crop. Keeping in view of importance of bio intensive module comprising soil application of neem cake seed treatment with imidacloprid installation of blue sticky traps, sequential spraying of selected insecticides. The trial was conducted at farmer's field in Telangana state through On Farm Trials and BC ratio 2.09 and 1.77 respectively. Another paper presented by Bijeta on insecticide and bio-pesticide management in Potato under rainfed area. Insecticide and bio agent both treatments significantly reduced white grub populations and mitigated damage to potato crops compared to control plots. Research paper on integrated management of Gram pod borer in Field bean presented by Y.P. Prasad. Integrated management of gram pod borer technology which involves installation of 12 pheromone traps per acre at the time of flowering. Application of neem oil 10000 PPM and need based application of emamectin benzoate 0.5 gm/liter. Demonstrated field were recorded with an average 6.5% pod damage by the pod borer compare to 70% in farmer's field. Another research paper presented by G.M. Vinay on high yielding and multiple disease resistant hybrid of tomato Arka Abhed. Tomato leaf curl virus, BW, early blight and late blight causes yield loss up to 70 – 100% in uncontrolled. Among the late blight of tomato is important one which leads total crops loss. In this regard high yielding and multiple disease resistant hybrid Arka Abhed increase 27.73% yield over the farmer's variety. All the innovative technology can be applied in the farmer's field.

Technical session III: Farm economics from micro to macro economy

Chair : Dr. Jitendra Kwatra, Director Extension, GBPUAT Pant Nagar, US Nagar
Co-Chair : Dr. A.A. Raut, Senior Scientist, ICAR – ATARI, Zone–IX, Jabalpur
Convenor : Dr. S.K. Tiwari, Scientist, KVK Sagar
Rapporteurs : Dr. S.R. Shrama, Dr. Akhilesh Kumar, Scientist, KVK Rewa & Dr. Ranvijay Singh, Scientist, KVK, Panna

The Technical Session third conducted in Video confessing hall, IABM, JNKVV Jabalpur dated on 02.03.2024 in the chairmanship of Dr. Jitendra Kwatra, Director Extension, GBPUAT Pant Nagar. Three lead papers presented in this season. First paper was presented by Dr. Moni Thomas, Director IABM, JNKVV, Jabalpur whereas 2nd & 3rd paper was presented by Dr. Manoj Sharma, Principal Scientist, PAU Ludiana and Shri Apoorva Gupta, DDM, NABARD, Jabalpur respectfully.

In the above session “Farm economics from micro to macro Economy”, out of 17 oral research paper listed among them 6 paper were presented by concern scientists. As we know that the agriculture sector continues to provide employment to about 58 percent of the country labour force and sustains over two third of our population. A recent survey revealed that nearly 40% of the farmers wanted to give up farming if option was available due to heavy expenditure in the farming and minimum gain. So development and dissemination of new less budget technology should be provided among the farmers to reduce expenditure in the farming under the condition organic and natural farming methods must be apply which prohibits the use of synthetically produced agro–inputs. Organic & Natural compounds when apply in soil increased the organic carbon resulting improved soil fertility and managing pest's problems to make healthy crops and environment.

First research paper was presented by Dr. A.K. Shrivastava to emphasized the area, production and productivity under organic farming in India as well as global level. He presented that highest area under organic farming was in Australia (35.5 million hectares) followed by Argentina (4.1 million ha), However, India acquired the sixth position with 2.66 million hectares. Environmental sustainability, healthy food, low incidence of pest and quality produce can be maintained only by adoptions organic & natural farming.

Research Paper emphasized the policies for gender mainstreaming in agriculture development indicated that women make almost half of the population in rural area and worked as farmers, workers and entrepreneurs but the face problems than men in accessing production resources, market and services for solving the women's problems government women farmer's entitlement bill 2011 on the recommendation of Prof. M.S. Swaminathan. This bill creates an environment in favor of women's engaged in the farming systems.

Central & State government continually promoted than organic & natural farming systems of crops production to reduce cost of cultivation and make health soil along with quality production in the view of fulfil the human needs for healthy food grain. in this presentation the success stories of Farmer Shri Jainarayn Rai described and concluded that Shri Rai obtained 8 q soybean, 12 q chickpea and 7q green gram per acre/ year. Shri Rai continually doing natural farming cultivation in 6 acre areas from last 6 years. Natural Farming system is knowing Less Budge Natural Farming produced quality food material without harming the environment. Several farmers adopted Less Budge Natural Farming on the basis of Shri Rai recommendation.

The present paper describes sensory quality of Aonla candy with different brix concentration and steeping times. Sensory evolution of develop Aonla candy was tested under tasting panel using 9-point scale and found better at 4 days steeping time without harmful microbial in the candy up to 120 days. after 120 days' storage, quality of candy decrease and prove unhealthy for health.

A case study on Banana Pseudo stem based waste to wealth enterprises and their important on women's social economics development done in Bemetara district of Chhattisgarh and found that extraction of Banana fibber, sap and scuther from the banana Pseudo stem are additional income for women's self-help group and also improved the self-confidence and socio economics status of farm families.

New Niger oilseed crop introduce in the tribal area Chhidawara district of Madhya Pradesh under Cluster frontline demonstration programme sponsored by food security mission, Govt. of India. all the innovative technologies were applied in the demonstration resulting more 60% yield was increased in compression to control. Because of high sold price Niger can be popularized among the oilseed crops in the tribal area in the small land holding farmers.

Technical Session IV: Technology transmission challenges

Chairs : Dr. D.P. Sharma, DES, JNKVV, Jabalpur
Co-Chair : Dr. Moni Thomas, Director IABM, JNKVV, Jabalpur
Convenor : Dr. S.S. Baghel, Senior Scientist & Head, KVK Seoni
Rapporteurs : Dr. B.K. Tiwari, Scientist, KVK Rewa, Dr. A.K. Choubey, Scientist, KVK Singrauli, Dr. Sarvesh Kumar, Scientist, KVK Harda

Four lead papers were presented in the session. First paper was presented by Dr. Neelam Venkateshwar Rao, Senior Scientist & Head, KVK, Karimnagar, Telangana. Second and third papers were presented by Dr. Sanjoy Borthakur, Sr. Scientist & Head, KVK Jorhat, Assam and Dr. A. K. Tripathi, I/c Sr. Scientist & Head, KVK Sagar-II, JNKVV, Jabalpur. Fifth paper was presented by Dr. A. K. Singh, Scientist, KVK, JNKVV, Jabalpur.

Out of 34 oral presentations 10 papers were presented by the delegates. The salient findings of the presentations are given hereunder-

The successful and efficient processing and harvesting of little millet is possible by using mechanical means only like using threshers rather to traditional methods by tribal farmers in Chhindwara district of MP. The quality and marketing appeal of little millet was improved by using mechanical processing methods by millet growing farmers. The millet and millet based products are still need of marketing boost and linkages for coming in consumer's food chain, they are still in queue to be first choice of children and other customers in India due to its taste and texture of millet products. Paddy thresher was found good for threshing of paddy crop for small land holding farmers in Narmada district of Gujarat for drudgery reduction of farm women and time saving of farm women for home management. The input provided by the KVK to the anganwadies for establishment of nutritional garden may enhance the nutritional status of the school going children by the supply of round the year green vegetable for their nutritional security was found successful in Ujjain district of MP. The Sirsa district of Haryana has the highest population of the sheep and goat but needs to be taking serious care of poor health of sheep and goat related to control of animal parasite and other ailments for sustainable growth and production. Rice transplanter was fount suitable tool for mitigation the problem of labour scarcity in Balaghat district of MP during the Kharif season in critical time of need. The rice transplanting done through Rice transplanter was found overall cost effective in comparison to manual transplanting and also time saving, uniform crop plant population, reduced water requirement in Balaghat district of MP. The Para tuberculosis chronic disease of goat still requires specific diseases control treatment but not still available in the market in Jabalpur district of MP. It requires a research upon it for control over this disease perfectly in future. The field pea cultivation emerging as a beautiful option for growing in follow lands during winter season where the less moisture is available at the point of time in West Bengal state for income generation of farmers.

Technical Session V: Nano Fertilizers, AI and biotechnology in agriculture

Chair : Dr. N.C. Sahu, Senior Scientist & Head, KVK Kolkata, WB
Co-Chair : Dr. Sanjay Borthakur, Senior Scientist & Head, KVK Jorhat, Assam
Convenor : Dr. Gyanendra Tiwari, Professor, CoA, JNKVV, Jabalpur
Rapporteurs : Dr. B.S. Dwivedi, Scientist Soil Science, CoA, JNKVV, Jabalpur, Dr. Jai Singh, Scientist, KVK Singrauli and Dr. Hemraj Dwivedi, SMS, KVK Satna

The Fifth technical session of the National conference held on third day, chaired by Dr. N.C. Sahoo and Co-chaired by Dr. Sanjay Borthakur. The session has started with three lead lecture has presented by distinguished scientists. First lead lecture has delivered by Dr. Yogita Gharde, Senior Scientist, ICAR-DWR, Jabalpur on different statistical tools can be applied to data analysis and implementation of data collected from OFTs, FLDs and other KVK's & activities. The deliberates by Dr. Yogita is very informative and enlighted the knowledge of KVK personnel's. Chair has remarked the presentations made by her, very enriched with statistical knowledge and information. Another lead lecture was presented by Dr. Sanjay Singh Scientist, Department of Plant Breeding & Genetics, College of Agriculture, JNKVV, Jabalpur on 'Role of biotechnological tools in improvement of rice'. Dr. Singh has very nicely described the different biotechnological tools used in rice improvement under climate change scenario. Session chairman Dr. N. C. Sahu has also delivered a lead lecture is microbial organisms and bio fertilizer in improvement of crop production. Dr. Sahu very sincerely presented Role of beneficial microorganisms in Agriculture.

A total 10 oral presentation proposed in this session, out of that only six oral presentations were made by participants. Mr. Deepak Chauhan has presented his research findings on the topic performance of Nano-DAP on Paddy crop is shahdol district. During his presentation he discussed Nano DAP gene significant increase in yield (47.68 qt./ha) of rice crop over existing practices. Second oral presentation was made by Dr. S.K. Tiwari on challenges of adopting Agriculture Drone Technology in Sector and its significant Benefits in

Agriculture production system. Dr. Tiwari has expressed drones are very useful specially in energy, cost and time saving, due to this use of drones in Agriculture became very useful. It reported agrochemicals used by drones same Rs.3800/ha and increase 1.25 q/ha yield over the conventional methods. Mrs. Rajani Prabha kori has make oral presentation an Agricultural Technology dissemination by Drone: A Review. Mrs Kori has calculated that the drone technology has improves crop yields, minimize cost of cultivation, same labour, covering unreachable area which can't be covered by conventional methods, hence it become futuristic technology for Agriculture. An oral presentation on influence of foliar application of NAA, Urea, Nano-Urea and bio fertilizer on front drop, retention and yield of Mango Variety *Langra* by Roushan Kumar. He suggested that the foliar application of NAA@ 40 PPM at full bloom and pre stage gave maximum no of fruit set and fruit yield than the other treatments viz. Urea, Nano-urea and biofertlizer. He recommended if farmers, used NAA@ 40 PPM at full bloom stage and pre stage, they must be got higher yield. Dr. Ashok Patra from Krishi Vigyan Kendra, Narkatiaganj, Bihar has concluded that the application of 100 kg nitrogen with 40 kg phosphorus and 20 kg potassium in one-hectare area is a best application for which productions because this recommended dose significantly increases yield and yield component in crop over farmer's practices. Dr. Sarvesh Kumar from JNKVV-KVK Harda has advocated farmer's reaction and perception towards innovations drone technology in Harda district. He remarked application of drone has ability to transform the Agriculture by reducing cost labour with the consideration standardizations of dose, speed of drone, height during spraying and age of plants. Mrs. Gigi Annee Abraham, suggested that the Internet of Things (IoT) may became very useful tools in future Agriculture by their application in date analysis for Crop selection, irrigation scheduling, nutrient and pest- management in previous way.

At the end of session, the Chairperson & Co-Chairman of the session has remarked that all presenters have nicely and precisely presented their fertilizers, Role of drone and IoT may future tools for enhancing productions and productivity of different crop and ultimately income of farming community which uplift their social status. Gave thanks to all participants and other who's present in the session.

Agriculture and Markets; Understand it

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INTRODUCTION

India pre-dominantly an agrarian economy. The country's over 54 per cent land is arable. Agriculture sector caters primary livelihood to nearly 58 per cent of country's population .It is one of the most important industries in the Indian economy contributing to almost 18 per cent of the GDP.The industry comprises of half of the labour market in the country.Agriculture along with fisheries and forestry accounts for one-third of the India's GDP and is its single largest contributor. Agricultural exports constitute a fifth of the total exports of the country.

Status and Market Size

Agriculture in India market size is estimated at USD 372.94 bn in 2024 and expected to touch USD 473.72 bn by 2029. The forecasted (2024-2029) CAGR of agriculture market is 4.90 per cent. The Agri-inputs market is worth USD 44 bn managed by over five lakh agri-input retailers in the country. Indian Food and grocery market is the world's sixth largest, with retail contributing 70 per cent of the sales. During 2023-24 (April-October), the share of processed vegetables, miscellaneous preparations and processed fruits, juices and nuts was to the tune of USD 446.84 mn, USD 758.94 mn and USD 367.85 mn respectively (https://www.ibef.org/industry/agriculture-india).

Between the period April 2000-September 2023, the Department for Promotion of Industry and Internal Trade (DPIIT), reported that the Indian food processing industry has cumulatively attracted a FDI equity inflow of about USD 12.35 bn. This accounts for 1.89 per cent of total FDI inflows received across industries

Agriculture's character

India has access to several natural resources that provides it a competitive advantage in the food processing sector. Due to its diverse agro-climatic conditions, it has a wide-ranging and large raw material base suitable for food processing industries.

Agricultural Market

Agricultural market is a place or arrangement where farmers can sell their produce at a fair and reasonable price. The efficiency of the system depends infrastructural and policy framework in the market ecosystem that attracts more and more farmers as well as traders for competitive and transparent transactions.

However, agricultural marketing is a complex physical and financial process. It includes all activities mostly related to grading, storing, transporting, and selling of the agricultural produce.

The four commonly found systems of agricultural marketing in India are

Sale in villages

In India over 50 per cent of the agricultural produce are sold in the nearby village markets of the farmers.

Sale in markets

Farmers also sell their produce in the weekly village 'hat' market, on fixed day in particular villages.

Sale in mandis

There is a network of nearly 1700 mandis spread across the country in the small and large towns. Farmers carry their produce to the mandi and sell them to the traders. Middlemen (brokers, commission agents or '*dalals*') play a major role in the deal. These traders further sell mills, processing units, factories and also to the retailers.

Co-operative marketing

Farmers to sell produce collectively through their co-operatives or societies to take the advantage of collective bargaining for a better price.

FOCUS AREAS FOR IMPROVEMENT IN AGRICULTURAL MARKETING

Indian farmers and agriculture have demonstrated its strength in food production for over five decades. Yet there is disparity among farmers which causes unrest in the country. A diagnostic approach reveals the following areas needs drastic policy interventions for improving the micro and macro economy in agrarian sector.

Storage facility

Majority of the farmers are small and marginal farmers. They do not have proper facilities to store their produce for longer periods. The annual loss to the tune of 15 to 30 per cent to due pests and moisture is too much at household level. To avoid this loss farmers are forced to sell their produce immediately after harvests at a price which is usually low and less remunerative.

Distress sale

The period from field preparation to sale of the produce vary from six to eight months. This means returns on investment period has a long gestation period of six to eight months, which is too much for any small and marginal farmers.

Investment during crop production is either met by borrowings from traders or money lenders. This compels them to sell off their produce to repay the debt and take more for next cropping season. Distress sale at low price is out of such compulsions.

Transportation

In recent decades villages are connected to town and cities through a labyrinth of good roads. Yet transportation of their produce to distant markets is a regular feature farmers face. Selling of their produce at cheaper price is a mitigation strategy of small and marginal farmers.

Unfavourable mandis

Existing mandis are also not farmer friendly. Delay in weighing and complicated system in the mandis, trap farmers into the net of the middlemen and commission agents who squeeze the profit from the helpless farmers.

Intermediaries

The supply chain between the cultivator and consumer has numerous intermediaries. These intermediaries (brokers, commission agents or '*dalals*') charge a good amount for their services, which is often at farmers' cost.

Unregulated markets

Majority of the rural markets are unregulated. Elements of malpractices in weighing , grading and standard operational of protocols in village markets in India are common.

Market intelligence

Market information system in rural India is weak and often inaccessible. Majority of the farmers remain unaware prevailing price structures in big markets. Thus, remain susceptible low prices often in cash offered for their produce by traders or middlemen in the area.

Organisation

Small and marginal farmers are loosely organised. Small surpluses from their sustenance farming leaves them with no bargaining power. Besides the burden of transportation and opportunity cost put pressure of them to offload their produce at the earliest to get back with the cash offered in the market.

Grading

Small and marginal farmers having less surpluses usually shy away from grading their produce. They know that their produce raised from imbalanced nutrient, abiotic and biotic stress are usually dominated by smaller grains.

Institutional finance

Public sector finances through loan instrument are often defaulted due to previous or successive crop failures, is a general trend in the villages. At this point, they succumb to the clutches of traders and moneylenders for loan under unfavourable conditions.

CONNECTING COMMODITY TO CONSUMERS

Krishi Vigyan Kendras over the years of its establishment is concentrating in transfer of technology, increasing crop production productivity and crop diversification. Now the time has come when KVKs should break its traditional boundaries of operation to train Farmers to marketing, branding and reaching consumers in different ways, bypassing the present system. The Scientists in KVKs should delve into the markets and understand the household consumption pattern. Though, this is a highly specialized area, but KVKs has demonstrated their unparallel strength in transforming the agriculture in India.

Household Consumption Expenditure Survey (HCES) is designed to collect information on consumption of goods and services by the households. The survey also collects some auxiliary information on household characteristics and demographic particulars of the households. Information collected in HCES is useful for understanding the consumption and expenditure pattern, standard of living and well-being of the households. The Monthly Per Capita Consumption Expenditure (MPCE) gives us a better understanding of household expenditures in both rural and urban areas (Table-1).

Table- 1: All-India mean MPCE (share of food and non-food items)

Items	Rural		Urban	
	Mean MPCE (Rs)	Share in total MPCE (%)	Mean MPCE (Rs)	Share in total MPCE (%)
Food	1,750	46	2530	39
Non food	2,023	54	3,929	61
Total	**3,773**		**6,459**	

Survey on Household Consumption Expenditure Fact Sheet: 2022-23; Fact Sheet on HCES: 2022-23, M/o S&PI, GoI Page 7 of 25

The mean MPCE was Rs. 1,373 and Rs. 2,001 respectively of bottom ranked 5 per cent of India's rural and urban population of the same category of population. Similarly, it was Rs. 10,501 and Rs. 20,824, respectively of top ranked 5 per cent of India's rural and urban population.

CONCLUSION

The next challenge before the KVKs will be market, the earlier it realizes it the better it will be for both farmers and the country. The system should reform its policies to train scientists to basics of marketing at the earliest.

Caterpillar Fungus (*Ophiocordyceps sinensis*): Production and Sustainability in Indian Perspective

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INTRODUCTION

Ophiocordyceps sinensis (syn. *Cordyceps Sinensis*) is a high value medicinal fungus belongs to division -Ascomycota, Class-Sordariomycetes, order-Hypocreales, family-Ophiocordycipitaceae, Genus- *Ophiocordyceps* and species- *O. sinensis*. The fungus was first described as *Sphaearia sinensis* Berk. (1843) then *Cordyceps sinensis* Berk. (Sacc. 1878). This entomopathogen has a limited distribution and their stroma has not been artificially cultivated so far while, another entomopathogenic fungus, *Cordyceps militaris* (an orange caterpillar fungus), has almost similar chemical properties to those of *O. sinensis* and can be easily cultivated.

Morphology

Similar to other *Cordyceps* species, *O. sinensis* consists of two parts, a caterpillar cadaver and stroma. The stroma is the upper fungal part and is dark brown or black while yellow when fresh, usually 4-8 cm.

Fig. 1. Cordyceps sinensis with larvae cadaver

Distribution

Native occurrence of the *O.sinensis* is mostly confined to the Himalayan Mountain in Tibet, India, Nepal and Bhutan at an altitude ranging from 3000-5000 meters. The *O.sinensis* is endemic in Tibetan Plateau including adjoining high altitude of Uttarakhand, Sikkim and Himachal Pradesh in India. It is found in the high altitude of Pithoragarh Uttarakhand, Chamoli and Uttarkashi. Extensive research has been conducted on the ecology, collection, utilization, trade route, management and significance and species diversity of *O. sinensis* in various parts of India. During recent years, caterpillar mushroom has emerged out as an important cash crop traded on a large scale and a new source of income in the rural areas in the higher altitude regions usually above 3000-5000 meters in Pithoragarh district of Uttrakhand, India.

Life cycle

This fungus parasitizes a range of caterpillars, most commonly the Thitarodes (*Hapialus armoricanus*, family- Hepialidae) in all around 40 species of Hepialus moth have been recognized and around thirty of them are infected by *O. sinensis*. The reproduction is highly host specific. Every single spore fragments into around 32 million propagules. These tiny propagules get attached to the larval stage of the insects and infected larva is then forced to move closer to the surface of ground. After invasion, the mycelium grows inside the body of the larva. The mycelium fills the interior of the entire caterpillar and mummifies it. The fruiting body always emerges out single, double or triple from the head of the larvae. The propagules present on the fruiting body are dispersed by the wind and attach to new host larva then a new life cycle begins.

Importance

Ophiocordyceps contains a wide variety of potentially important constituents, including polysaccharides, ophiocordin (an antibiotic compound), cordycepin, cordypyridones, nucleosides, bioxanthracenes, sterols, alkenoic acids and exopolymers etc. The constituents of *Ophiocordyceps* were thoroughly studied and a crystalline substance Cordycepic acid was isolated and identified, which identified later as d- mannitol. Cordycepin and cordycepic acid are regarded as the most important constituents of this fungus. Herbal medicinal preparations from *O.sinensis* have become a growing business in various parts of the world as for instance; Bhutan is an emerging market for *Ophiocordyceps* and its uses in China shown a tremendous increase since last few years. There are data of clinical trials that support the efficacy of *Ophiocordyceps* as a medicinal herb, especially for disorders related to the liver, kidney and immune system. A number of studies indicate that *Ophiocordyceps* (and also its mycelial extract) possess certain anti-cancer, anti-metastatic and immuno-stimulating properties. It is also reported to have anti-oxidant activity. However, the medicinal uses of the *O. sinensis* for health benefits are believed to have been known since centuries. Some of them are - anti aging, strong aphrodisiac, memory power, effective treatment of respiratory and pulmonary diseases, improves functioning of liver, use in treating heart problem and use by athletes.

Cost of one kg of the fungus at the final destination (brokers in national and international markets) is much higher than the price paid to the field gatherers. In the Indian market the *O. sinensis*. is being sold at the rate of Rs. 10,00,000=00 to 12,00,000=00 per kg. whereas, the fungus is sold for 1,20,000=00-1,50,000=00 RMB/Jin (1 Jin=600g) in Lithang, China. It is believed that in the International market the fungus may fetch a price between 1.5 and 2 million Rupees per kg (US$ 30,000-40,000). The amount paid varies among the trade channels which start from the wild material gatherers in the field, then to the brokers and agents who collect the dried material from the various locations and sell it at a higher price. However, rapid and immediate marketing of this fungus is not required as the fungus is usually sold and consumed in a dried form. Its small size and easy storage conditions make the transportation much easier.

Survey:

- Local market of Dharchula and Munsiyari surveyed during 2009-2019.
- Assessed the quantity and prices obtained by the gatherers in various years.
- Dealers price of the fungus in Dharchula and Munsiyari market for onward sale were examined.
- Economic implications analyzed on the basis of data obtained during survey.
- Cost of the fungus in local market varied Rs. 2,50,000 – 4,00,000 in 2009 to Rs. 4,50,000 - 800,000 in 2019.
- The estimated volume of trade in Uttarakhand varied between 1050-1500kg during 2009 to 2019.

Trade system, Uttarakhand, India

There is no proper marketing channel / system for trade of *O. sinensis* in Uttarakhand, India.

- The supply of the fungus is made to the agents by field gatherers directly/ through primary collectors.
- The agents further supply to brokers/contractors available in local market (Dharchula & Munsiyari, Pithoragarh, Uttarakhand).
- Finally, the fungus is sold by brokers in the International market from where it is procured by the International pharmaceutical companies and some parts exported to China through Nepal.

Resource sharing and conservation

In Indian context there is urgent need for –

- Legal framework, at national level, for protection of the species
- Facilitation through processes and channel for developing open markets in the country like China.
- Creating awareness among the stakeholders about the depletion of resources, particularly on the

face of climate change and over exploitation.

- Involving communities in protection of habitats and incentives for villages
- Strengthening of research on screening, sustainable harvest and commercialization of products

Regional cooperation framework is required between the countries to

- Establish legal market channels
- Check revenue losses through illegal transportation
- Develop a mechanism for knowledge sharing and dialogues between the various stakeholder
- Initiate collaborate research

Fig. 2: Cleaning and grading by a family of local gatherers before trading

Challenges and Strategies to Manage Ground Water Resources of Punjab for Sustainable Agriculture

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ABSTRACT

During the past half century, the Punjab State achieved exemplary growth in food-grain production with adoption of rice-wheat system. The over exploitation of underground water resources has posed the sustainability issues of existing cropping system. The fast-receding water table in the central Punjab demands policies and agronomic management practices for water saving techniques. This paper discusses the Govt initiatives on water management issues and agronomic practices recommended by experts of agriculture to resolve the dwindling underground water of Punjab for sustainable development of agriculture.

INTRODUCTION

Punjab is a small state and occupies only 1.57% of the India's total geographical spread and is a part of the Indo-Gangetic plains formed due to alluvial deposits of Sutlej, Beas, Ravi and Ghaggar. Punjab contributes 21.2% of paddy and 31% of wheat to the Central pool. The major source of irrigation water for crops like paddy and wheat is groundwater. As a result, from 1966–1967 to 2017–2018, the area irrigated by tube wells grew from 24.5 to 71.5% (Singla *et al,* 2022). Over the past 50 years, the state's groundwater resources have suffered due to the rapid development of tube wells and the area under them (Fig. 1 and 2 as per CGWB, 2021). There was 3.56, 34.35 and 12.5 lakh ha area under 0-3, 3-10 and 10-20 m water table during 1998 which fluctuated to 0.75, 10.89, 18.2, 15.07 and 5.41 under 0-3, 3-10, 10-20, 20-30 and >30 m water table depth during 2018 indicating that the area of the state having depth to water table more than 10 m has increased much more (Figure 3).

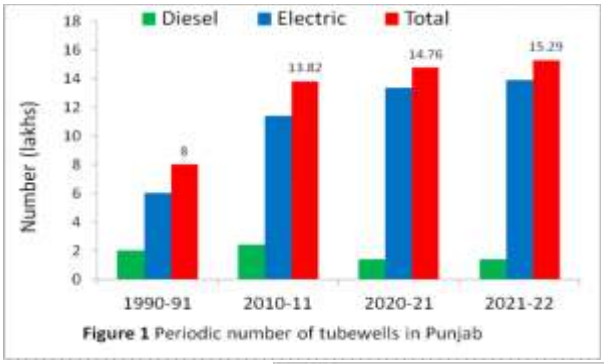

Figure 1 Periodic number of tubewells in Punjab

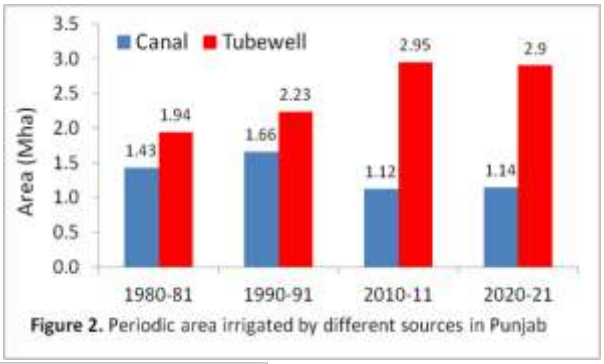

Figure 2. Periodic area irrigated by different sources in Punjab

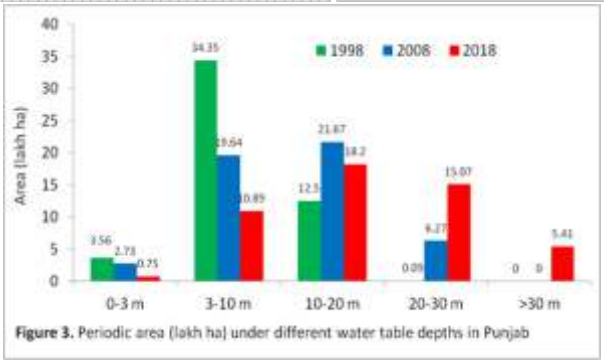

Figure 3. Periodic area (lakh ha) under different water table depths in Punjab

FACTORS RESPONSIBLE FOR DEPLETION OF UNDERGROUND WATER

Mono cropping

The area under paddy cultivation increased from 4 lac ha in 1970–1971 to 31.67 lac ha in 2022–2023, which is about 77 % of the net sown area. Similarly, the net sown area under wheat increased from 41% (1970–1971) to nearly 44% in 1990–1991, 34.9 and is presently around 85%. Also, the net area under irrigation has increased from 70% in 1970–1971 to 98% in 2021-22. All these combined together have put a tremendous pressure on the water resources.

Canal water supplies

In 1980–1981, the area under canal irrigation was 1.43 million ha that rose to 1.66 million ha in 1990–1991 and then decreased to 1.14 million ha in 2021-21 (Figure 2). Total surface water available at different headworks is about 17,900 Mm^3. Of these, 14,500 Mm^3 is available at the outlet. According to an estimate the groundwater contribution from rainfall and seepage from canals as 16,800 Mm^3 thus making the total availability of water as 31,300 Mm^3 (Aggarwal *et al,* 2009). The crop water demand has been worked out as 44,000 Mm^3 thus leaving an annual deficit of 12,700 Mm^3. In order to meet crop demand the ground water is being over-exploited using shallow and deep tube wells in the state. In 1976, the union government allocated 3.5 million acre feet (MAF) of water to Haryana out of undivided Punjabs 7.2 MAF total water availability. The Ravi–Beas Water Tribunal, headed by Supreme Court Judge Balakrishna Eradi, was set up to reassess water availability and recommend how the water was to be shared. In 1987, the tribunal upheld the legality of the earlier water-sharing agreement and recommended increasing Punjab and Haryana's shares to 5 MAF and 3.83 MAF, respectively. Punjab government has demanded constitution of an appropriate tribunal for reallocation of the Ravi-Beas waters, due to the change in the circumstances which pertains to drastic reduction in the availability of Ravi-Beas waters from 17.17 million acre feet (MAF) to 14.37 MAF based on 1981-2002 flow series. The water has got further reduced to 13.38 MAF based on the latest flow series 1981-2013. The dynamic ground water resources of the country including Punjab are being periodically assessed jointly by Central Ground Water Board (CGWB) and State Governments. As per the 2020 assessment, in Punjab, the total annual ground water recharge is 22.8 Billion Cubic Meter (BCM) and the annual extractable ground water resource is 20.6 BCM. The annual ground water extraction for all uses is 33.85 BCM, out of which 32.8 BCM (97%) have been utilized for irrigation purpose. There is now urgent need to reassess the available water flowing in the rivers in the changing scenario of climate change.

Free/subsidized power

In Punjab, power for agriculture was totally free from 1997 to 2002 and from 2005 onwards. An unmetered power tariff (flat tariff) induced farmers to use electricity recklessly because the marginal cost of electricity use was almost zero (except for labour cost). This led to the intensive mining of groundwater and consequent drastic fall in the water table. These power subsidy policies virtually sounded the death knell of aquifer health and stability. A parliamentary standing committee has recommended restricting free electricity to the farmers to curtail the misuse of groundwater.

Increased tube well density and groundwater draft

Free or practically free electricity has led to an increase in the number of tube wells, particularly in the central and northern region of Punjab and the use of water was irrational. In 1990–1991 there were 8 lakh tubewells and the number increased to 15.29 lakh in 2021-22 (Fig. 2).

Change in rainfall pattern

Rainfall is the most significant source of groundwater recharge and hence changes in the rainfall pattern leave distinct impact on the groundwater regime of an area. Monsoon rainfall has more effect on water table depth. The variability in rainfall is much more during different years but there was a general tend of decline in rainfall from 1970 to 2020 (Fig. 4) which

may also be the cause of depletion in ground water as to meet crop demand more water has to be extracted from ground.

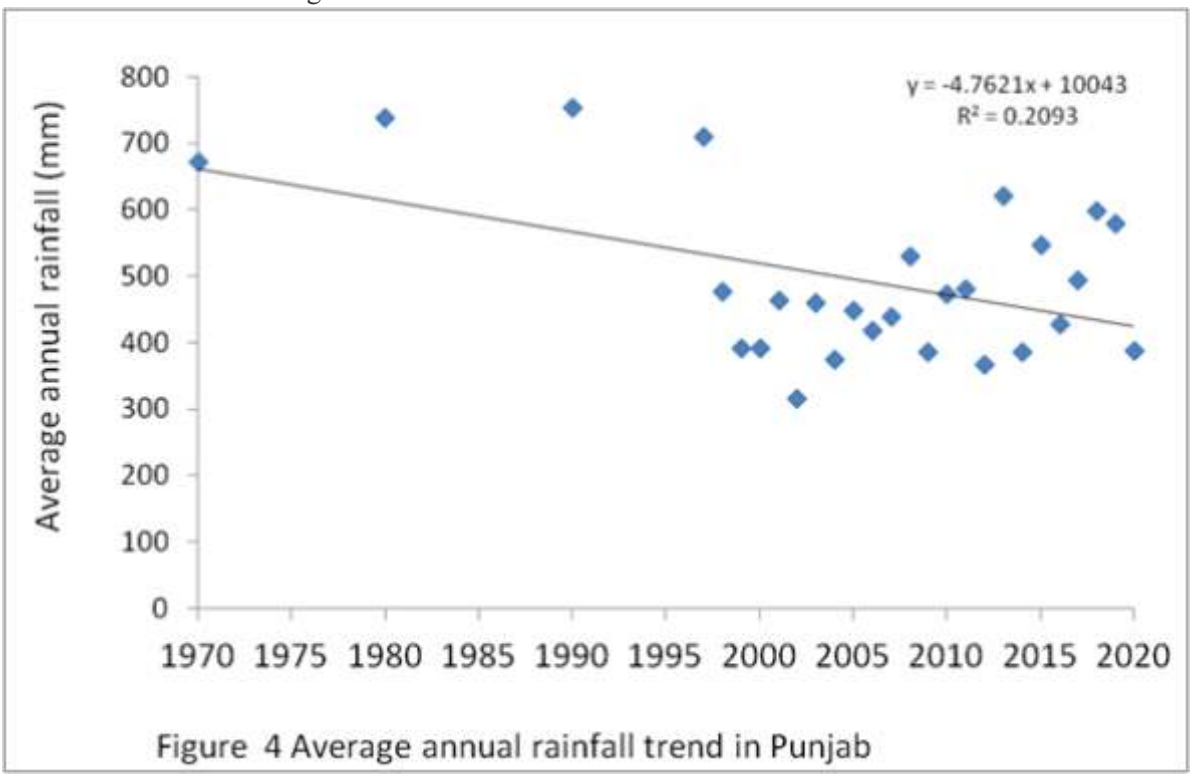

Figure 4 Average annual rainfall trend in Punjab

POLICY INTERVENTIONS

Preservation of Sub-Soil Water Act, 2009

It is not just the rice crop per se but its transplanting date that decides the rise or decline in the water table. Earlier, farmers used to practice the early transplantation of rice. They transplanted the rice crop during the summer seasons peak *i.e.,* in May. As a result, rice cultivation depended entirely on groundwater. In the absence of rainfall or surface water irrigation, groundwater was extensively withdrawn for preparing the rice field through regular irrigation until the onset of the monsoon (mid-June). Further, due to the hot and dry season and no rainfall, rice fields would experience considerable evapo-transpiration losses. All of these unsustainable irrigation practices proved detrimental to the groundwater level and the state's overall water and food security. To curb the rapidly falling groundwater level, state govt preserve the subsoil water by banning the paddy transplantation before the monsoon's onset through Preservation of Sub-Soil Water Act, 2009. The primary objective is to prohibit paddy nursery sowing and paddy transplanting before specific notified dates. The core provision in both is setting a date in May as the earliest date before which a farmer cannot sow the paddy nursery. The legislations also empower an authorized officer to enter a farmer's field to assess any violations. If violations are found, the officer can direct the delinquent farmer to destroy the nursery. In non-compliance, the authorized officer can destroy the nursery or the transplanted paddy and recover costs. The State has notified sowing of paddy nursery from 10th May of the year and transplantation of paddy from 10 June onwards under the "Punjab Preservation of Sub-Soil Water Act, 2009". The transplantation of paddy has been shifted to commensurate with onset of monsoon season so as to conserve the precious groundwater. Delaying paddy transplanting to June 25 or late saves 1,000 to 2,000 m^3 per hectare. With adoption of alternate wetting and drying, and keeping maximum 50 mm depth of irrigation water in the paddy field can save 1,500-2,500 m^3 per hectare. Delaying paddy transplanting to June 25 or later coupled with growing short duration varieties can also save 1,500-2,500 m^3 per hectare.

Direct seeding of rice

All the paddy growing farmers of the state are being made aware of the benefits of the Direct seeding of rice (DSR). They are also being encouraged to put at least some of their area under DSR to have first-hand experience about the technology (Gill *et al* 2023). In the year 2019, about 501 thousand hectare area was covered under DSR which was increased in the year 2020-21 to 554.29 thousand hectare. In addition, short duration varieties like PR 126 are also being promoted.

Crop diversification

Alternative crops to rice such as cotton, basmati, maize, oilseeds and pulses, fruits and vegetables, dairy etc need to be encouraged in different agro-climatic conditions with the help of effective support price, processing and export infrastructure (Gill et al. 2023). With shifting from paddy to kharif maize water saving of 10,000 m^3 per hectare, to millets (bajra) or oilseeds (groundnut) or pulses (moong bean) water saving of 11,000 m^3 per hectare each can be achieved.

Agronomic practices

Use of small irrigation plots (15-20 plots per hectare) for wheat crop can save water up to 350 m^3 per hectare. Direct sowing of wheat in standing paddy stubble using zero-till drills such as Happy Seeder or Super Seeder with water saving up to 700 m^3 per hectare. Controlled irrigation of wheat field as per PAU recommendations can save water up to 750-1000 m^3 per hectare. Furrow irrigation in bed-planted wheat can save water up to 750 m^3 per hectare. Irrigation through sub-surface drip system can save water up to 3,500-4,000 m^3 per hectare. The State of Environment Report of Punjab estimated that a 10% increase in irrigation efficiency can help to bring additional 14 million ha area under irrigation. Punjab could take learning lessons from countries like Israel, which is based on the principle of 'More crop per drop'. Now various subsidies are being provided by the State and Central Government for promotion of micro irrigation in the state. The paddy sowing with traditional puddling technique over the years has led to development of hardpan in soil that stops recharge of rain water. So, paddy cultivation without puddling practices (ridge transplanting) as per PAU recommendations can also save water. Application of straw mulch improves the water use efficiency and helps in water saving by reducing the ET losses (Jalota *et al.* 2000) and increased yields of number of field crops during summer months.

Reallocation of canal water

The rational distribution of canal water among Doaba, Majha and Malwa regions in Punjab can also help to check the steep decline of underground water in central Punjab.

Artificial recharge of aquifers

The Central Ground Water Board (CGWB) has proposed new schemes on artificial recharge and aquifer mapping and management under the Twelfth Five-Year Plan period. In this, about 79,924 structures in rural and 375,000 in urban areas are proposed for the Punjab State. It is estimated that influence of recharge scheme will be observed about 26,650 km^2 area and it will help to check decline in water level. The aquifer mapping will help to assess future prospects for the groundwater resource, particularly with regard to the extent and thickness of aquifers and characteristics such as transmissivity, storativity, and groundwater quality. A package of measures to increase the artificial recharge to augment the groundwater reservoir has to be taken. It has been estimated that the total unutilized water works out to be 0.433 million hectare meters, out of which 0.372 million hectare meters is through rivers and the rest comes through drains and nullahs.

Improvement in irrigation efficiencies

Average irrigation efficiency of irrigation systems, at present, is very low ranging from 30 to 40 per cent. Water is lost during conveyance through seepage from main canal, branches, distributaries, minors, water courses and field channels. The average water losses from unlined canals, branches and distributaries, and water courses are 8, 17, 20 percent respectively, of water released from reservoir.

Lining is an effective way of minimizing conveyance losses. Conveyance losses can also be avoided by using underground pipeline system where the water is conveyed in a pipeline. The State Government is providing 50% subsidy to individual farmers for laying of RCC Underground Pipe Line System to propagate on-farm water conservation.. The gap between irrigation potential created and actual irrigation achieved also needs to be bridged. This is possible by arresting siltation in canals and reservoirs and by remodelling, reconditioning, repair, maintenance and upgradation of existing canal system to provide assured water supply up to the tail end.

Rainwater harvesting

Roof Top Rain Water Harvesting has been made mandatory in all buildings above 200 sq.yds. by amending the buildings by-laws. In Punjab, a total of 4,262 water conservation/ water harvesting works and 35,809 renovations of ponds works have been taken up under MGNREGS till 30th June, 2021. Government of Punjab has constructed low dams to provide irrigation facilities under Bharat Nirman Program costing Rs.170 crore. These dams indirectly help in augmenting the ground water resources of the State and help in arresting the declining ground water table.

Conjunctive use of canal and poor quality water

The conjunctive use of surface and groundwater will help in developing strategy of irrigation for optimal agricultural development. The studies have revealed that an integrated approach for conjunctive use of surface water and poor quality groundwater supplemented with application of gypsum amendment and proper facilities for drainage on sodic soils could also reduce pressure on fresh water use. etc. Integrated wastewater management by treatment, recycle and re-use by identifying and designing innovative solutions for domestic and/or industrial sectors can also be a viable option.

Some other initiatives taken up by Punjab Government

The "Paani Bachao, Paisa Kamao" Scheme was launched by Government of Punjab to check depletion of underground water by offering monetary benefits to the farmers for every unit of power they save. Government of Punjab has enacted the Punjab Water Resources (Management and Regulation) Act, 2020 on February 12, 2020 for ensuring the judicious, equitable and sustainable utilization and management of the State's critical water resources. The Punjab Water Resources and Development Authority, 2020 had been established under section 3 of this Act which shall ensure development, management and conservation of water resources of the State. A special committee of the Punjab assembly has recommended several steps, including formulation of a policy on maintaining balance between recharging and extraction of water and an audit of all sectors, for checking the depletion of underground water level in the state as per suggestions by experts of the water resources department and Israel-based company Mekorot. There should be an audit of demand and supply in all sectors, be it drinking water, use of water in agriculture and industry. The committee recommended the formation of a special purpose vehicle for micro irrigation to reduce water consumption in the farm sector.

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Current Challenges and Strategies for Management of Soil Health and Sustainable Productivity

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INTRODUCTION

Soil is a key component of the natural system and as a vital contributor to human commonwealth through its contribution to food, water and energy security and as a mitigator of biodiversity loss and climate change. The importance of "Natural Resource Management" is higher than ever before for the need to ensure sustainable food production in the face of increasing food demand, changing climate, increased biotic pressure and declining resource productivity. With only 2.4% of the global land area, India is habitat to 17.5% of world human population. India is projected to be the world's most populous country by 2025 surpassing China and therefore increase in food demand will be there. With little possibility of increase in the arable land area, the enhanced food demand is to be met from declining land quality and consequently with increased input use. Thus, land degradation because of the decline in soil health is a major barrier to ensure sustainability in food production of the country. Among the various aspects of natural resources regulating food production, maintaining soil health is one of the key factors contributing to sustainable agricultural productivity. Maintaining a soil quality is essential for sustaining higher crop productivity with quality produce under intensive agriculture systems.

According to the Director General of the FAO, Jose Graziano da Silva, today, world has more than 805 million people facing hunger and malnutrition. Soils are under increased pressure because population growth will require an approximately increase of 60 per cent in food output and competing land uses. Unfortunately, 33 per cent of our global soil resources are under degradation and human pressures on soils are reaching critical limits, reducing and sometimes eliminating essential soil functions (34). By 2025, India would need to produce 350 million tonnes of food grains to feed 1.3 billion people of the country. Contrary to the ever increasing demand for food, the country wide long-term experiments revealed that the rate of response to added fertilizers and the factor productivity of major crops are declining year after year under intensive cropping systems. This highlights the need for developing efficient nutrient management strategies for sustaining higher crop productivity and soil quality under intensive agriculture systems. Balanced fertilization of NPK and other deficient nutrients in different crops proved better for higher crop yields and arresting nutrient mining under intensive cropping systems. Recently, emphasis has been given to utilize all available organic and inorganic nutrient sources including legumes and bio-fertilizers in integrated plant nutrient supply system mode to overcome wide negative nutrient balance in different production systems. The practices of liming or amending the soil with organic manures have substantially improved the productivity of the acid soils and also detained decline in soil pH. More recently the site-specific nutrient management (SSNM) and Soil Test Crop Response (STCR) based prescriptions are gaining popularity due to their superiority over blanket nutrient recommendations. Further, urbanization pressure has taken away productive lands over the years in the country which is a matter of grave concern. The size of average land holdings is decreasing day by day. The hunger task force of United Nation has made soil health improvement as one of the five recommendations for increasing agricultural productivity and fight hunger in India.

INDICATORS OF SOIL HEALTH DETERIORATION

a. Stagnating food grain productivity

The food grain productivity growth rate has stagnated after 1981-90. The trend shows a decline or very little variation in the productivity growth rate in spite of an increase in fertilizer use. The growth rate has increased from 1.7% per annum during 1971-80 to 3.48% per annum during 1981-90. However, afterwards, the growth rate has declined and at present can be said to be at a plateau stage.

b. Declining productivity growth rate in major crops

The Indian agriculture since last two-three decades witness a plateau in productivity in major crops. The decline is in spite of development of new cultivars and enhanced fertilizer use. In the last two decades, the productivity growth rate has reduced by almost half in most of the food grain crops as well as in oilseeds per annum, though in case of pulses, the growth rate has remained inconsistent.

c. Declining fertilizer response

A reduction in crop response to fertilizer application is widely noticed across several production systems. This is acute particularly in the Rice-Wheat cropping system belt of northwest India, which compels farmers to apply more fertilizer to get the same crop yield as in the preceding years (18). The constant decline in factor productivity in respect of fertilizer use is a prominent indicator of soil health deterioration and decline in soil resilience capacity.

d. Multi-nutrient deficiency

With increase in agriculture intensification, the soils are getting continuously exhausted of secondary plant nutrients such as sulphur and micronutrients. At present, widespread deficiencies of sulpur and zinc are witnessed in the country and significant response to application of these nutrients has been observed. As per the latest available data, 41% of the soil samples tested are deficient in sulphur (26). As far as micronutrients are concerned, 43% samples are deficient in available Zn, 12% samples in Fe, 18.3% in B, 5.4% in Cu and 5.5% in Mn (22). Boron deficiency is observed in soils with low organic matter content and in highly leached soils. Soils of Odisha, Jharkhand, West Bengal, Karnataka, parts of Bihar, Tamil Nadu and four districts in Gujarat are highly deficient (more than 50%) in Boron (22).

e. Widespread plant nutrient deficiency

Majority of Indian soils are deficient in major plant nutrients. The district wise available data on NPK status of different soils of 500 districts during the period 1995-2008 showed that out of the 500 districts studied, soils of 283 districts are low, 182 districts medium and 33 districts are high in available N (29).

f. Declining fertilizer response

A reduction in crop response to fertilizer application is widely noticed across several production systems. This is acute particularly in the Rice-Wheat cropping system belt of northwest India, which compels farmers to apply more fertilizer to get the same crop yield as in the preceding years (18). The constant decline in factor productivity in respect of fertilizer use is a noticeable indicator of soil health content (15). In more than 90% of the districts (combining low and medium category), availability of N and P is critical constraint to maintain soil productivity and soil health.

POSSIBLE CAUSES OF SOIL HEALTH DETERIORATION

Imbalance in use of fertilizers

Imbalanced use of fertilizers is one of the major causes of soil health decline. It is a major concern in both low and high fertilizer using states. As revealed from the fertilizer consumption data, the ratio of N: P2O5: K2O at the All India level is presently at awfully distorted level of 8.2:3.2:1, as compared to the ideal level of 4:2:1. The ratio is much vague in the north alluvial plains and in intensive agricultural states of India. For instance, the ratios are 38.8:13.8:1, 121.4:41:1 and 204.4:54.3:1 in the states of Uttar Pradesh, Punjab and Haryana, respectively. The imbalanced use leads to depletion of native P and K from soil when excess N fertilizer is added. The highly imbalanced use of plant nutrients adversely affects the soil health and long term soil productivity.

Change in land-man ratio

With almost same arable land, the food grain production has increased by about five times since independence. This has been possible due to intensification in agriculture with the help of fertilizers, high yielding cultivars and irrigation. However, the per capita arable land availability has reduced from 0.35 ha

in 1950-51 to 0.14 ha in 2010-11. Thus, the supporting capacity of the available land is over-stretched, which has reflected in the form of a exhaustion in the soil productivity after certain years. The other possible causes of soil health deterioration are physical degradation caused by soil erosion, compaction, crusting; chemical degradation caused by wide nutrient gap between nutrient renewal and supply, high nutrient turn over in soil plant system coupled with low and imbalanced fertilizer use, less use of secondary and micronutrients, insufficient input of organic sources because of other competitive uses, irrigation induced water logging and salinization, acidification and aluminum toxicity in acid soils and salinity and alkalinity in soils. Biological degradation caused by organic matter depletion and loss of soil fauna and flora; soil pollution from industrial wastes, excessive use of pesticides and heavy metal contamination.

Concept of soil health or quality

In general, soil quality and soil health are often used interchangeably and are considered identical. Health is most often used to emphasize the linkage between soil and human or animal health, and the idea that soil works as an organism or system. The term "quality" is used more as a technical term. The central issue in soil quality research is the critical soil functions that soils perform. The simplest definition of soil quality is "the capacity of soil to function" (10). Some other definitions also highlight the critical issue of soil functions or soil services. Keeping in view the concept of sustenance of soil services, soil quality is defined as the continued capability of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, maintain the quality of air and water environments, and promote plant, animal, and human health (4). The major soil functions related to crop production are: infiltration and storage of water, retention and cycling of nutrients, pest and weed suppression, detoxification of harmful chemicals, carbon sequestration and production of food and fibre. In the context of soil properties, soil health deals with integrating the physical, chemical and biological properties of soil.

Soil health assessment framework

The need and challenge for maintaining soil health under intensive land use has led to the growth in the "soil health and soil quality research". In Asia, the major causes of soil health deterioration are nutrient imbalances in soil, excessive chemical fertilization without organic supplements, soil pollution and soil erosion processes (8). The per capita food production in Africa is declining largely due to depletion in soil quality and soil health (27). Despite the above, direct measurement of soil health or soil quality is a difficult proposition. The best possible methodological framework is to assess soil health through soil properties that are sensitive to changes in management practices. The sensitive soil properties encompassing physical, chemical and biological properties are used as indicators. Thus, the soil health assessment approach consists of the following basic steps:

Selection of minimum dataset

The selection of key or representative indicator parameters which best describe the system under study, is the first and the most critical step in soil quality study. The soil quality or the capacity of soil to function should be reflected by the indicator parameters, or else known as soil quality indicators. Selecting a group of such indicators forms the minimum dataset (MDS) for comparative or dynamic assessment of soil quality. As proposed, the selection of MDS should fulfill the following criteria (3): i) Integrate soil physical, chemical and /or biological properties and processes, ii) Should be applicable under diverse field conditions, iii) Complement either the existing database or easily measurable data, iv) Respond to land use, management, climate and human factors, and v) Able to measure changes both at plot and landscape scale.

However, several methods including statistical procedures have been employed for MDS selection, till date, the 'expert opinion' method is the most commonly used. This requires expert

knowledge about the soil functions and the systems to be studied. But, it suffers from disciplinary biases. The difficult question of which variables to include out of the several possible indicator parameters, is simplified by using statistical procedures. Thus, the statistical methods such as factor analysis, principal component analysis, linear and multiple regression analysis, cluster analysis, multiple correlation and star plots reduces the possibility of disciplinary biases and help in reducing the data volume and selecting the indicators which represent the particular soil function the most. In the semi-arid region of Andhra Pradesh, Mandal et al (2011) using PCA identified cation exchange capacity, exchangeable sodium percentage, available Zn and P, available water content and dehydrogenase activity, as the most important indicators for evaluating soil quality. Qualitative assessment is done on-farm and involves no special measurements or analysis. At the most, it involves very common tools to assess compaction, penetration resistance, etc., and take into account those parameters which can be identified or assessed visually or through feel. This method is subjective in nature and involves experience and also suffers from user bias. The ratings are given in terms of few categories such as "poor, fair or good" or low medium- high and may be expressed in scores in the 1 to 10 scale.

Soil quality test kits

The soil health test kits provide a quick and easy route to have an idea about key soil properties. As compared to elaborate and routine laboratory tests, kits save time and labour and give fairly accurate estimates for selected soil properties which can give idea about the soil health. The kits commercially available in India mostly provide estimation for soil chemical parameters including soil pH, EC, organic matter content, available NPK content, etc., However, for a comprehensive knowledge about the soil health, the test kits should have provision for analysis including important physical, chemical and biological soil properties.

STRATEGIES TO ENHANCE SOIL HEALTH

A. Building carbon stocks in soil

Soil organic carbon is considered to be of key importance in maintaining soil quality. It is commonly recognized that organic matter in these soils plays an essential role in improving soil physical, chemical and biological processes. Soil organic carbon (SOC) is one of the most important indicators of soil quality and soil health (7). The important practices which mainly contribute to improve soil organic carbon content are as follows.

1. Promotion of conservation agriculture

Location and crop specific conservation agriculture (CA) modules need to be identified and promoted in the primary food producing zones of the country. The three basic principles of CA are: cover of at least 30% soil surface, minimum disturbance to soil surface and crop rotation. The CA practices help in soil organic matter build up, carbon sequestration and enhance adaptation capacity of the plants to endure abiotic stress.

2. Soil erosion control and management

Soil erosion is one of the primary causes of soil health deterioration. Erosion takes not only soil but the fertile soil. Hence, on-farm soil erosion control through bioengineering measures such as integration with vegetative barriers and hedge rows, cover crops, green manure crops are some of the cost-effective alternatives which can be promoted in larger scale so as to harness the benefits of the management practices. Rapid growing cover crops particularly the surface covering legumes such as cowpea protect the soil surface from high intensity rain fall during monsoon and pre-monsoon months. The additional benefit comes from the nutrient rich biomass, which increases the erosion resistance of the soil.

3. Green manuring

Apart from adding nitrogen to soil, green manuring crops such as sesbania, gliricidia add enough

biomass so that the soil physical properties improve. From the available literature, it is known that green manuring provides 50 to 150 kg of N /ha in about 90 days. Promotion of green manuring help saving the cost of chemical fertilizers apart from improvement in soil physical, chemical and biological properties.

4. Vermiculture and vermicomposing

Vermiculture may be encouraged to provide earthworms to produce vermicompost. At least one vermiculture unit in each village needs to be promoted with efficient earthworm species to supply the cultures to the vermicomposting units. Both vermiculture and vermicomposting units need to be encouraged with appropriate incentives. This also generates local employment.

5. Composting and enriched compost

All surplus biomass on the farm, i.e. crop residues, weeds, pruning, surplus fodder, and any biomass produced on bunds and wastelands need to be used for on-farm composting. Rapid and efficient composting techniques need to be followed and popularized. The composts may be enriched through inorganic amendments like rock phosphate, pyrite, gypsum, mica waste and glauconites. Also, the compost may be enriched with useful microorganisms like P solubilizers, N fixing microbes, and biocontrol agents. For rapid composting, cellulose decomposing organisms may be added at the thermophilic stage of composting.

6. Cow dung management

The cow dung or any other animal dung along with bedding material, refuge and leaf cover material may be composted with efficient composting techniques. Efficient bio-cultures involving N fixing microbe species, P solubilizing bacteria and bio-control agents may be added to enrich the FYM. During the preparation stage, the FYM may also be amended with the amendments like rock phosphate, pyrite, gypsum, mica waste and glauconites. The amendments and microbial cultures may be subsidized for rapid adoption by the farmers specially those who are resource poor.

B. Balanced and improved fertilization approaches

1. Balanced fertilization promotes Nutrient Use Efficiency (NUE)

In an epoch of multiple nutrient deficiencies, a single nutrient approach can lower fertilizer use efficiency (FUE). Balanced nutrition implies that there are no deficiencies, no extremes, no antagonisms and no negative interactions. All nutrients must be at an optimum level by themselves and in relation to each other enabling positive interactions to enhance yields. Experimental results on the benefits of balanced fertiliser use are numerous. Apart from NPK nutrients, Zn, Fe, Mn, S and B have assumed importance due to their emerging deficiencies. Long-term field experiments revealed that the yields of different cropping systems increased significantly with the balanced application of NPK, Zn, and S as compared to N, NP and NPK treatments (32). The research studies conducted at Pantnagar and Modipuram also revealed that Rice-Wheat yield could be increased significantly by the application of Zn along with NPK as compared to NPK alone (21). Therefore, it is necessary to promote the balanced fertilization among the farmers to achieve higher FUE and crop yields while sustaining soil fertility.

2. Site specific nutrient management (SSNM)

The conventional blanket fertilizer recommendation causes low fertilizer use efficiency and imbalanced use of fertilizers. Estimation of fertilizer requirements based on quantitative approaches can assist in improving yields and increasing nutrient use efficiency. This calls for field specific integrated crop management strategies that include site specific quantitative knowledge of crop nutrient requirements, indigenous nutrient supply, and recovery efficiency of applied fertilizer. Frameworks for site specific nutrient management have been developed for Rice (2) and Wheat (17). The SSNM and STCR approaches appear to be essentially the same as both of them calls for integrated nutrient management recommendations based on crop nutrient requirements, indigenous nutrient supply and recovery efficiencies of applied nutrients.

3. STCR based nutrient recommendation to crops

General blanket fertilizer recommendations are fixed and can't proportionate with variability and changes in soil nutrient status, crop demand and crop management. Therefore, an alternative approach could be that fertilizer is applied based on recommendations emanating from Soil Test Crop Response relationship (STCR) data. Among the various methods, the one based on yield targeting is unique in the sense that this method not only indicates soil-test based fertilizer dose but also gives the level of yield the farmer can hope to achieve if good agronomic practices are followed in crop production. The essential basic data required for formulating fertilizer recommendations for targeted yield are (i) nutrient requirement in kg per quintal of produce, grain or other economic produce, (ii) the percent contribution from the soil available nutrients, and (iii) the percent contribution from the applied fertilizer nutrients. Major aspects of the target yield concept have been discussed by Subba Rao and Srivastava (2001) and Muralidharudu et al (2012). Adjustment equations for desired yield targets for different crops growing on various soils have been worked out from basic data derived from several field experiments. The STCR approach allows balanced fertilizer use under resource constraints and helps in maintaining soil fertility. When fertilizer availability and resources of the farmers are limited, planning for low yield target (but higher than the yield levels normally obtained by farmers) ensures efficient and economic use of available fertilizers.

4. Integrated Plant Nutrient Supply (IPNS) strategies for different cropping systems

The basic concept of the principle of integrated nutrient management is to maintain or adjust plant nutrient supply to achieve a given level of crop production by optimizing the benefits from all possible sources of plant nutrients. The basic objectives of IPNS are to reduce the fertilizer requirement, to restore organic matter in soil, to enhance nutrient use efficiency and to maintain soil quality in terms of physical, chemical and biological properties. Bulky organic manures may not be able to supply adequate amount of nutrients, however their role becomes important in meeting the above objectives. Long-term studies (9) have indicated that it is possible to substitute a part of fertilizer N needs of *kharif* crop by FYM without any adverse effect on the total productivity of the system in major cropping systems such as rice-rice, rice-wheat, maize-wheat, sorghum-wheat, pearl millet-wheat, maize-wheat and rice-maize. Therefore, it is necessary to popularize the IPNS strategies for different cropping systems for achieving higher crop yields and fertilizer use efficiency.

5. Adoption of best management practices

Best management practices (BMPs) despite enhancing the economy and efficiency of inputs used, contributes to the improvement in soil health. The BMPs related to nutrient management can broadly be grouped as i. Nutrient supply to match to crop requirement and uptake, ii. Improved application method of nutrients, iii. Improvement in physical properties of fertilizers and use of inhibitors to reduce losses, iv. Soil conditions and crop and water management, and v. Bio-inoculants and green manures.

C. Managing problem soils through soil amendments

1. Management of acid soils

Management of acid soils should focus on production potential either by addition of amendments or to manipulate agricultural practices to enhance fertilizer use efficiency and superior crop yields under acidic condition. Application of lime to neutralize the exchangeable Al to a certain extent has been found effective. Liming improves the base status, inactivates Fe, Mn and Al in soil solution and consequently reduces P fixation. Further, liming stimulates microbial activity in soil leading to mineralization of organic N in soil and fixation of atmospheric N. Improvement in the availability of soil and fertilizer P by liming the acid lateritic soils has been reported. Different doses of lime starting from partial to full lime requirement was found superior to increase grain yields of pulse and oilseed crops (13). Liming alone at

the rate of 2-4 quintals / ha in furrows increases the yield of different crops by 14-52% over farmers practice (20).

2. Alkali or sodic soils management

Nitrogen is the most limiting nutrient in these soils because of low intrinsic fertility, low amounts of organic matter, poor symbiotic fixation of atmospheric N and higher volatilization losses leading to low efficiency of applied fertilizer N (19). To increase crop production and N use efficiency in rice-wheat system (i) apply 25% more N than the recommended doses for normal soils (ii) split N application in three doses, 50% as basal, 25% as top dressing after 21 days and another 25% after 45 days of transplanting/sowing (23) (iii) green manuring practice with *sesbania* which adds 60-80 kg N equivalent to the N added through urea, and (iv) apply fertilizer N at the time of puddling and mix in the soil despite of broadcast on the surface. In contrast to normal calcareous soils, efficiency of water soluble P in these soils is very high. For judicious use of P fertilizers it is recommended not to apply any P fertilizers initially 3-5 years after reclamation, thereafter only 11 kg P/ha can be applied in rice only for another 5-10 years and then apply 22 kg P/ha to both rice and wheat crops. Due to high pH, ESP, calcium carbonate and less organic matter, efficiency of applied Zn fertilizer is much less and the crops especially rice suffers. To have normal crop of rice and wheat, zinc sulphate 10-20 kg /ha should be applied to both rice and wheat crops. Efficiency of applied Zn can be increased by using recommended doses of amendments to lower down pH/ESP of the soil, which increases the solubility of Zn and growth of the plant. In case of acute deficiency, spray of 0.5% zinc sulphate solution for better results. To partly meet the plant needs and to increase the efficiency of the fertilizers, it is recommended to apply FYM @ 10 t/ha to the rice crop. Use of green manure to rice with *sesbania* helps in increasing N supply @ 60-80 kg N/ha and mobilize soil P @ 10-11 kg P/ha (33).

3. Management of saline soils

In potentially waterlogged saline soils, which are the core problems of the canal irrigated commands, the crops suffer due to the toxic effects of excess soluble salts and low water availability due to high osmotic pressure of soil solution. In addition to lowering the water table depth through subsurface drainage and leaching of soluble salts, application of fertilizers is necessary to supply the nutrients and to increase the tolerance of the crops to soil salinity under such situations. Low efficiency of applied fertilizers in saline soils is due to poor plant growth as affected by soil salinity, low uptake/utilization of the nutrients due to antagonistic effects and higher losses during leaching of the salts. After undertaking reclamation through subsurface drainage and leaching of excess salts from the root zone, crops like pearl millet, wheat, mustard, barley and sorghum can be successfully grown on these soils. For optimum crop production, application of N @ 160 kg/ha to wheat crop and 120 kg/ha to other crops increase the yield (24). Salinity decreases the availability of soil P. Application of P up to 26 kg/ha increases the crop yield due to direct application of P and by minimizing the chloride toxicity. Application of K @ 50 kg/ha significantly increases wheat yield and N use efficiency (25).

D. Strategic Action Plan

Often, soils are treated as just dumping grounds for fertilizers to extract more and more yields. Besides, India's fertilizer policy is skewed against soil health. Farmers today use so much urea carrying only nitrogen, because it has a price advantage as compared to phosphorus and potassium. Their perception is what they lose on phosphorus and potassium (because of higher open market price) can be more than compensated by the uncontrolled use of urea (because of substantial amount of subsidy). In this process, they distort the healthy nutrient balance in soil severely affecting the carbon balance, leading to all the subsequent soil-related problems. This calls for an immediate policy intervention. Creating awareness among all farmers for soil testing and analysis; and providing soil health cards to all those who do not have yet following-up with those who have already been issued to assess the outcome or whether

they have any problems

Monitoring-cum-concurrent evaluation studies need to be conducted through systematically drawing plans village-wise to ensure that farmers are using the soil health cards for the purpose for which they are issued and assess the economic benefits of the National project on management of soil fertility. Healthy management information system must be put in place to ensure effective implementation, assess the economic benefits realized and initiating remedial measure if there are any problems. Effective use of print and electronic media should be made to create awareness for soil health management in each village during the years 2016-18 and ensure that targeted number of STLs, mobile STLs and FQCLs are established/strengthened, staff trained for capacity building.

EMERGING ISSUES AND FUTURE PROSPECTS

Use of advanced technology for soil health assessment

Assessment and monitoring of soil health and soil based resources through the conventional laboratory analysis is time consuming and labour expensive. In view of the growing importance of soil health monitoring in sustainable agricultural production, it is important to explore the use of sensor and electronic technology in monitoring key indicator properties. Deriving such information and blending it along with innovative use of geographical information system (GIS) and remote sensing shall help in increased application in the areas of risk prioritization, fertilizer scheduling and planning for efficient crops and management practices.

Incentives for best management practices adoption

Indian agriculture is mostly dependent on small and marginal farm holdings. The small and marginal farmers are more interested in short-term benefits more willingly than long-term issues such as soil health improvement. A recommended practice finds little acceptance with these group of farmers if it does not provide better income and higher food production. Hence, policy level decision should be taken to incentivize the farmers for adoption of BMPs (30).

Identification of suitable soil quality indicators

As the routine laboratory analysis for the key soil quality indicators is very expensive and time consuming, it is desirable to identify few suitable indicators which can give a fairly good idea about the soil health. Further, in most of the soil testing laboratories, the chemical parameters are routinely analyzed. However, due emphasis to the biological and physical parameters should be given. The biological activity in terms of earthworm counts, cotton strip assay, labile carbon content, potentially mineralizable C and N, biolog plates, etc., are some of the possible procedures which need testing and promotion in varied agro ecosystems.

Soil quality test kit development

As discussed earlier, in India and in many other countries, the available soil test kits analyze the soil chemical parameters only. However, there is a need to develop soil quality test kits which aside from chemical parameters also analyze key physical and biological parameters.

Conclusion

Indian agriculture has reached to turning point with a decelerating growth in productivity. It is unequivocal that maintaining soil health is essential for sustaining crop productivity and produce quality under intensive agriculture systems. The increased food need of the future is to be met without much expansion in the cropped area and thus a healthy soil system is required to support the food production.

Essential investments are needed for the implementation of sound nutrient management programs including fertilizer and manure inputs to relieve nutrient stress to maintain the soil health. Negative nutrient balances are clear indicators for soil degradation and non-sustainability of the cropping systems, which must be arrested. Efficient recycling of nutrients from available organic residues, manures and composts can assist in narrowing the gap between nutrient removals by crops and insufficient nutrient

replenishment. However, a key component of integrated plant nutrient management in India will continue to be the mineral fertilizers. Among the nutrient management strategies, IPNS based on STCR approach/SSNM emerge to be a viable technology/ measure to sustain higher crop productivity and assure better soil quality under intensive agriculture systems. Nutrient management strategies need to be tailored to the needs of the farmers with different reference bases with focus of on farm composting.

All possible resource conservation measures need to be adopted depending on the availability of water, nutrients and agro-climatic limitations, including the concept of conservation agriculture in crop production. Amelioration of problems soils and use of poor quality water in agriculture is very essential for accelerating the crop productivity with proper amendments for enhancing the soil health.

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Molecular Plant Breeding: Achievements and Opportunities

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INTRODUCTION

Increased food output will be necessary due to the growing global population, although some research indicates that crop yields are currently increasing at a slower rate than in the past (Pingali and Heisey, 1999). This necessary increase in crop output will have to take place in the backdrop of growing water scarcity, shrinking arable land areas and environmental degradation (partially due to agriculture), rising pollution, the unavoidable emergence of new pathogen and pest races and biotypes, and potential negative effects of climate change. Therefore, plant breeders and agricultural scientists have an unprecedented challenge in trying to increase crop yields.

The area of plant breeding that uses molecular biology methods to improve the accuracy and efficiency of breeding programs is known as "molecular plant breeding." Our ability to realize and modify the genetic composition of plants for enhanced qualities like yield, disease resistance, and nutritional content has greatly increased as a result of this method. Although conventional breeding is expected to continue improving yields, new methods like biotechnology will be required to increase the likelihood of success (Ortiz 1998; Ruttan 1999; Huang *et al,* 2002). Plant breeding could benefit greatly from the application of DNA marker technology, a branch of biotechnology that originated from molecular genetics and genomics research. DNA markers can be used to identify allelic variation in the genes underlying these traits because of genetic linkage. Efficiency and accuracy in plant breeding could be significantly improved by employing DNA markers. A facet of the emerging field of "molecular breeding" is marker-assisted selection (MAS), which refers to the use of DNA markers in plant breeding.

The latter two decades of the 20th century saw the introduction of molecular markers to help with the numerous tasks associated with crop breeding initiatives. Because phenotypic markers are less effective at discriminating features and are more impacted by environmental factors, DNA-based markers have been developed (Ahmad and Anjum, 2018). According to Ahmad *et al* (2020), molecular markers are genes or specific DNA segments that are indicative of variations at the DNA level. According to Saqib *et al* (2019), there is no guarantee that molecular markers will correlate with morphological features that are expressed. According to their choice and the purpose of the study, each marker has advantages and disadvantages of their own (Pena *et al,* 2020). There are some important molecular techniques which enhanced the production, resistance and accuracy of the genetic information received from the parents for the improvement of breeding traits in crop plants. Some important techniques come under molecular plant breeding is as under

Molecular Markers

Certain DNA sequences known as molecular markers can be used to determine whether particular genes or genomic regions are present. These markers are useful resources in genetics, molecular biology, and other fields, such as molecular plant breeding. Molecular markers offer a means to examine inheritance patterns, analyze genetic variation, and help choose desired features in plants and other species. The following are some important categories of molecular markers and their uses:

Microsatellites, also known as simple sequence repeats (SSRs), are short, repeating DNA sequences that are utilized to detect genetic diversity. They are extensively employed in population studies and genetic mapping. Single-base differences in the DNA sequence that can be used as markers are known as single nucleotide polymorphisms, or SNPs. SNPs are often employed in high-throughput genotyping because they are prevalent in genomes.

RFPs are polymorphisms in the sequence of DNA that, when digested by particular restriction enzymes, produce distinct patterns of fragments of DNA. In the past, RFLPs were among the earliest kinds of molecular markers utilized in genetic mapping.

Using PCR (polymerase chain reaction), certain genomic DNA fragments are amplified for AFLPs. They are employed in genetic diversity research, genetic mapping, and genetic fingerprinting. Short, arbitrary DNA sequences amplified by PCR are known as RAPD markers. They may not offer as much information as other markers, but they are useful for quick and easy DNA fingerprinting. PCR is used to amplify particular DNA sequences called SCARs, which are produced from polymorphic DNA fragments. Compared to RAPD markers, they are intended to be more stable and repeatable. GBS is a high-throughput sequencing method that enables multiple marker genotyping at the same time. It is applied to population genetics, genetic mapping, and marker finding. While they amplify areas in between microsatellite sequences, ISSRs and SSRs are comparable. They are employed in population research and genetic diversity analyses.

Marker-Assisted Selection (MAS)

Molecular markers are used in marker-Assisted Selection (MAS), a breeding approach that helps select individuals with desirable features in plant breeding. In traditional plant breeding, plants are chosen for their observable properties and then crossed to produce offspring that possess those traits. By enabling breeders to recognize and choose plants with certain genes or markers linked to the desired traits, frequently before the qualities are observably manifest, MAS improves this process. It has proven effective to use marker-assisted selection to a number of crops, including important food crops like rice, wheat, maize, and soybeans. It has been essential in creating better plant types with higher yields, better tolerance to diseases, and other commercially significant features. Molecular procedures including DNA sequencing, genotyping, and molecular mapping are used to identify genetic markers linked to the desired qualities. Molecular markers are used to identify individual plants in a breeding population and then used to build marker profiles for those plants. These profiles show whether particular genes linked to the desired attributes are present or absent. Using these molecular markers, breeders can then choose plants with the desired genes or alleles linked to desirable features. This makes it possible to identify prospective individuals in the breeding population early and precisely.

MAS speeds up the breeding process by choosing plants based on their genetic composition rather than waiting for phenotypic expression of characteristics. This is especially helpful for qualities that take a long time or are challenging to evaluate visually.Breeders can examine if several markers associated with distinct genes are present or absent in the same plant using MAS, which enables simultaneous selection for multiple phenotypes.

It could take multiple generations to acquire the necessary qualities using conventional breeding techniques. Because MAS enables breeders to make better-informed decisions in early generations, it helps reduce the number of generations required. Why MAS reduces the possibility of unintentionally picking undesirable features by offering a greater degree of accuracy in the selection of plants with particular genetic traits.In general, MAS improves breeding program efficiency, which makes it a useful tool for creating novel plant varieties with enhanced disease resistance, improved agronomic features, or other desired qualities. MAS is frequently combined with conventional breeding practices, enabling a thorough strategy that incorporates the benefits of both molecular and conventional breeding procedures.

Genomic Selection

Genomic Selection (GS) is a breeding approach that predicts an organism's genetic merit for different phenotypes by using information from its entire genome. Instead of depending on phenotypic observations and a small number of genetic markers as in traditional breeding approaches, genomic selection makes use of high-throughput DNA sequencing tools to examine a huge number of markers spread across the genome. This strategy works especially well for complicated qualities that are influenced by several genes. Genomic selection has been used with success in a number of crops, such as fruits, vegetables, and grains. It is now a useful tool in contemporary plant breeding, helping to create more accurate and effective breeding programs that can handle issues like food security, climate change, and changing agricultural demands.

MAS is often used in conjunction with traditional breeding techniques, allowing for a comprehensive approach that combines the advantages of both traditional and molecular breeding methods. The breeding population provides phenotypic information on the desired qualities. A training population is developed, comprising individuals with both genotypic and phenotypic data; this could include observations on yield, disease resistance, quality attributes, or any other characteristic desired for improvement. A statistical model that links the genetic markers to the observed phenotypic variation is developed using this population.

Statistical techniques, like Bayesian approaches and genomic prediction models (like Ridge Regression), are used to determine the association between the phenotypic traits and the genetic markers. To predict an individual's genetic worth in the breeding population, the model is trained on the training population. Using a separate group of people (the validation population) who were not part of the training population, the predicted accuracy of the model is verified. This aids in evaluating how well the model can predict trait values in fresh individuals. Breeding decisions are then based on genomic projections. The process of genetic improvement is sped up by selecting for further breeding those individuals with the best genetic values for the desired qualities.

Benefits of Genetic Selection

Even before the phenotypic expression of features becomes evident, genomic selection makes it possible to forecast genetic merit early in plant growth. It allows for the simultaneous selection of several traits, offering a more thorough method of breeding. By speeding up the selection process, genomic selection can drastically cut down on the amount of time needed to meet breeding objectives. The accuracy of forecasting an individual's genetic potential for different traits is improved by the use of genome-wide markers. By weighing the contributions of several genes, genomic selection sheds light on the genetic architecture of complex characteristics.

Transgenic Approaches:-

In transgenic plant breeding, foreign genes are inserted into a plant species' genome to give particular traits or qualities. This method, which is a subset of genetic engineering, has been applied extensively to improve agronomic features like tolerance to herbicides, resistance to diseases and pests, and increased nutritional content. A transgene, or gene from a foreign species, is usually inserted into the target plant's genome throughout the process. Although transgenic techniques have been successful in producing crops with desired qualities, they have also given rise to questions about the effects they will have on the environment, the safety of food, and moral issues. To allay these worries and guarantee the ethical application of transgenic technology in agriculture, ongoing research and regulatory supervision are being conducted.

The desired attribute is taken into consideration while selecting the transgene, also referred to as the foreign gene or insert. Genes for disease resistance, insect resistance, herbicide tolerance, or higher nutritional content may be among them. To transfer the transgene into plant cells, vectors—most frequently plasmids or viral vectors—are employed. Additional genetic components, like as terminators and promoters, are typically included in these vectors to control the transgene's expression. The transgene is inserted into the plant cells using plant transformation techniques. Agrobacterium-mediated transformation and biolistic (gene gun) techniques are common approaches. A plant cell containing an integrated transgene is known as a transgenic plant. The transgene merges into the plant's DNA. Usually, molecular analysis is used to verify the integration. A plant cell containing an integrated transgene is known as a transgenic plant. The transgene merges into the plant's DNA. Usually, molecular analysis is used to verify the integration. The transgene's promoter sequence regulates its expression, dictating when and where the gene is active. Terminator sequences aid in controlling the transcription process and indicate the end of a gene. The transgene's promoter sequence regulates its expression, dictating when and where the gene is active.

Terminator sequences aid in controlling the transcription process and indicate the end of a gene. To identify and choose successfully transformed cells, selectable marker genes are frequently

incorporated into the transformation process. Transgenic cells can be identified thanks to these indicators' resistance to specific antibiotics and herbicides. The transgene causes the transgenic plant to exhibit the desired phenotype after it has been incorporated. This could be the production of an enzyme that allows for the tolerance to herbicides, a protein that confers insect resistance, or an increase in nutritional value. Transgenic plants are subjected to extensive testing in order to assess their performance in various environmental situations. Prior to commercial release, regulatory agencies evaluate the safety and any environmental impact.

Typical Uses for Transgenic Techniques

In order to give resistance against particular pests, Bacillus thuringiensis (Bt) genes that produce insecticidal proteins are frequently inserted. Certain herbicides can be tolerated by transgenic plants, enabling efficient weed management without endangering the crop. To strengthen the plant's immune system, genes that offer resistance against different pathogens, such as bacteria, fungi, or viruses, can be added. Crops can benefit from transgenic techniques to improve their nutritional value by having higher vitamin or mineral contents. To increase crop resilience, genes that provide resistance to environmental challenges like salinity or drought can be introduced.

CRISPR-Cas9 Technology

The groundbreaking gene-editing technique known as CRISPR-Cas9 technology enables exact alteration of DNA within an organism's genome. "Clustered Regularly Interspaced Short Palindromic Repeats," or CRISPRs, are particular DNA sequences that are present in the genomes of bacteria and other microbes. The enzyme known as CRISPR-associated protein 9 (Cas9) functions as a molecular shear.

The innate defense systems of bacteria and archaea—a class of single-celled microorganisms were the model for the CRISPR-Cas9 system. These microbes defend themselves against viruses and other external objects by using CRISPR-derived RNA and different Cas proteins, including Cas9. Even though CRISPR-Cas9 technology has a lot of potential, researchers and legislators need to be mindful of ethical issues and possible off-target impacts. Sustained investigation and conscientious use of this technology are important to guarantee its secure and efficient implementation across diverse domains. This technology worked to guide a RNA (gRNA), a short RNA sequence that is intended to complement the target DNA sequence. The Cas9 enzyme is then mixed with this gRNA. The gRNA and the Cas9 enzyme combine to form a complex. This complex has the ability to identify and attach itself to the particular target DNA sequence. After being inserted into the organism's cells, the Cas9-gRNA complex uses base-pairing with the complementary gRNA sequence to locate the target DNA sequence. The Cas9 enzyme precisely cuts the target DNA at the place indicated by the gRNA after the Cas9-gRNA combination attaches to the target DNA. The natural healing processes of the cell are activated by this cut.

Applications of CRISPR-Cas9 Technology

CRISPR-Cas9 can "knock out" or disrupt specific genes, rendering them non-functional, by causing errors in the repair process. Modifications to the sequence can be made specifically by providing a template for the DNA repair process. Genes may now be precisely altered because to this. CRISPR-Cas9 is widely used in functional genomics research, where it mutates or disrupts certain genes to uncover their roles. Utilizing CRISPR-Cas9, specific genetic alterations associated with a disease are introduced to generate animal or cell models of the condition. CRISPR-Cas9 is used in agriculture to generate crops with desired characteristics, such as higher production, disease resistance, or greater nutritional value. The potential therapeutic applications of CRISPR-Cas9 in medicine, including the management of specific illnesses and genetic issues, are currently being researched.

Functional Genomics

Within the field of molecular biology, functional genomics aims to comprehend the roles and interplay of genes within an organism's genome. It entails analyzing the functions of individual genes, their products, and their interactions within the framework of the complete genome to determine how genes affect an organism's physiology, behavior, and development. Important elements and methods in functional genomics includes.

Knowing the places and times at which genes are active is made easier by an understanding of gene expression patterns. Techniques like RNA sequencing (RNA-Seq) and microarrays are used to investigate the transcriptome, or total collection of RNA molecules generated by the genome. High-throughput technologies are used to carefully study gene function on a large scale. This includes techniques like as RNA interference (RNAi), CRISPR-Cas9 gene editing, and overexpression screens. Researchers can "knock down" or specifically suppress the expression of specific genes using tiny RNA molecules and then watch how the organism responds.

The CRISPR-Cas9 technology allows the examination of gene function by modifying or disrupting specific genes and observing the resulting phenotypic alterations. the analysis of every protein produced by a cell, tissue, or organism. Mass spectrometry and other techniques that reveal details about the relationships and functions of proteins are used to identify and quantify proteins. investigating each and every metabolite (small molecule) present in a cell, tissue, or organism. Understanding the metabolic pathways and how they are genetically regulated is aided by this approach. Assigning functions to the genes inside a genome by predicting the roles of genes based on sequence analysis, resemblance to known genes, and experimental data.

Examining how genes interact in biological pathways and networks. Understanding the roles that genes play in several cellular processes and their broader functional context is made easier with the help of this strategy. comparing the genomes of several animals in order to uncover components that are divergent and conserved. Genes and regulatory components that have remained constant throughout evolution might be revealed in this way. combining data from many functional genomics techniques to create a complete picture of the role of genes. This allows for the integration of data from genomes, transcriptomics, proteomics, and other "omics" techniques. Functional genomics is used in agriculture to find and change the genes controlling productivity, disease resistance, and nutritional value, among other desired crop properties.

Businesses may improve their microbial strains for use in biofuel generation, industrial processes, and other applications with the aid of functional genomics. Understanding the evolutionary history of genes and regulatory elements in different organisms.

High-Throughput Sequencing

Next-generation sequencing (NGS), sometimes referred to as high-throughput sequencing (HTS), is a potent and effective technique that makes it possible to quickly and concurrently sequence a huge number of DNA or RNA molecules. Compared to conventional Sanger sequencing, this technique offers faster, more affordable, and higher-throughput methods for sequencing DNA, which has completely changed the field of genomics research. Important attributes and traits of high-throughput sequencing include:

HTS enables the simultaneous sequencing of several DNA or RNA fragments. This parallel approach significantly increases the rate at which data are created. High-throughput sequencing technology can create millions or even billions of sequences in a single run, enabling the production of massive volumes of data quickly. Most HTS technologies provide relatively short sequence reads when compared to traditional Sanger sequencing. On the other hand, read lengths have improved due to technology advancements. HTS is widely used in metagenomics, transcriptomics, functional genomics, epigenomics, personalized medicine, and genomics research.

Common HTS platforms include Oxford Nanopore Technologies, Pacific Biosciences (PacBio), Ion Torrent (Thermo Fisher), and Illumina. Each platform offers benefits and drawbacks that influence which should be used based on the objectives of the research. Samples of DNA or RNA are prepared to build a sequencing library before sequencing. Typically, this step of library preparation is breaking up the DNA or RNA, adding sequencing adapters, and amplifying the pieces so they can be sequenced. Due to the massive volumes of data generated by HTS, advanced bioinformatics tools and processes are required. Analysis includes read mapping, variant calling, de novo assembly, and other uses based on the study's goals. High-Throughput Sequencing has transformed the field of genomics research by giving

researchers the rare chance to examine the minute intricacies of transcriptomes, epigenomes, and genomes. Thanks to its numerous applications and constant advancements, technology is improving everything from fundamental research to clinical diagnostics.

Bioinformatics

The multidisciplinary area of bioinformatics integrates computer and biological sciences to analyze, comprehend, and handle biological data, especially that obtained from high-throughput technologies like genomics. It is essential to the organization and comprehension of complicated biological data, advancing the fields of structural biology, proteomics, genomics, and other life sciences.

The creation and administration of databases for the effective storage of biological data is a component of bioinformatics. These databases contain data on gene expression, protein structures, DNA sequences, and other topics. For the analysis and interpretation of data from genome sequencing initiatives, bioinformatics tools are indispensable. This involves identifying the functional, regulatory, and genetic components that make up a genome. In order to determine conserved areas, uncover functional components, and comprehend evolutionary links across species, comparative genomics studies compare the genomes of various species. using computer techniques to the analysis and prediction of biological macromolecules' three-dimensional structures, such as proteins and nucleic acids. This facilitates comprehension of their roles and interactions. Building evolutionary trees and researching the evolutionary links between various species using genomic data are two applications of bioinformatics.

Recognizing the roles that genes play and how they interact with one another in biological processes. This covers functional annotation, high-throughput experiment interpretation, and gene expression data analysis. Data from mass spectrometry and other proteomics techniques are analyzed and interpreted using bioinformatics tools. This covers functional analysis, measurement, and protein identification. examining and evaluating information on every tiny molecule (metabolite) present in a biological sample. Understanding metabolic pathways and metabolite identification and quantification are aided by bioinformatics. combining information from several "omics" domains to simulate and comprehend the intricate relationships seen in biological systems. This method makes it possible to see biological processes holistically. Bioinformatics is used in the medical field to evaluate clinical and genomic data for identifying, diagnosing, and personalizing therapy.

The creation and use of data mining and pattern recognition algorithms to extract valuable information from huge biological datasets is known as bioinformatics. understanding system-level behavior by analyzing and modeling biological networks, such as networks of interactions between proteins and metabolic pathways.The identification of possible therapeutic targets, virtual compound screening, and the examination of medication interactions and toxicity are all aided by bioinformatics.

Bioinformatics allows researchers to assemble important insights from the massive volumes of biological data produced by high-throughput technology, it has become an essential component of contemporary biological research. Bioinformatics is essential to the advancement of biological and computational sciences since it propels new discoveries and breakthroughs in the life sciences.

CONCLUSION

In summary, molecular breeding is a novel strategy to plant breeding that increases the precision, efficacy, and speed of crop improvement by the application of state-of-the-art molecular biology tools. This multidisciplinary approach combines genomics, bioinformatics, and genetics to solve the issues of global food security, environmental sustainability, and changing climatic conditions. To sum up, molecular breeding is at the vanguard of agricultural innovation, offering ways to raise crop productivity, resilience, and nutritional value. As science and technology develop, molecular breeding may play a significant role in defining the future course of resilient and sustainable agriculture.

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Nano -fertilizers for Better Soil Health and Eco-Friendly Agriculture

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ABSTRACT

Indian agricultural growth story over the years has been commendable and fertilisers have played a key role in it. In our quest for food and nutritional security for the masses, vital resource base of the soil has been compromised resulting in Multi Nutrient Deficiencies (MNDs) and eventually, soil fatigue. Risk and uncertainty in agriculture has also grown with climate change affecting crop productivity. Next, green revolution therefore, has to come from minimal resources with maximum output to justify sustainability at farm level. Fertiliser industry by virtue of providing fertiliser, a key input for agriculture production is conscious of these challenges and is contributing to improve crop productivity and agricultural sustainability of the nation. Industry has evolved and has brought contemporary and novel fertilisers *viz.,* slow and controlled release fertilisers, fortified fertilisers, customised fertilisers, 100 % water soluble fertilizers, secondary and micronutrient fertilizer, Biofertilizers, Bio stimulants and now nano fertilisers like Nano Urea and Nano DAP to meet the requirement of crops and soil. Precision and targeted application with smart fertilisers like nano fertilisers are a must for conserving soil health and promoting eco-friendly agriculture.

INTRODUCTION

Currently, whole world is channelizing towards achieving Sustainable Development Goals (SDGs) as extreme weather events, climate exigencies, hot /cold or dry spells, flash floods, eutrophication of water bodies, algal blooms etc. are no exception. For achieving this, reduction in Green House Gas Emissions (GHGs) by adopting alternative eco-friendly fertilisers, resource conservation technologies along with suitable policy interventions are required. No wonder countries like Australia are investing in research to enhance nitrogen use efficiency by 20% while New Zealand is mulling over fertilizer tax. Canada is infusing innovation to reduce N_2O emission from farming while France is on way to reduce 15% of its N_2O emission by 2030. Brazil National fertilizer plan -2050 has brought alternative fertilizers to the fore. China's zero growth goal in fertilizers usage and India's own nutrient based subsidy (NBS) programme are policies to promote precision and targeted application of nutrients with commensurate reduction in losses to soil-air and water. Indian government is also forthrightly, promoting alternative / organic fertilisers and reducing the use of chemical fertilisers through its PM Programme for Restoration, Awareness Generation, and Nourishment & Amelioration of Mother Earth (PM-PRANAM).

SUSTAINABLE DEVELOPMENT GOALS

Sustainable Development Goals (SDGs) largely entail action by all countries to promote universal prosperity while protecting the planet, tackling climate change and ensuring environmental protection. Agriculture remains critical for attaining SDGs because it significantly contributes to food production for ever-increasing population and depleting resources. In agriculture the input cost accounts for major share in the cultivation expense and any innovation in achieving higher use efficiency of inputs has greater significance for nature and mankind. The introduction of fertilizer responsive and high yielding crop varieties has made the farming more fertilizer dependant. Synthetic fertilizers greatly impact the world's food security but the use efficiency of these fertilizers is low leading to higher quantum of application. While reviewing various reports on fertilizer use efficiency studies, it is understood that the efficiency of fertilizer nitrogen is only 30%, while phosphorus and sulphur record 15-20%, and 8-12% respectively. With regards to micronutrients, the efficiency is very low as most field studies suggest that the use efficiency is less than 5%.

Intensive cultivation, imbalanced use of fertilisers, lack of crop diversification and reduced application of organic input as a component of integrated nutrient management have compromised the

health of our soils. Breakthrough interventions and disruptive technologies are thus, much needed to increase the use efficiency of nutrients in agriculture as business as usual is inclement for our own survival. The prime goals of SDGs are zero hunger, good health and well-being, clean water, industry and innovation; climate action mainly which are linked with sustainable and eco-friendly agriculture. Nanotechnology is expanding its wings in many fields and in agriculture nano systems can create huge positive impact by enhancing the use efficiency of various agricultural inputs. The size and shape of nanomaterials vary significantly that facilitate numerous applications in almost all fields. Many lifestyle transformations have been achieved with the progress of nanomaterials research and applications.

Nanotechnology can help the fertilizer industry too in designing nano formulations with controlled release of nutrients. Nanocomposite technology can effectively regulate the release of nutrients from synthetic fertilizers helping to enhance the fertilizer use efficiency and reducing the loss of applied nutrients. The nano fertilizers are capable of releasing the encapsulated nutrients very slowly thus making the nutrients available for plant uptake throughout the crop growing season. Many reports confirm the potentiality of nano systems in ensuring sustainable crop cultivation with low carbon foot prints. It is therefore, heartening that necessary regulatory guideline have been made by India to promote nano agricultural inputs and Fertiliser Control Order (FCO) has already provided necessary permission through gazette notification for the commercial production of Nano Urea and Nano DAP. These initiatives by the government largely motivates the scientists and various stakeholders engaged in translational research to promote nanotechnology-based inputs in agriculture.

IMPACT OF NANOTECHNOLOGY

The impact of nanotechnology on fertilizer industry is highly significant as any improvement in the existing fertilizer scenario shall enhance the use efficiency of the fertilizers, thus minimizing the quantum of fertilizers used in the crop production systems. This would ease the fertilizer subsidy burden to the government and also help in reducing the environmental pollution due to over application of chemical fertilisers. On nano fertiliser production side, the resource conservation in terms of energy and raw material requirement; emissions and outflows to environment are almost negligible. Also the environment footprints and less expenditure in terms of logistics, storage and warehousing provides a definite edge to nano fertilisers.

Indian government through right policy measure like PM-PRANAM scheme is encouraging States/UTs to make farmers aware of organic / alternative fertilisers and reduce chemical fertilisers. Incidentally, fertiliser subsidy out flow was more than INR 2.5 lakh crores during FY 2022-23. Under PM-PRANAM scheme, the Indian States which will reduce the use of chemical fertilisers by use of organic / alternative fertilisers, half of the subsidy savings as a result of that reduction will be allocated to those states, and such states can use that amount to make farmers aware and promote the use of organic / alternative fertilisers, as well as development of the states. Nanofertilisers are potential alternative fertilisers that can bring the desired change for better soil health and sustainable agriculture.

Nano fertilisers do have their quota of challenges and controversies but that can't be valid ground to overlook ongoing transformative research in this field. Any new technology needs to be questioned and evaluated in terms of efficacy- safety and toxicity criteria and weighed in terms of overall utility for agriculture and other life forms. For this research network has to be ethical, collaborative, considerate and result oriented. Strong linkage between global Universities/research organizations, stakeholders including farmers and policy makers is needed to harness benefits of agricultural nanotechnology. Optimisation of crop production systems through intervention of nanotechnology and Nano fertilisers will certainly pave the way for achieving sustainable development goals (SDGs) and steps have rightly been taken in that direction by farmers own Fertiliser Cooperative - IFFCO.

Prospects and Opportunities of Agrotourism in North East India

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ABSTRACT

India is primarily an agrarian economy and more than half of the India's population is directly or indirectly dependent on Agriculture. In India, revenue from agrotourism is growing at an annual growth rate of 20 percent (*Business Economics*, 2019). Agrotourism brings visitors closer to nature and rural activities in which they can participate, be entertained and feel the pleasure of touring. It is the symbiotic association of farming sector, tourism industry and farm business. The basic principle of agrotourism is creating a win-win situation for farmers and visitors through the mutual exchange of rural feeling and economic benefits at mutually agreed upon arrangements. In India aagrotourism was initiated in 2004. Pandurang Taware is known as the Father of Agrotourism Concept in India. 'North East India' consisting of 8 states, covers 7.9% of the total geographical land area of the country with total area of 2.62 lakhs square kilo meter and this region is often referred to be 'paradise unexplored' due to its enchanting natural scenic beauty, flora and fauna, rich biodiversity along with pleasant weather, historical and cultural heritage, distinct and diversified ethnic heritage. Therefore, it will be easier for attracting tourists to agrotourism spots. There is abundance of opportunities for one to develop agrotourism sector in north east India. The development of agritourism services in North-eastern states of the country requires systematic improvement of knowledge and skills by current and potential rural service providers.

INTRODUCTION

Agrotourism is a mixture of agriculture and tourism which attracted both domestic and international tourists alike. It can more precisely be described as a form of commercial activity that combines agricultural activities with tourism and attract individuals to farms, ranches, or other agricultural establishments. The primary goal of agrotourism is to offer visitors entertainment as well as educational experiences, and at the same time generate revenue for the farmers who are engaged on it. Agrotourism market in India is expected to grow at the compounded annual growth rate (CAGR) of 19.9% between 2023 and 2028 (IAMRC).

The development of Agrotourism is very much useful for a developing country like India as it helps the development of the rural India. Rural development implies both the economic betterment of people as well as greater social transformation. In order to provide the rural people with better prospects

for economic development, agrotourism can play a crucial role. In the developed countries, people use to visit village settings just to experience and live a relaxed and healthy lifestyle in fresh atmosphere, and this concept has now emerged as a formal kind of tourism. North-East India is well blessed by Nature and it lays at the centre of one of the world's richest biogeographic areas. Though NE India is a very backward region in the whole country, yet it has the greatest potentiality to develop the region into a potent force through agrotourism.

Reasons for Rising Trend of Agritourism:

- **Disconnect from nature in regular urban life:** The world is dominated by urbanisation and technology. This makes people look for a way to reconnect with nature. They want to experience simple living, which is significantly hard in existing landscapes. Agrotourism helps them to reconnect to the nature and to the root.
- **New Learnings:** Agrotourism provides a mode for education about agriculture, environmental conservation, and different agricultural practices. Tourists, primarily small children, learn about the food production process, which enable them to know, from where their food comes.
- **Supporting Local Communities:** Rural areas often face economic challenges, leading to migration towards urban settlements. Agrotourism helps them economically and inspire to preserve the traditional way of life.
- **Genuine Exchange of Cultures:** Agrotourism allows genuine interaction of tourists with local cultures. This interaction fosters cross-cultural understanding leading to preservation of traditions as well as making tourists aware of the traditions.

Significance of agrotourism:

The growth of agrotourism brings a variety of benefits:

- Alternative livelihoods and income diversification: It gives revenue directly into rural communities, boosting their livelihood. It reduces the sole dependence on traditional agricultural earnings.
- Environmental protection and management: Agrotourism focuses on eco-friendly method of organic cultivation and sustainable practices, producing healthier food and promotes environmental conservation.
- Infrastructure development and community development: It helps in creation of infrastructure in the rural area.
- Sustainable and eco-friendly tourism experiences
- Cross-cultural interaction leading to greater social cohesion
- Employment generation in rural area
- Incentivise farmers to use unused resources
- Raises the respectability of agricultural profession and status of farmers
- Helps urban people to understand rural life and agricultural activities
- Retention of rural youth in Agriculture

Principles of agrotourism:

Agrotourism should ensure 3 basic principles:

i. **Something for visitors to see:** Agrotourism can offer many things to see for visitors or tourist animals, birds, farms, nature, culture, dress, festivals, and rural games etc.
ii. **Something for visitors to do:** Tourists can participate in different agricultural operations, bullock cart riding, buffalo riding, milking, cooking, and the rural games etc. during the visit to the agrotourism spots and enjoy.
iii. **Something for visitors to buy**: Agrotourism can offer the tourists to buy different products like farm-fresh agricultural products, handicraft products, dress materials, value added products as memento for remembrance.

Scope of agrotourism:

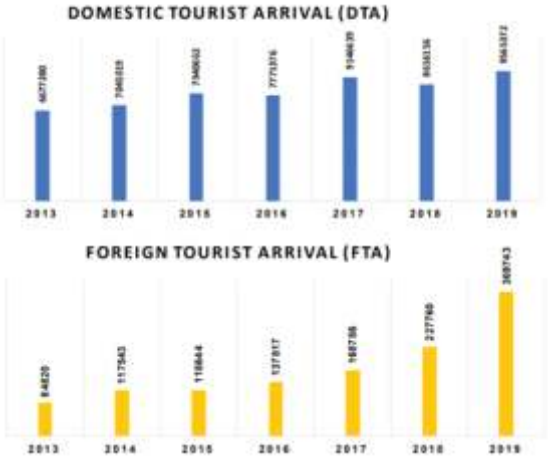
1. **An inexpensive gateway:** In agrotourism, lodging, meals, entertainment, and travel costs are the lowest. The idea of agrotourism expands the reach of travel and tourism to a greater populace due to its affordability.
2. Satisfy curiosity about farming and rural life: Agrotourism which revolves around farmers,

villages and agriculture has the capacity to satisfy the curiosity of the urban population. They can have the idea about plants, animals, source of food, culture and tradition, rural life etc.

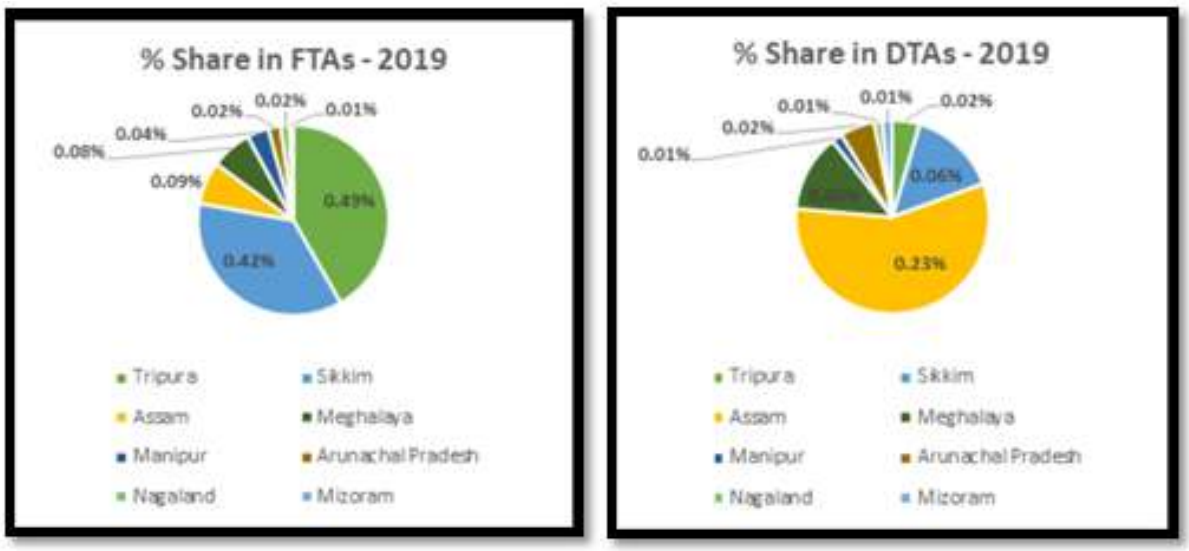
3. **Desire for** peace and tranquility**:** Due to its location distant from cities and close to nature, agrotourism naturally fosters calm and peace.
4. Health consciousness of urban population and finding solace with nature friendly means: Ayurvedic which is a pro-nature medical approach has roots in villages.
5. Interest in natural environment
6. Nostalgia for their roots on the farm: Any suburbanite's goal is to travel to rural areas and spend time with family. However, having even basic amenities might be problematic. Agritourism makes an effort to solve this issue.
7. Rural recreation: The entire family may enjoy a variety of amusement like rural games, festivals, food, clothing, and nature.
8. Educational value of Agrotourism: This offers a special chance for education through enjoyment, where learning is enjoyable, efficient, and simple. Doing is learning, and seeing is believing.

Scope of Agrotourism in North East India

The North Eastern region of India has **a rich cultural heritage and is home to diverse landscapes, including hills, mountains, and valleys.** North-East India is composed of eight states *viz*., Assam, Arunachal Pradesh, Meghalaya, Manipur, Nagaland, Mizoram, Tripura and Sikkim. The region is blessed with scenic natural beauty, salubrious weather, rich biodiversity, rare wild life, historical sites, distinct cultural and ethnic heritage and warm and welcoming people. The region offers unforgettable visits for tourists interested in wild life, religious, cultural and ethnic tourism, river cruises, golf and a host of others. There is also great scope for mountaineering, trekking and adventure tourism in the region. This region is relatively unexplored, but with the recent surge in tourism, more people are discovering the beauty and charm of it. According to Ministry of Tourism, Government of India during 2022 the region witnessed record-breaking tourism in the Northeast Region having **over 11.8 million domestic visitors** and over 100,000 international travellers**.**



Source: Ministry of Tourism, Government of India, available at: https://northeastgis.in/wp-content/uploads/2023/05/Sector-Profile_Tourism



Source: Ministry of Tourism, Government of India, available at: https://northeastgis.in/wp-content/uploads/2023/05/Sector-Profile_Tourism

Northeast of India is having highly diverse agro-climatic conditions. It has varied geography & topography, rich natural resources, biodiversity, colourful and diverged lifestyle, unique handicraft and handlooms and diverged food habits which are matter of enjoyment as well as learning for the tourists. It is home to many wildlife sanctuaries like Kaziranga National Park famous for the one horned rhinoceros, Manas National Park, Nameri, Orang, Dibru Saikhowa in Assam, Namdhapha in Arunachal Pradesh, Balpakram in Meghalaya, Keibul Namjao in Manipur, Intanki in Nagaland, Khangchendzonga in Sikkim. The mighty Brahmaputra flows through the length of Assam where tourists can enjoy memorable river cruises and the flowing rivers of Arunachal Pradesh which feed the Brahmaputra offering incredible white water rafting experiences. [North Eastern Council, Government of India (www.necouncil.gov.in)].

Some of the state-wise top destinations:

Arunachal Pradesh:

- Tawang: Tawang situated at an elevation of 3048 m in northwestern part of Arunachal Pradesh, it is home to the Tawang Monastery which is the second largest and oldest in Asia. There are many other places of interest like Sela Pass, Jang Waterfalls, PTSO Lake etc.
- Ziro: A picturesque town in Lower Subansiri district, it is home to the Apatani tribe. Famous for gentle pine clad hills and paddy cum fish culture. Ziro is also included as in India's Tentative List for UNESCO's World Heritage Site.
- Mechuka: also known as Menchukha, is a small picturesque town at an elevation of 1829 mt. in West Siang District.
- Pasighat: Is the oldest town of Arunachal Pradesh founded in 1911 A.D. by the British. The Brahmaputra emerges from the foothills of Pasighat under the name of Dihang or Siang. [North Eastern Council, Government of India (www.necouncil.gov.in)]

Assam:

- Kaziranga National Park: A World Heritage Site, the park hosts two-thirds of the world's One-horned rhinoceros and also occurs the highest density of tigers among the protected areas in the world and was declared a Tiger Reserve in 2006. The park is home to large breeding populations of elephants, wild water buffalo and swamp deer.

- Kamakhya Temple: A famous Hindu temple dedicated to the goddess Kamakhya. It is one of the oldest of the 51 Shakti Pithas situated on the Nilachal Hill in western part of Guwahati, it is the main temple in a complex of individual temples dedicated to the ten Mahavidyas.

- Brahmaputra River: It is one of the major rivers of Asia and is a trans-boundary river flowing through China, India and Bangladesh. About 2900 km long and flows for about 916 km in India.

- Sivasagar: Was the capital of the Ahom Kingdom and is well known for its Shiva Temple, Ahom palaces and monuments, tea gardens and oil industry.

- Majuli: World's largest river Island and home of Vaishnavite culture and located in the Brahmaputra River. [North Eastern Council, Government of India (www.necouncil.gov.in)]

Manipur:

- Loktak Lake: It is situated 48 km from Imphal, capital of Manipur and is the largest fresh water lake in the NERegion. Small islands that are actually floating weeds on which the Lake-dwellers live in the backdrop of the shimmering blue water.

- Moirang: Situated near the Loktak Lake, this town is one of the main centres of early Meitei folk culture and has a special place in the history of the Indian Freedom struggle as it was at Moirang that the flag of the Indian National Army was first unfurled on April 14, 1944 and has an INA Museum.

- Ima Market: It is a unique all women's market, having 3,000 or more 'Imas' or mothers who run the stalls. It is split into two sections on either side of a road. [North Eastern Council, Government of India (www.necouncil.gov.in)]

Meghalaya:

- Shillong: It is the State Capital of Meghalaya also known as the “Scotland of the East” because of the rolling hills around the town. Shillong has steadily grown in size since it was made the civil station of the Khasi and Jaintia Hills in 1864 by the British. In 2016 it was voted "India's Favourite Hill Station" by HolidayIQ.com.

- Cherrapunji: It is credited as being the wettest place on Earth, but nearby Mawsynram currently holds that record. Cherrapunji still holds the all-time record for the most rainfall in a calendar month and in a year.

- Mawlynnong: It is a village in the East Khasi Hills district about 90 km from Shillong and is famous for its cleanliness and natural attraction.

- Dawki: A border town with Bangladesh, it has the beautiful Umngot River as a major tourist attraction.

- Mawphlang Sacred Grove: One of the most famous sacred forests preserved by traditional religious sanction about 25 km from Shillong. [North Eastern Council, Government of India (www.necouncil.gov.in)]

Mizoram:

- Aizawl: The state capital, is situated at about 1132 m above MSL and is a bustling city set on ridges of steep hills.

- Thenzawl: A village located at a distance of 43 km from Aizawl. The Tropic of Cancer runs through this picturesque village.
- Hmuifang: it is situated in an elevation of 1619 m, is covered with virgin forests reserved since the days of the Mizo chiefs.
- Vantawng Falls: It is located at a distance of about 137 km from Aizawl and is the highest and most spectacular of all the waterfalls in Mizoram. [North Eastern Council, Government of India (www.necouncil.gov.in)]

Nagaland:

- Khonoma: A historic village located about 20 km from the state capital Kohima.
- Wokha: Home of the Lotha tribes is a land of beautiful mountain ranges and rivers and is known for its vibrant dances and folk songs.
- Pfutsero: A picturesque town in Phek district is the highest altitude town and the coldest inhabited place in Nagaland. One can also take a day trip to Khezhakeno village, a very important village in the context of the Naga history. It is said that the first Nagas stayed at this village before moving on to other parts of Nagaland.

Sikkim:

- Gangtok: It is the capital of Sikkim, located at a height of 5500 feet. With a spectacular view of the Khangchendzonga, the town provides the perfect base for travel through the state.
- Changu Lake: the lake is 38 km from Gangtok and at an altitude of 12,400 feet. The lake derives its water from the melting snows of the mountains surrounding the lake. Of legendary beauty, the lake looks different at different seasons.
- Rumtek: It is located around 23 km from Gangtok, it is a quiet getaway and home to the Rumtek Monastery which is the largest monastery in Sikkim.
- Aritar: It is located in east Sikkim, blessed with lush green forests, sweeping hills of paddy fields and placid lakes hidden inside deep forests. The Aritar Gumpa is one of the oldest monasteries in Sikkim belonging to the Karma Kagyu lineage order of Tibetan Buddhism. [North Eastern Council, Government of India (www.necouncil.gov.in)]

Tripura:

- Ujjayanta Palace: It is located in Agartala, state capital, the former royal palace of Tripura (princely state). The palace was constructed between 1899 and 1901 by Maharaja Radha Kishore Manikya and stands on the banks of a small lake surrounded by Mughal gardens.
- Tripura Sundari Temple: The temple is one of the 51 holiest 'Shaktipeeths' (Shrine of the goddess of power) in India as per Hindu mythology.
- Rudrasagar Lake: About 55 km away from Agartala near Melaghar. In the centre of the lake the famous lake palace 'Neermahal' is located. The lake witnesses a large number of migratory birds every winter.
- Unakoti: It is located about 178 km from Agartala, Unakoti means one less than a crore and it is said that these many rock cut carvings are available here. These carvings are located at a

beautifully landscaped forest area with green vegetation all around which add to the beauty of the carvings. [North Eastern Council, Government of India (www.necouncil.gov.in)]

Potential areas for promotion of agrotourism in North East India:

- ✓ Plantation tourism (e.g. tea gardens of Assam)
- ✓ Forest village tourism (e.g. in Goalpara district of Assam)
- ✓ Beel/wetland tourism (e.g. Pala wetland of Mizoram/Son Beel of Karimganj, Assam)
- ✓ Orchard tourism (e.g. Dambuk region of Arunachal Pradesh)
- ✓ Riverine/char area tourism (E.g. Majuli in Assam)
- ✓ Hill farm tourism (e.g. terrace farms of Arunachal Pradesh)
- ✓ Fruit/flower village tourism (e.g. Sohliya- Strawberry village of Meghalaya/Jampui hills of Tripura – orange festival)

Swot analysis of agrotourism in North Eastern Region:

For formulating strategy by consolidating the strengths, overcoming the weaknesses, building on the opportunities and mitigating the threats SWOT analysis is very much important. The SWOT analysis for agrotourism in North East India is formulated below (Choudhury *et al*., 2018):

STRENGTHS:

- · North East India is full of rich natural resources and diversity.
- · Rich cultural heritage is the great potential across the North Eastern regions.
- · Homestays may be a good option for the people because, in North-East India people from all the communities are very much welcoming.

WEAKNESSES:

- · As most of the states are hilly, accessibility and transportation is a concern.
- · Security threats/perceptions: people always make some wrong perception on the basis of one or two spot incidents.
- · Regional spread of resources is not uniform.
- · Very poor brand recall/ Less advertisements.
- · Marketing strategy: In agrotourism also marketing strategy is very much important, without marketing mix no will know about the region. It can be done in three ways e.g. by government, by local people itself or by the tourist itself.
- · Accommodation facilities/infrastructure at rural places is very rare.
- · Scarcity of skilled as well as unskilled labour for homestay, training in this respect for the local people should be organized for the hospitality of the tourist.

OPPORTUNITIES:

- The region offers all in respect of culture, heritage, nature etc. what a tourist looks for.
- The region has many unexplored areas, which are having very high potential for tourism.
- Diversified handicraft and handloom available in the region which can be developed as industry and thereby can improve tourist inflow trend.
- Connected to Soust East Asia through international border.

THREATS:

- Instability in the region and neighbouring regions affects tourist inflows in North Eastern States.
- In respect infrastructure, the region is lagging behind, thus there is strong competition to North Eastern Region circuit from other circuits.
- Probable cultural fabric degradation, which may result in dissolving tourism attraction.
- Over use and commercialisation of sensitive eco zones would lead to depletion of resources and dilution of attraction

Way forward

- Strategic planning and its implementation by concerned government departments like agriculture, horticulture and tourism in collaborative manner
- Creation of service providers in the project areas. Provision of necessary training for such providers is also important
- Policy support for agrotourism at the government level
- Promoting agrotourism start-ups through business incubation centres
- Enabling FPOs to initiate agrotourism as an adjunct business activity
- Encourage venture capital or private equity funding for agrotourism
- For greater effectiveness of agrotourism, approaches to integrate the local traditions and culture are important
- Branding and marketing
- Exploit locational advantage for agrotourism purpose
- Digital transactions for easier access by providing online facilities for bookings & payments

For the expansion of agrotourism concept among the rural mass of the region Govt. agencies can play a vital role as per the mandate of the agencies. The Krishi Vigyan Kendras of the region can arrange awareness among the people and give necessary trainings wherever necessary. The KVKs can develop small agrotourism model in their demonstration farms for demonstration as well as training purpose which will not only encourage the rural mass more particularly the rural youths but also give an opportunity for generation of additional income for the KVK as well.

CONCLUSION

Agrotourism offers a unique chance to integrate components of the tourism and agricultural sectors and provides producers with an extra source of income as well as a channel for direct marketing to consumers. It also offers visitors 'rural experiences,' with the purpose of providing a source of income for farmers and communities in the surrounding area. The development of agrotourism is very much useful for a developing country like India. For economic betterment of people and greater social transformation agrotourism can play avital role. North-East India is well blessed by nature and one of the world's richest bio-geographic areas. The region has the greatest potentiality to develop through agrotourism as the North Eastern Region is full of rich natural resources and diversity, also rich cultural heritage (Choudhury *et al*., 2018). Agrotourism is multi-faceted and may entail farm/ agricultural tourism, cultural tourism, nature tourism, adventure tourism, eco-tourism and with the help of concept of homestay, people from especially North Eastern Region can earn money for their livelihood by which they can also increase their standard of living.

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Recent Interventions in Sugarcane Farming for Enhancing Cane Yield and Farm Income with Special Reference to Punjab

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ABSTRACT

Sugarcane (*Saccharum* spp. complex) is an important sugar crop of subtropical region (NWZ zone) comprising states of Punjab, Haryana, Uttrakhand, Uttar Pradesh and Rajasthan of the country. In Punjab, it is the second most important industrial crop after Cotton, being cultivated on an area of 95 thousand hectares that caters the need of 16 (9 cooperative and 7 private) sugar mills running in the state. Sugarcane scientists and technocrats of the state associated in the improvement of sugarcane crop through various conventional and non-conventional approaches encounter problems of narrow genetic base of crop, complex genome, poor fertility, genetic recombination as well as long breeding selection cycle. During 2015-16 crop season, the concerted efforts of sugarcane scientists, sugar mills and farmers on various researchable aspects has led to harvest cane productivity of 750 quintals per hectare and recorded sugar recovery of 10.07 percent in the state. To sustain the sugar industry of Punjab, it very important to advise sugarcane grower for the choice of the varieties and their planning based on different maturity groups, planting season and type of crop (plant/ratoon). At present, thirteen high yielding, good quality and red rot tolerant sugarcane varieties; 7 in early maturity group (CoPb 95, CoPb 96, Co 15023, CoPb 92, Co 118, CoJ 85 and CoJ 64) and 6 in mid-late group (CoPb 98, CoPb 93, CoPb 94, Co 0238, CoPb 91 and CoJ 88) have been recommended for commercial cultivation, of these three new varieties viz,, CoPb 92 (early) and CoPb 93 & CoPb 94 (mid-late) are found promising for cane yield, commercial cane sugar (CCS) and showing encouraging results among farmers and sugar mills. Since, sugarcane is the raw material for the sugar industry, its juice is used for the manufacturing of gur, shaker, sugar and cane tops are used as fodder while the by-products of the sugar industry include bagasse, molasses, filter-cake, wax etc. The percentage of sucrose varies from 12-18% depending of the variety of cane, its maturity, condition of soil, climate and agricultural practices followed by the growers. In order to sustain cane crushing in mills, planting of varieties in early: mid-late (3:2), early (Autumn: Spring: Ratoon :: 1:1:1) and mid-late (Plant: Ratoon :: 1:1) ratios have been advocated. Besides, recent technological interventions like FIRB (furrow irrigated raised bed), sub-soiling (1mx1m), crop geometry (120mx30m paired row trench planting), single bud chip nursery raising and intercrops (wheat, cabbage, garlic, sarson, onion etc.) have resulted in enhancement of per unit area productivity of sugarcane. In addition, recommendation for management of borer complex (especially early shoot and top borer) with Coragen and Ferterra agro-chemicals have paid dividends to growers and industry in terms of cane production and sugar recovery. Therefore, execution of aforesaid planning and interventions through extension activities in mill command areas are advocated to sustain sugarcane agriculture for the benefits of growers and industry in the state.

INTRODUCTION

Sugarcane, one of the oldest crops known to man, is a major crop of tropical and sub-tropical regions worldwide. Sugarcane is a glycophyte, sucrose storing member of tall growing perennial monocotyledonous grass. It belongs to the family *Gramineae* and genus *Saccharum* L. (Price, 1967; Arceneaux, 1967). It is grown between 35°N and 35°S latitude from sea level to 1600 m above sea level. It is cultivated on a variety of soils around the world from loamy sand to clay. It requires a temperature of 24°C to 30°C and an evenly distributed rainfall/irrigation of 2000 mm for optimum growth (Anonymous, 2017a). Thus, tropical climate is the most suitable for sugarcane cultivation. However, the sugarcane crop is also being successfully grown in subtropical areas. It is being indigenous to India and main source of

sugar, gur and khandsari. About two-thirds of the total sugarcane produced in India is consumed for making gur and khandsari and only one third of it goes to sugar factories. It also provides raw material for manufacturing alcohol. In Punjab, sugarcane occupied about 94 thousand hectares during 2016-17. The average cane yield was 300 quintals per acre. The average sugar recovery was 10.06 per cent. Presently, there are 16 sugar mills in Punjab, out of which 9 are in co-operative sector and 7 are in private sector. The cumulative crushing capacity of the working 16 sugar mills is 49766 TCD (tonnes crushed per day). To run the aforementioned 16 mills profitably for 180 days up to their full crushing capacity, about 1.80 lakh hectare area is required under sugarcane crop so that about 896 lakh quintals of sugarcane is available for crushing (Anonymous, 2017 b). During the year 2014-15, area under sugarcane was 94,000 hectares from which 705 lakh quintals of sugarcane was produced, out of which 569 lakh quintals of sugarcane was crushed and 53.6 lakh quintal of sugar was produced (Anonymous, 2016 a). Recent trends in sugarcane area, average yield, recovery and production in Punjab are presented in Fig. 1. Sugarcane plays a major role in the economy of sugarcane growing areas and, hence, improving sugarcane production will greatly help in economic prosperity of the farmers and other stakeholders associated with sugarcane cultivation.

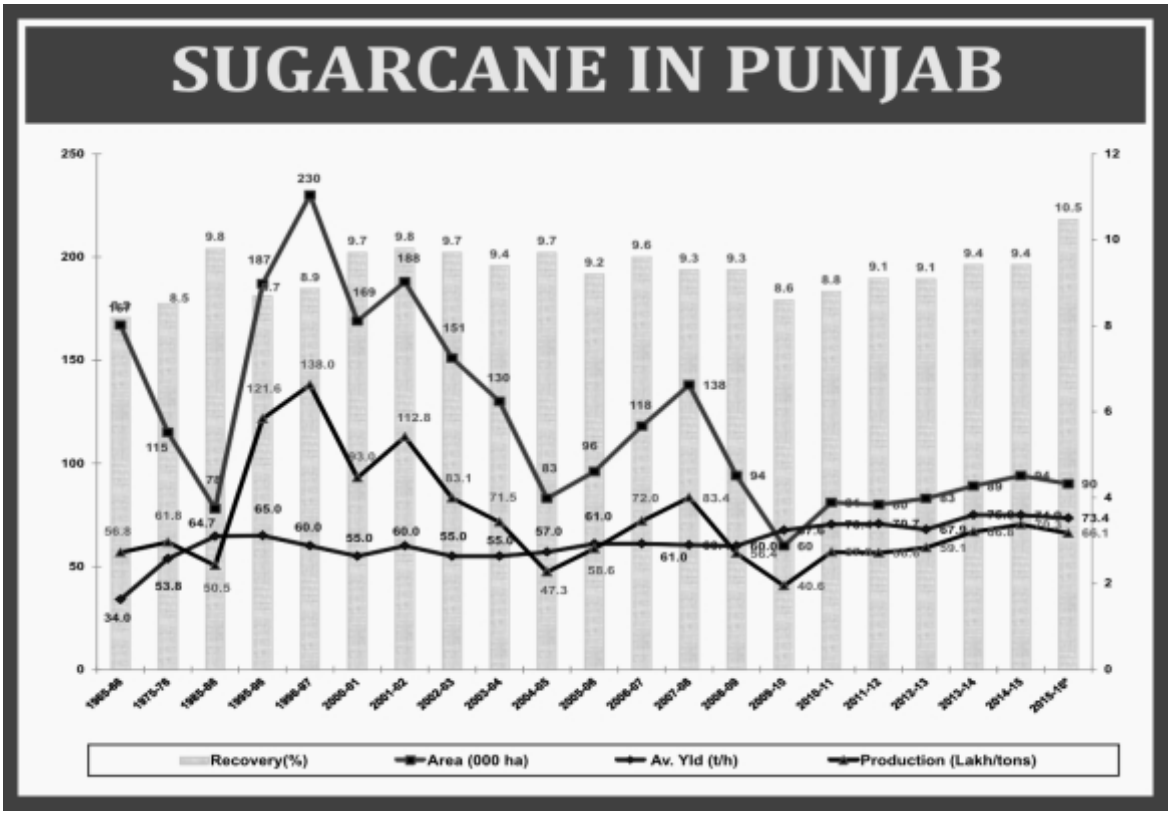

Figure 1: Trends in sugarcane area, average yield, recovery and cane production in Punjab

But the deficit depicted above in the demand and supply of the sugarcane production in the command area hints at the non-realization of resources to the optimum level over the years. The reason might be lower adoption of improved sugarcane production technology. Development of new technology is generally not a major problem but the difficulty is that of acceptance and diffusion of these techniques by the farmers. Hence an attempt is being made through this article to consolidate and disseminate the latest sugarcane production technology.

Constraints in Sugarcane Production

Sugar industry has two major areas of concentration, subtropical region comprising of Uttar Pradesh, Bihar, Haryana and Punjab and the tropical states of Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh in the southern part. Sugarcane being a long duration crop (12-14 months), faces various abiotic stresses like shortage of water, high temperature during summer, low temperature during winter,

flooding during rainy season, nutritional stress, salinity, alkalinity and biotic stresses like fungal diseases as red rot, smut, wilt, rust, pokkah boeng, grassy shoot disease by phytoplasma, bacterial, insects like sugarcane borer, scales, white fly, white wooly aphid, mille bugs and white grub etc. (Vishwanathan, 2011), which are responsible for reduced sugarcane yield and sugar productivity. By excess use of irrigation and chemical fertilizers, the soil has been degraded causing the problems in sustainability of the crop. Sugar industry in Punjab has been plagued with several problems which call for immediate attention and rational solutions.

Low Yield of Sugarcane:

Although India has the second largest area under sugarcane cultivation, its productivity is low as compared to some of the major sugarcane producing countries of the world. For example, India's yield is only 70.8 t/ha as compared to 90 t/ ha in Java and 121 t/ ha in Hawaii (Anonymous, 2017c). This ultimately results in short supply of sugarcane to sugar mills. Efforts are being made to solve this problem through the development of high yielding, early maturing, frost resistant and high sucrose content varieties of sugarcane for the northern region of India.

Short crushing season:

Manufacturing of sugar is a seasonal phenomenon with a short crushing season varying normally from 4 to 6 months in sub-tropical as compared to 8-10 months in tropical India. The mills and its workers remain idle during the remaining period of the year. One possible method to increase the crushing season is to plant and harvest sugarcane at appropriate intervals in different areas adjoining sugar mills. This will increase the duration of supply of sugarcane to sugar mills.

Fluctuating Production Trends:

Sugarcane has to compete with several other food and cash crops like cotton, oil seeds, rice, etc. Consequently, the land available to sugarcane cultivation is not the same and the total production of sugarcane fluctuates. This affects the supply of sugarcane to the mills and the production of sugar also varies from year to year.

Abiotic and biotic stresses:

In sub-tropical region, the extremes of climate are characteristic feature. During April to June, the weather is very hot and dry and the temperatures are extremely high (>45ºC). December and January are the very cold months with temperature touching sub-zero levels in many places. The major portion of the zone *i.e.,* the North-West zone comprising the areas in Haryana, Punjab and Western U.P., has very low temperature in December-January which often causes frost. Because of extremes of weather, the active sugarcane growth is restricted to 4-5 months only. The cane yields are lower in the sub-tropics due to short growing season, moisture stress, more pest and disease problem, delayed planting after wheat and very poor ratoon. The major diseases of sugarcane like red rot, wilt and cryptic disease like RSD have spread to newer areas and genotypes. In the absence of effective control measures, life span of high sugar varieties will be shortened and thus, will hinder the stability of sugarcane production. Moreover, diseases like red rot and wilt are the major bottlenecks in the development of high sugar cane genotypes. Several pests, viz. early shoot borer, top borer, stalk borer, black bug and Pyrilla are serious pests, which cause heavy losses to crop and thereby decreasing productivity in subtropical areas because the environment is more conducive for pest build up. Sugarcane being a crop of long duration (12-14 months), overlapping generations and concealed habitat of borers and simultaneous heavy incidence of sucking pests makes the chemical control difficult, ineffective and highly expensive. The management of these stresses will necessitate the development of better cultivation and integrated diseases and insect-pests management modules.

High cost of Production:

Sugarcane cultivation is labour intensive, inefficient technology (small holding), uneconomic process of production result in high cost of manufacturing. The production cost of sugar in India is the highest in the world. Intensive research efforts are required to decrease the sugarcane production cost by introducing new technologies for efficient production in the sugar mills. Production cost can also be

reduced through proper utilisation of by- products of the industry.

Labour scarcity and scope for mechanization:

Human labour is an important input factor in sugarcane production. The participation of human labour is seen right from preparatory cultivation till harvesting. Being a long duration crop of 12-14 months and its sowing spread from October to May, sugarcane is a labour intensive crop. Since, most of the cane operations are carried out manually and the use of machinery is limited for field preparation especially inter-culture operations, as it requires at least 5 operations including manual planting, application of pesticide, weeding, propping and harvesting. So, there is a need that appropriate and cost-effective machines be developed that can be used by the farmers. This in turn imparts great scope for the mechanization of cane cultivation. All the above factors put together are responsible for varietal degeneration. To increase in sugarcane productivity is the main concern of sugarcane breeding programs and development of high yielding early and mid-late maturing and inbuilt multiple stress tolerant varieties are therefore needed for sustaining sugarcane cultivation in future.

Recent Interventions for Sustainable Sugarcane Farming

1. Raising Yield Ceiling through Improved Varieties

The yield declaration, stagnation and decline observed in high yielding environments have become a danger signal in sugarcane production. The cane production and productivity under Punjab conditions have reached a yield plateau during last two decades (Sanghera *et al*, 2014). It is thus imperative to find ways and means to lift the present yield level, due to adoption of high-yielding varieties (HYVs), optimize the use of various inputs such as water and fertilizer, in order to make the sugarcane production efficient, cost effective, and suitable for resource poor farmers, sustainable and environment friendly (Sanghera *et al*, 2016 c and 2016 d). Many improved sugarcane varieties (both early and mid-late group) have been recently released for general cultivation in the state by PAU Ludhiana to sugarcane growers for high yield and sucrose per cent (Sanghera *et al*, 2016 a and 2016 b) (Table 1). The release of new varieties viz, CoPb 95, CoPb 96, Co 15023 (early) and CoPb 98 (mid-late) have added to varietal diversity in their respective maturity groups and will help in sustainable sugarcane farming in the state.

Table 1: Summary of sugarcane varieties along with their salient characteristics recommended for Punjab

Sr. No.	Variety	Maturity Group	Average Yield (q/acre)	Sucrose (% in juice/ month)	Salient characteristics
1	CoPb 95	Early	425	17.0-17.5 (Dec-Jan)	Canes are tall, thick* with zigzag internode alignment and purplish green in colour with broader leaf canopy. It has field resistance to the prevalent pathotypes of red rot disease, moderately resistant to smut and also less susceptible to top borer. It is a good ratooner, non-lodging and frost tole rant.
2	CoPb 96		382	16-0-18.0 (Nov-Dec)	Canes are medium thick, cylindrical and yellowish green in colour. It is a good ratooner. It is tolerant to the prevalent pathotypes of red rot disease. Quality of gur is very good.
3	Co 15023		310	16.0-18.0 (Nov-Dec)	Canes are medium thick, cylindrical and yellowish green in colour. It is tolerant to the prevalent pathotypes of red rot disease. T

Sr. No.	Variety	Maturity Group	Average Yield (q/acre)	Sucrose (% in juice/ month)	Salient characteristics
4	CoPb 92		335	16.2-17.4 (Nov-Dec)	Medium thin, tall purple -green colored canes, high tillering variety, resistant to prevalent pathotypes of red rot disease and excellent ratooner. Gur quality is very good.
5	Co 118		320	16.2-17.2 (Nov-Dec)	Thick purple green colored canes, field resistance to prevalent pathotypes of red rot disease. It is shy tillering variety, an average ratooner and its gur qua lity is excellent.
6	CoJ 85		305	16.0-17.5 (Nov-Dec)	Shy tillering variety with thick green colored canes, tolerates low temperature stress too. It is an average ratooner and susceptible to red stripe disease. Due to its heavy canes, it is prone to lodging, hence requires proper earthing up. Quality of gur is excellent.
7	CoJ 64		300	16.1-17.5 (Nov-Dec)	It is a good germinator, with profuse tillering and medium-compact growth. Its canes are medium thick, greenish yellow and solid. It has become highly susceptible to red -rot. It is susceptible to top borer. Quality of gur is excellent.
8	CoPb 98	Mid-Late	400	17.0-19.0 (Jan-March)	Canes are tall, thick, cylindrical and yellowish green in colour. It is a good ratooner. It is tolerant to the prevalent pathotypes of red rot disease. The average cane yield is about 400 quintals per acre.
9	CoPb 93		390	17.06-19.6 (Jan-Feb)	Tall and Thick yellowish -white canes, tolerant to prevelant pathotypes of red rot disease and high tillering variety with excellent ratoonability. Quality of gur is good.
10	CoPb 94		400	16.40-19.2 (Jan-Mar)	Tall and thick greenish -yellow canes, tolerant to prevelant pathotypes of red rot disease and high tillering variety.
11	Co 0238		365	17.06-19.57 (Jan-Feb)	Tall, medium thick and yellow green canes. It is susceptible to top borer and tolerant to the prevalent pathotypes of red rot disease. It is a good ratooner. Quality of gur is also good.
12	CoPb 91		410	16.89-19.25 (Jan-Mar)	Tall, thick and yellow green canes. It is tolerant to the prevalent pathotypes of red rot disease. It is a good ratooner.
13	CoJ 88		335	17.1-19.20 (Jan-Feb)	Tall, medium thick and greyish green canes. It tends to behave as early -mid in maturity and also suitable for saline water conditions and tolerant to prevalent pathotypes of red rot disease. It is an excellent ratooner. It is good for cogeneration. Quality of *gur* is excellent.

1.1 Varietal Planning:

Sugarcane plays a significant role in Indian agriculture being a major source of white sugar in the country. It is cultivated in an area of 5.3 m ha with an average productivity of 70.8 t/ha in country while the corresponding figures for Punjab state is 94.0 thousand hectares and 70.0t/ha, respectively (Anonymous, 2016a). At present, there are 16 sugar mills running in Punjab, out of which 9 are in Co-operative sector and 7 are in private sector. The cumulative crushing capacity of the working 16 sugar mills is 49766 TCD. To run the aforementioned 16 mills profitably for 180 days up to their full crushing capacity, about 1.80 lakh hectare area is required under sugarcane crop so that about 896 lakh quintals of sugarcane is available for crushing. During the year 2022-23, area under sugarcane was 96,000 hectares from which 705 lakh quintals of sugarcane is produced, out of which 569 lakh quintals of sugarcane was crushed and 53.6 lakh quintal of sugar was produced. Realization of high yield of sugarcane with high sucrose percent recovery relies on the core varietal planning of entire sugarcane command area by industry and growers. The complete spectrum of varietal planning and crushing schedule is given in Table 2 below.

Table 2: Varietal Planning and Crushing schedule recommendation

Varieties*	Crop	Months
CoPb 95, CoPb 96, Co 1 5023, CoPb 92, CoJ 64,CoJ 85 and Co 118	Ratoon (A & S)	November and December
CoPb,98, CoPb 93, CoPb 94, CoJ 88, CoPb 91 and Co 238	Ratoon (S)	December and January
CoPb 95, CoPb 96, Co 15023, CoPb 92, CoJ 64,CoJ 85 and Co 118	Plant (A)	December and January
CoPb 95, CoPb 96, Co 15023, CoPb 92, CoJ 64,CoJ 85, Co 118 and CoJ 88	Plant (S)	January and February
CoPb 98, CoPb 93, CoPb 94, CoP b 91 and Co 238	Plant (S)	February, March and April

*Varieties are written in the order of preference for crushing (A-Autumn; S-Spring).

Important Considerations for Varietal Planning:

a) The area under early and mid-late varieties should be in ratio of 3:2, respectively.
b) Under early varieties, Spring: Autumn should be planted in the ratio of 2:1, respectively.
c) Proportion of Ratoon crop: Plant crop is maintained as 1:1.

2. New Frontiers in Pre and Post Planting Techniques:

Four to six deep ploughings are required to produce good tilth in field to prepare land for sugarcane planting. Each ploughing should be followed by planking. Furrow turning plough for the first ploughing must be used to pulverize the soil for better soil texture and aeration.

2.1 Sub soiling:

Sub soiling is a process of deep tilling of the ground mainly practiced to un-compact the soil that has occurred due to use of heavy machinery in present day farming. It also improves aeration of the soil and diffusion of nutrients. Tilling deeper would incorporate the subsoil with the top soil. In sugarcane crop, criss-cross sub soiling at 1.0 m spacing should be done once in three to four years before preparing the field. This is done by tractor drawn sub-soiler (chiseler) to the depth of 45-50 cm (Fig. 2) followed by planking to break the clods and then prepare seed bed. This will help in breaking the hard pan below fertility zone, help in increasing water infiltration rate and better penetration of sugarcane roots.

Figure 2: Sub soiling with tractor drawn chiseler

2.2 Tractor operated sugarcane cutter planter:

The planting of sugarcane crop is conventionally done through ridger requiring 30-35 labourers/ha for undertaking various planting operations. These include sett cutting, furrow opening, application of fertilizers in furrows, seed treatment, dropping of cane setts in furrows, application of insecticide, soil covering over the setts in furrows and planking. Owing to non-availability of man power in sufficient number during these days of labour crisis, increased labour input and shrunken time window gap in between two crops planting and also sugarcane planting being a time consuming process, it poses problems before sugarcane growers having 90-92 per cent of the plant area under spring and summer planting. Under these conditions, the germination of buds gets adversely affected due to loss of soil and sett moisture. Keeping this in view, the adoption of two-row tractor operated sugarcane cutter planter (Fig. 3) displays an opportunity through which one can plant 1.50-2.0 hectares with the help of 4 labourers in a day, performing all the planting operations in a single pass.

Figure 3: Two-row tractor operated sugarcane cutter planter

Since these planting operations are done simultaneously, there is no loss of soil and sett moisture resulting thereby 8-10 per cent higher germination. This implement is operated with 35.0 HP. Tractor. The complete sugarcane fed by the labour sitting on the machine is cut automatically into pieces before dropping into the furrows 90 cm apart by the planter. Fertilizers and chemicals are also applied simultaneously by the planter. The seed rate of sugarcane setts of length 23 to 42 cm varies from 32-35 q/acre. This machine can save about 25% cost of operation in comparison to traditional method.

Table 3: Comparative analysis of various implements used for sugarcane planting on its germination, yield and net returns (Anonymous, 2017d)

Particulars	Country plough	Ridger	Cutter planter
Planting cost (Rs./ha)	2550	2450	1200
Germination (Per cent)	36	35	42
No. of shoots (000/ha)	281	282	292
No. of millable cane (000/ha)	104	105	111
Yield (t/ha)	72	73	76
Gross return (Rs./ha)	68400	69350	72200
Production cost (Rs./ha)	26369	26251	26369
Net return (Rs./ha)	42031	43099	45831
Benefit-cost ratio	2.59	2.64	2.73

Considering the cost efficiency, this machine can be used on custom hiring basis also. The comparative performance along with the benefit-cost ratio of different equipments used for sugarcane planting is given in Table 3 above.

2.3 Paired row trench planting:

For sugarcane planting, farmers are using single row trench plantation technique in which inter-row distance is 60-70 cm and due to this spacing about 90-95 trenches per acre are obtained. The trenches are dug by 3 or 5 row trench digger and seed setts of sugarcane are placed at the bottom of the trenches. Then the seed setts are covered by soil with planking. For planting of sugarcane, 85-90 qtl seed sett is needed for one hectare and nearly 10-15 irrigations are given to the crop annually. The major problems in single row trench planting are narrow row spacing, high seed rate, high labour input, high water consumption and difficult crop management operations such as propping up and weeding. The chances of insect and pest attack are higher due to poor wind circulation and poor sunlight penetration etc.

For better crop stand and saving irrigation water, paired row trench planting of sugarcane must be adopted. In this technique, two rows of sugarcane are planted in 30 cm broad and 20-25 cm deep trenches. The cane setts are placed at the bottom of the trenches and covered with the soil left in between two rows. The distance between two trenches should be 90 cm. Trenches can be drawn using newly developed tractor operated PAU designed trencher. In addition to water saving, this method gives comparatively higher cane yield, easy propping up operation and reduces lodging. Ease in mechanical weeding either with power tiller or with tractor operated high tyne cultivator and thus labor can be saved. Because of wider space available in between set of rows, the intercropping of garlic or onion can be done by which system productivity can also be increased. The wider space between two sets of cane allows easy transportation of harvested cane and no damage to roots.

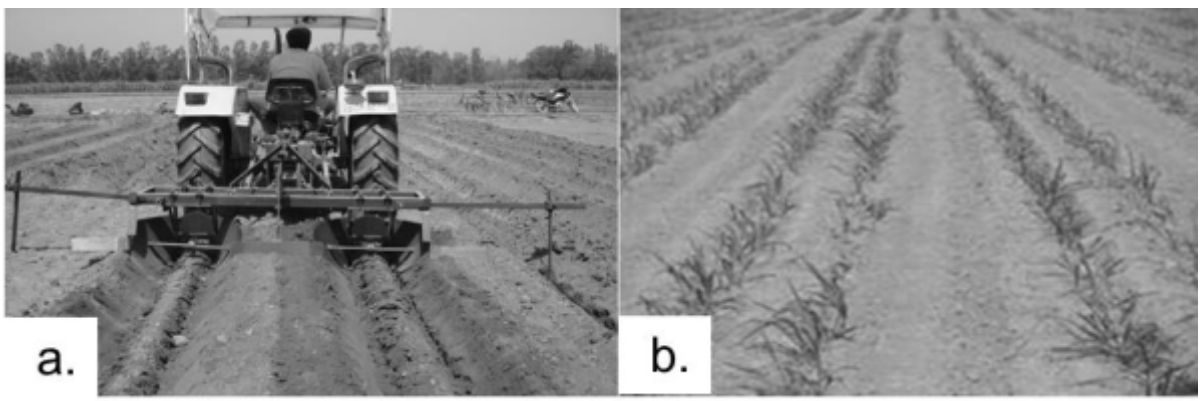

Figure 4 a. Tractor drawn paired row trench planter in operation, b. View of sugarcane germination in paired row planting

2.4 Furrow Irrigated Raised Bed Method (FIRB):

To stabilize the farmer's income, inter-cropping is a usual feature of cane growers. For that matter, the system of inter-cropping in sugarcane must be profitable. Wheat and sarson are the two most relished inter-crops of small growers of autumn cane growing farmers. Philosophy in successful intercropping is providing enough space to crop plans that they don't compete for light, moisture, air and nutrients. Either of the crops should not suffer due to shading effect. Sugarcane can also be planted in standing wheat crop sown by furrow irrigated raised bed (FIRB) planter (Anonymous, 2014). The furrows in standing wheat crop should be reshaped in January to loosen the soil. Apply irrigation in reshaped furrows preferably in the evening before planting of sugarcane setts. The setts may be planted the next day by pressing into the soil manually in pre-opened furrows between the beds, using treated 3 budded setts, during the second fortnight of February to March (Fig. 5).

Figure 5 a. Wheat sown on raised beds, b. Furrows made between beds of standing wheat crop in February-March, c. Sugarcane setts planting in standing wheat crop and d. Sugarcane crop stand after harvesting of wheat crop.

The details of cane yield, its components in sole sugarcane crop, wheat as an intercrop in sugarcane with or without FIRB technique compared for cane yield and cane equivalent yield is appended in Table 4.

Table 4: Comparative details of different sugarcane-wheat intercropping techniques on cane yield and component traits

S. No.	Planting Technique	Cane length (cm)	Millable Canes (000/ha)	Single cane weight (kg)	Cane Yield (t/ha)	Wheat Yield (t/ha)	Cane Equivalent Yield (t/ha)
1	Autumn Planted Sugarcane	154.0	126.9	0.607	76.1	-	76.1
2	Autumn Planted Sugarcane + Wheat (1:2 rows)	130.5	109.4	0.607	65.4	35.9	83.7
3	Autumn Planted Sugarcane + Wheat (1:3 rows)	128	96.5	0.541	52.1	37.9	71.4
4	Sugarcane planted after harvest of 15 November sown	137.7	99.7	0.539	53.4	39.3	73.3
5	Sugarcane planted after harvest of 15 December sown	132.3	92.6	0.519	48.2	29.8	63.3
6	Cane planted in February in furrows of 15 Nov. sown	149.7	120	0.597	71.6	33.8	88.8

S. No.	Planting Technique	Cane length (cm)	Millable Canes (000/ha)	Single cane weight (kg)	Cane Yield (t/ha)	Wheat Yield (t/ha)	Cane Equivalent Yield (t/ha)
7	Cane planted in March in furrows of 15 Nov. sown	140.3	110.4	0.587	64.9	34.3	82.4
8	Cane planted in February in furrows of 15 Dec. sown	142.3	112.8	0.529	59.8	23.3	71.6
9	Cane planted in March in furrows of 15 Dec. sown	136.3	105	0.571	59.0	25.6	72.1
10	Sole Sugarcane planted in Spring (Feb.) at 75 cm	152.3	122.7	0.572	70.1	-	70.1
CD (0.05)		14.8	20.1	NS	11.7	8.5	12.1

2.5 Crop Geometry amelioration for Mechanical Harvesting:

Sugarcane farming is very labour intensive and requires heavy use of machinery. The increase in labour wages as well as its scarcity has led to enhanced dependency of growers on farm machinery in different operations. In order to make use of the equipment to be economically viable, growers must consider factors such as the cost of the equipment in relation to the operation and utilization of equipment, the limitations and suitability of the equipment, slope of the land, field access and other factors such as soil compaction and crop damage and harvesting losses. Wider row spacing is preferred for mechanisation and should be compatible with the wheel tracks of infield machinery and equipment to avoid cane stool damage. The cane setts must be planted at 120 cm row spacing or by using 120:30 cm paired row trench method. This will help in mechanical harvesting of sugarcane. When harvesting mechanically, the variety should also have the attributes like non-brittle cane to reduce losses, resistance to lodging, minimal tops and trash, self-trashing or loose leafed to facilitate trash removal and ratoonability. Chopper harvesters (Fig. 6) have however met most of the requirements of harvesting under a larger range of conditions, slopes, lodged cane, green cane, and topping requirements. Due to their high costs, mechanical harvesters require a large throughput to make them cost effective. The extraction vehicles that support the harvester also need to be taken into consideration. Mechanical harvesting systems also require infield management to minimize field and stool damage due to the high level of infield traffic.

Figure 6: Chopper Mechanical Sugarcane Harvester

General considerations for opening future avenues of mechanical harvesting of sugarcane:

1. For mechanised harvesting to be successful in the sugar industry, several factors like mill receiving facilities, cane payment system and breeding of cane varieties suitable for mechanised harvesting operations require urgent attention.
2. The development and adoption of mechanised harvesting systems are driven by a shortage of manual labour and not by the prospect of lower production costs.
3. The successful implementation of a fully mechanised harvesting system is directly related to pre-planning and level of supervision for sugarcane planting area. The level of efficiency required may only be reached after the second or third season. This is so because it takes time to alter field layouts and field practices to optimise machine performance.
4. Machinery operators also need time to acquire the skills and techniques necessary to maximise machinery performance.
5. The formation of harvesting or contracting groups may improve the viability of the relatively more sophisticated and expensive mechanised harvesting machinery.

1. Capitalizing on Intercropping in sugarcane

Sugarcane is a long duration crop that remains in field for 12-14 months. To harness better returns or enhanced productivity per unit area it is beneficial to grow it with other small duration crops suitable for spring and autumn planting seasons. Some promising crop combinations are detailed below**:**

1.1 Spring Planting:

Amid spring planted sugarcane, vegetables such as cabbage, onion, bell pepper, summer squash and tomato can be grown profitably. However, better results were achieved with summer moong, summer mash and mentha crop, since these caused the lowest reduction in cane yield.

i. Summer Moong/ Summer Mash:

Intercropping of one row of summer moong or summer mash in between two rows of sugarcane planted in spring season may be sown to get an additional grain yield of 1.5 to 2.0 qtl/acre of summer moong/summer mash. It does not affect the cane yield but improves the soil fertility. The brief summary of these intercrop cultural practices is presented in Table 5.

ii. Mentha:

Mentha can also be grown as an intercrop in spring planted sugarcane crop. One row of mentha between two rows of sugarcane may be planted. Mentha and sugarcane can be planted simultaneously in the first fortnight of February. Use one quintal of mentha suckers per acre. In addition to fertilizers recommended, additional 18 kg N (39 kg Urea) and 10 kg P_2O_5 (62 kg Super Phosphate) per acre must be applied. Half N and full P must be applied during planting and remaining N may be applied about 40 days after planting. Only one cutting of Mentha should be taken.

Table 5: Intercrops in spring planted sugarcane crop (Anonymous, 2016b)

Practice	Summer Moong	Summer Mash
Variety	Recommended	Recommended
Seed rate/ acre	4 kg	5 kg
Time of sowing	March 20 to April 10	March 15 to April 7

3.2 Autumn Planting:

Intercropping is a tool to promote autumn planting giving 15-20 per cent higher cane yield and 0.5 units more sugar recovery than spring planted cane. The autumn sugarcane based intercropping systems involving pulses, oilseeds, cereals and vegetables. Many crops like wheat, raya, toria, gobhi sarson, potato, garlic etc. can be used as intercrops in autumn planted sugarcane crop as presented in Table 6. The most profitable intercrops are autumn sugarcane + winter maize (cobs), autumn sugarcane + garlic, autumn sugarcane + wheat, etc.

Table 6: Intercrops in autumn planted sugarcane crop (Anonymous, 2016b)

Name of Intercrop	Variety	Sowing/ Planting time	Seed rate (kg/ acre)	No. of rows between two cane rows	Spacing between rows of intercrop	Harvesting time	Remarks
Potato	Chandermukhi or any other short duration variety	20 Sept. - 15 Oct	800	1	–	End of Dec.	Wheat & onion intercrops can also be taken after harvesting potato crop in en d Dec.
Wheat	Recommended varieties	Last week of Oct - 15 Nov	16	2	20 cm	Mid - April	--
Raya (Brassica juncea)	Recommended varieties	Whole of October	1	2	30 cm	Mid - March	Sow raya either with planting of sugarcane in Oct or after giving first irrigation.
Gobhi Sarson (B. napus)	GSL-1 or GSL-2	10 Oct - 31 Oct	1	1	–	First fortnight of April	--
Toria (B. campestris var. Toria)	Recommended varieties	20 Sept - 30 Sept	1	2	30 cm	End Dec.	Wheat can also be sown after Toria is harvested.
Winter Maize	Partap 1	25 Oct - 10 Nov	7	1	–	May	Sow maize after irrigation or in third week of October
Cabbage	Recommended varieties	Last week of October to November	--	1	--	January and February	Transplant 4 to 5 weeks old seedlings from end Oct to November
Radish	Recommended varieties	October	04-May	2	30cm	January	--
Peas	Recommended varieties	October	22	2	30 cm	--	--
Gram	Recommended varieties	25 Oct - 10 Nov	12	2	30 cm	April	--
Garlic	Recommended varieties	4th week of Sep to first week of October	112	3	15cm	April	For paired row trench planted sugarcane, use 85 to 95 kg garlic seed.

4. Use of *Azotobacter/Consortium* bio-fertilizer in sugarcane: An eco-friendly approach

Among different group of biofertilizers, nitrogen fixing and phosphorous solubilizing bacteria may be considered to be important since they improve plant nutrition. Plant Growth Prompting Rhizobacteria (PGPR) in the biofertilization of crops has been a well-known fact that these PGPR strains may promote growth either by fixation of atmospheric nitrogen or by solubilization, if minerals such as phosphorous and they can also promote growth production of plant growth regulators. The occurrence of *Azospirillum*, *Azotobacter*, *Pseudomonas* and *Bacillus* in the rhizosphere of many plants have been well documented earlier (Rajasekar and Elango, 2011). Application of *Azotobacter/Consortium* biofertilizer @ 4 kg/acre in the furrows at the time of planting would be helpful in increasing the cane yield. The culture is available with the Department of Microbiology, Punjab Agricultural University, Ludhiana, commercially for use in sugarcane crop.

5. Targeted Plant Protection Measures:

Matching with long diversity of conditions under which sugarcane is grown; there is wide spectrum of pests and diseases which have come to acquire a place of priority for control on regional or inter-regional basis due to the agro-climatic management conditions associated with the area, especially in Punjab. In addition, the susceptibility of the variety to the diseases and pests aggravates the situation and creates additive problems.

5.1 Early Shoot Borer:

Early Shoot Borer (ESB) attacks the crop during the early part of cane growth during April-May, before internode formation. Larvae enter the cane laterally through one or more holes in the stalks (shoot) and bores downwards as well as upwards killing the growing point. Thus it cuts of the central leaf spindle, which eventually dries forming a 'dead heart'. The dead heart can be easily pulled out. It emits an offensive odour. Borer infestation during the germination phase kills the mother shoots resulting in the drying up of the entire clump which may cause heavy yield losses as it affects the plant stand/unit area. To avoid its attack, application of 10 kg granules of Regent 0.3 G (Fipronil) in the furrows along the cane setts before covering with soil or spraying 150 ml Coragen 18.5 SC (Chlorantraniliprole) or 45 ml Imidagold 17.8 SL (Imidcloprid) or 2 litres of Chlorpyriphos 20 EC in 400 litres of water/acre along the rows at post-germination stage (about 45 days after planting) effectively controls the early shoot borer. Slight earthing up after application of insecticide followed with light irrigation is mandatory.

5.2 Top Borer:

Top borer, a white moth, attacks the terminal portion of the cane during cane formation stage and induces axillary buds to germinate, causing bunchy top. Subsequently, third and fourth generations cause maximum damage. The larva first tunnels into the midrib of the leaves and causes a white streak which later turns reddish brown, usually in the second to fifth leaf from the top. As a result of biting across the spindle, a number of shot holes are formed in the leaf. In tillering phase of the crop, the attacked shoots die, side shoots (tillers) develop producing a bunchy top appearance. Severe yield loss and quality deterioration occurs due to top borer. Depending upon the incidence level yield loss may be up to 20-30%. For its effective control, apply 10 kg granules of Ferterra 0.4 GR or 12 kg Furadan encapsulated 3G (Carbofuran) or Thimet encapsulated 10 G (Phorate) at the base of the shoots in the last week of June or in the first week of July only if the top borer damage exceeds 5% level. Earth up slightly to check the granules from flowing with the irrigation water and irrigate the crop immediately. This operation will control the third brood of the top-borer which does the maximum damage.

6. Quality Seed Production and Assurance:

Sugarcane is vegetatively propagated for commercial cultivation and requires huge quantity of seed. Different kinds of planting materials viz., cane setts; settlings and bud chips are used for raising sugarcane crop. Stem cuttings or sections of the stalks called "setts" propagate sugarcane. Each set contains one or more buds. Cuttings are taken from the selected canes. The normal practice in sugarcane growing states of the country is to use commercial crop of sugarcane for seed purposes. Sugarcane yields and recovery of sugar deteriorate because of lack of good quality seed. Inadequate availability of quality seed of new sugarcane varieties and poor seed replacement rate adversely affect the realization of

potential cane yield of varieties. Seed replacement with fresh commercial seed is done only after 4 years (Solakhe, 2016). Diseases are one of the major constraints in the profitable cultivation of sugarcane. Sugarcane is vegetatively propagated and it favours accumulation of pathogens of most of the diseases. Hence along with seed canes, disease causing pathogens are also introduced into new areas. Slow accumulation of different pathogens over a period of time makes minor diseases into major one. Several epidemics due to red rot, smut, wilt, grassy shoot, ratoon stunting, yellow leaf and leaf scald occurred in the past indicated that disease infected seed can played significantly in their creation and further spread. Affected planting material poses a major problem in propagation and exchange of germplasm, and eventually in breeding and distribution of superior genotypes. To obtain disease-free seed, a separate seed nursery should be maintained. Do not use the commercial crop for seed, as many pests and diseases go un-noticed in commercial crop.

6.1 Sugarcane Micropropagation:

Micropropagation is the first major and widely accepted practical application of plant biotechnology. It is a key tool of plant biotechnology that has been extensively exploited to meet the growing demands for elite planting material in the current century. Sugarcane micropropagation involves the use of small explants (meristems) which are cultured on a nutrient medium under sterile conditions. Using the appropriate growth medium and growing conditions explants can be induced to rapidly produce multiple shoots, and, with the addition of suitable hormones produce new roots. Sugarcane micropropagation is the practice of rapidly multiplying stock plant material to produce a large number of progeny plants under aseptic conditions using modern plant tissue culture methods. This is a simple method because of the ease of multiplication, saves cost of producing planting material. Micropropagated sugarcane plants are used as breeder's seed in seed multiplication system and seed obtained from micropropagated plants are used as foundation seed (Nerkar 2006; Tawar, 2006). The plants should be spaced 60 cm apart with a row to row to spacing of 90 cm, followed by immediate irrigation.

6.2 Bud Chip Technology:

Sugarcane is normally propagated by stalk cuttings consisting of 2 to 3 bud sett. In conventional system, about 6–8 tons seed cane /ha is used as planting material. Establishing the sugarcane crop using bud chips in place of setts could save about 80% by weight of the stalk material, however this technology has not been scaled up at commercial levels due to poor survival of bud chips under field conditions. So, it is advised to prepare a pre-hand nursery of seedlings from bud chips and then transplanting the seedlings in field at an appropriate time.

6.2.1 Nursery Raising:

For the nursery, an area of 100 square meters is used to produce seed for one hectare land. This is covered with shading net over the young plants and to create more favorable conditions for growth. Only five quintals (5 qtls.) of healthy, disease-free, 7-9 month old canes are required for establishing one acre of field. Out of this, only buds are taken. They are separated from the cane with the help of a specially-designed tool called bud chipper. Damaged, split and sprouted buds are discarded after chipping. The weight of chipped buds is about 85 kg (<5% of the cane weight). The rest of the canes can be sold to sugarcane juice vendors. The chipped buds are chemically treated with to prevent any disease infestation and are filled into gunny bags. A plastic sheet is spread in a corner of the shaded net and sugarcane trash/rice straw is spread evenly on it and water was sprinkled over the material. Chemical-treated gunny bags are laid flat, side by side, on the trash and the buds are spread inside the bags evenly. One more layer of trash is spread above the moist gunny bags and water is sprinkled over it. The entire packs are covered with a polythene sheet. The buds are kept in this position for 5-6 days for pre-sprouting. After the 6th or 7th day, the gunny bags are opened and the well- sprouted bud chips are transferred into plastic trays.

The well sprouted buds are placed in cavities of plastic trays (one per cavity) having a mixture of sawdust, coco-peat and vermicompost below and above the buds. After filling, all the trays are spread inside the net shed and a plastic sheet is placed over them for two days by tightly covering for avoiding entry of water, air or sunlight into the trays. Watering to the trays having seedlings is done in the evenings

based on their moisture content for the next 25 days using spray cans. About 30-35 days after sowing of the nursery, transplanting is done at spacing of 4 ft x 2 ft in the field immediately followed by irrigation in furrows rather than by inundating the whole field. This resulted in saving of huge quantity of water. These seedlings are also used for gap filling in the field.

6.2.2 Economic Considerations:

In sugarcane cultivation, seed is the main input cost, amounting to Rs. 25,000-30,000 per hectare. The cost of seed can be greatly reduced by producing seed in a special seed nursery as described above. For this, farmers can be motivated to produce their own seed nurseries using the above said method; they can reduce the cost of cultivation of sugarcane crop by a huge amount. The economic aspect of sugarcane crop establishment through conventional and bud chip technique is given in detail in Table 7.

Table 7: Economic Comparisons for sugarcane crop establishment through conventional and bud chip technique

S. No.	Particulars	Conventional Method	Bud Chip Technique	Savings (%)
1	Current rate of seed/ha (kg)	8,700 -10,000	165 -200	95
2	Cost of seed/ha (Rs.)	26,000 -30,000	13750	53
3	Seed requirement for state (tons)	564,220	84,633	85
4	Seed cost for state (Rs. crores)	169.26	25.38	85
5	Area for seed requirement (ha)	9,466	1,410	85

6.3 Quality Control Practices to produce a healthy and disease free sugarcane seed:

The following aspects have been emphasized for maintaining the quality of tissue culture raised sugarcane plants:

1. Genetic purity of source material: The genetic purity of the variety to be micropropagated should be certified by the breeder/research organization identified for the maintenance of the variety.
2. Source material: The explant should be taken from vigorously growing healthy plants raised from heat-treated setts and grown under optimum moisture and nutritional conditions. The crop raised from micropropagated seedlings should not be used as source material.
3. Accreditation of micropropagation laboratory: Micropropagation laboratory should be accredited by an appropriate authority to ensure technical competence and satisfactory infrastructure.
4. Micropropagation protocol: Micropropagation protocol should ensure only minimal genetic changes. Shoot multiplication cycles should be restricted to avoid morphological variation.
5. Seedling establishment: The seedlings should be well-established in soil mixture with good root system and with 4 to 5 green leaves at the time of supply to user agencies.
6. Disease indexing: The micropropagation-raised plants should be indexed for freedom from viruses and virus like diseases through ELISA, and molecular methods. Standard molecular techniques may be used to assess the genetic purity of plants.
7. Seed production: The micropropagation-raised seedling should be treated as breeders' (primary) seed. This seed should be further propagated through vegetative cuttings to produce foundation (secondary) seed and then commercial seed. Inspection of the field at the breeders' seed production stage must be done to remove any off types.
8. Commercial seed: Commercial seed thus produced should be used up to four years.
9. The seed stalks propagated from the moist hot-air-treated seed only must be obtained. The treated seed is planted at the Research Stations of the university and is further propagated at the sugar mills farms and farms of selected cane growers. This seed is supplied to the growers to raise the healthy seed-crop.
10. Plant the seed crop in the last week of March after the planting of commercial crop is over.
11. Give a fertilizer dose of 90 kg of N per acre to seed crop. Apply N in 3 equal doses at planting, in May and in mid-July. High dose of N will result in good quality of immature cane-seed.

12. Follow the plant protection schedule strictly to keep the crop free from insect pests and diseases to raise a healthy and quality seed cane crop.
13. Frost injury results in low germination of sugarcane. Therefore, protection of the seed crop against frost is of utmost importance by irrigating it frequently during December and January months.

CONCLUSION:

Sugarcane cultivation in Punjab has suffered a lot on account of shifts in favour of wheat after the introduction of Green Revolution strategy. Sugarcane scientists and technocrats of the state associated in the improvement of sugarcane crop through various conventional and non-conventional approaches encounter problems of narrow genetic base of crop, complex genome, poor fertility, genetic recombination as well as long breeding selection cycle. To sustain the sugar industry of Punjab, it very important to advise sugarcane grower for the choice of varieties and their planning based on different maturity groups, planting season and type of (plant/ratoon). Besides, recent technological interventions like FIRB (furrow irrigated raised bed); sub-soiling (1mx1m), crop geometry (4m paired row trench planting), single bud chip nursery raising and intercrops (wheat, cabbage, garlic, sarson, onion etc.) have resulted in enhancement of per unit area productivity of sugarcane. In addition, recommendation for management of borer complex (especially early shoot and top borer) with Coragen and Ferterra agro-chemicals have paid dividends to growers and industry in terms of cane production and sugar recovery. Therefore, in order to sustain cane crushing in mills, the development of the varieties capable of giving higher cane yield and sugar recovery along with field stability and good ratoonability, adoption of suitable varieties and their blending, adoption of suitable time and method of planting, promotion of intercropping, promotion of mechanization, strengthening of seed production programme, water management, integrated nutrient management approach, integrated pest management, ratoon management, refinement of agro-techniques for sustainable farming system and management of sugarcane under late planting situation. Besides, for making sugarcane farming a sustainable and profitable enterprise, the credit flow and its proper utilization have to be ensured through regulatory framework.

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Recent Plant Protection Measures for Control of Diseases in Millets

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ABSTRACT

Millets are a group of small seeded cereal comprise sorghum, pearl millet, finger millet, little millet, kodo millet, foxtail millet, barnyard millet, proso millet and browntop millet. These crops have easy adoption and can grow successfully in extreme climatic conditions. Diseases are one of the major constraints of millets production & improvement in productivity. A number of fungal and few bacterial, viral, nematode pathogens and partial phanerogamic root parasites are reported to infect the crops at different stages of crop growth. Blast, downy mildew, rust, smuts, ergot, grain mold and spp. are economically important diseases of millets. Few diseases like leaf blight in kodo millet, udbatta in kodo and foxtail millet are reappearing at different millet growing areas. Banded blight in small millets, foot rot of finger millet, leaf blight of little millet and browntop millet, leaf blast of little millet, barnyard millet and browntop millet, rust of browntop millet and *Klebsiella* leaf streak in sorghum are emerging or new diseases. Clean cultivation, removal of infected plants, use of resistant cultivars, and use of bio-control agents as seed, soil application and foliar spray are the feasible plant protection strategies for theses resource poor crops. Need based prophylactic spray of pesticides may be used as last option for management of the disease

INTRODUCTION

Millets popularly known as *Sri Anna* are a diverse group of small seeded dryland cereals generally cultivated in traditional agricultural systems with lesser amount of farm inputs in low fertile soils. Sorghum, pearl millet, finger millet, little millet, kodo millet, foxtail millet, barnyard millet, proso millet and browntop millet are region specific millets, provide nutritional food security to resource poor peoples. Globally, these crops are grown in 30.6 m ha covering 117 countries with maximum area in India (29%) followed by Niger (23%), Sudan (8%), Male, Nigeria (7%),Chad, Burkina Faso (4%), China and Senegal (3%). Global production of millets is 30.9 m t (USDA,2023) and India is the largest producer of millets which accounts about 40% of the total millet production. In India, highest area of millets was under pearl millet (6.7 m ha) followed by sorghum (3.8 m ha), finger millet (1.2 m ha) and other small millets (0.4 m ha) during 2021-22 (Directorate of Millets Development, Jaipur,4th adv. Estimate).These are C4 plants and are beneficial to its grower, consumer and even planet. Millets are well known for their hardiness, their ability to withstand prolonged periods of drought, low maintenance, low water demand, pest resistance, suitable for various cropping systems, rich nutritional and medicinal values and fodder value. A number of diseases are reported in different millet crops that infect at various crop growth stages resulting in enormous loss in quality and quantity of yield under favourable conditions. Some diseases were earlier minor now becoming major. Similarly, few diseases reappeared in moderate to severe form in various parts of the country (Yadava and Jain, 2006, Nagaraja *et al*, 2007, 2015,2016,2020, Patro *et al*, 2018, 2020, Jain *et al*, 2023. Subedi, 2023). Fungal diseases are more common and cause considerable loss in grain yield as compared to other plant pathogens.

I. Fungal diseases

1. Blast

Blast of finger millet, pearl millet, little millet, barnyard millet, browntop millet caused by *Pyricularia grisea* and blast of foxtail millet caused by *P. setariae* is one of the serious threat of millets occurs widely at all millet growing areas (Tharana Poonacha *et al*, 2023). The young seedlings are more prone to the pathogen and showed burnt appearance under favourable conditions. The pathogen infects and develops elliptical, diamond or spindle shaped lesions surrounded by yellow halo on the leaf blade.

Under favourable conditions lesions enlarge and coalesce to form large necrotic areas. In finger millet, the most damaging stage is neck blast followed by finger blast. Yield loss varies depending on the onset of the disease, severity, crop variety and prevailing weather conditions. Average loss in finger millet due to blast is reported 28-36 percent and 30 to 40 percent in foxtail millet and 13 to 15 percent in pearl millet. In foxtail millet, small circular spots with gray centers are formed which measures 3-5 mm in diameter surrounded by a brown margin. In barnyard millet, circular to spindle shaped spots of varying sizes are form on leaf blade. Moderate temperature, high humidity, cloudy days with intermittent rains is favourable for the spread of the disease.

Management: Use of disease free seeds and resistant varieties are economical and eco-friendly options for the management of blast. Pathogen has a wide host range. Hence removal of weeds, wild host plants or self sown plants helps to reduce the blast incidence. Early sowing and maintaining optimum plant population in the field reduces the blast severity significantly. In finger millet, seed treatment with *Trichoderma harzianum* and one spray of *Pseudomonas fluorescens (P.f.)* @ 0.3% at the time of flowering followed by second spray of *P. f.* 10 days later can control all the blast infections. Seed treatment with *Pseudomonas fluorescens* @ 10 g/kg seed + foliar spray with Tricyclazole + Mancozeb 62% WP @ 0.5 g/lit.water, 1st spray at flowering and 2nd spray 10-15 days later controls the blast infections. Seed treatment with Chitosan @2 g/kg seed and two foliar sprays with *P.f.* @ 10 g/lit. water at panicle initiation and grain filling stage is effective against finger millet blast. Seed treatment with tricyclazole @ 8 g/kg seed followed by one foliar spray of *Prosophis juliflora* (10%) plant extract is effective. Two sprays of carbendazim (0.05%) or first spray of Chlorothalonil (0.2%) and second spray of mancozeb (0.2%) were found effective and economical.

2. Leaf spot and leaf blight: All the millets are reported to infect with leaf spot and blight causing pathogens. In finger millet, the disease is caused by *Drechslera nodulosa* and is next to blast in terms of severity and distribution. The pathogen affects all parts of the plant. Sowing of infected seeds causes either pre or post emergence rotting. Characteristic brown to dark brown spots appeared on the leaf lamina. In foxtail millets, *Drechslera setariae* produces brown coloured spots of leaves which enlarge, coalesce and cover the entire leaf blade. Subsequently, the leaves dry up. Leaf blight of browntop millet caused by *Bipolaris setariae* was first time recorded during 2018 from Bengaluru and about 75% plant were found infected. Minute brown lesions (1-5 mm) with small halo are formed on the adaxial surface of the leaves. Afterwards, spots were coalesced and leaves become blighted. Leaf blight of little millet caused by *Alternaria alternata* was first time reported from Bengaluru during 2018 and up to 53 percent disease incidence was recorded. Formation of dark brown, circular to oval necrotic spots surrounded by concentric rings on upper leaf surface are characteristic symptoms of the disease were of little millet . As the disease progressed, infected leaves become blighted. In kodo millet, leaf blight caused by *Alternaria tenuissima* was reported for the first time in India from Kanpur during 1980 and the disease reappeared in a moderate to severe form on kodo millet at Karnataka and M.P. during 2013. Characteristic pale and straw coloured small scattered lesions are formed on the leaf blade. Severely affected plant showed a blighted appearance causing premature drying of leaves from tip to downward.

Management: Seed treatment with Carbendazim @ 1 g per kg seed and one foliar spray of Mancozeb (0.2%) is recommended .Application of Cuman (0.3%) once at flowering and second 15 days later is effective .Foliar spray of synthetic products from garlic oil, neem oil, neem leaf, turmeric rhizome and garlic bulb is effective to minimize the disease incidence. Five foliar sprays of *Impatiens balsamina* and *Solanum nigram* are found effective against leaf blight. Use of Resistant/moderately resistant varieties is the cheapest way to combat with the disease.

3. Downy mildew: Downy mildew of pearl millet and foxtail millet (*Sclerospora graminicola*), sorghum (*Peronosclerospora sorghi*) and finger millet (*Scleropthora macrospora* is an important disease occurs at the seedling stage and continues till maturity of the plant. On sorghum and pearl millet, symptoms are visible on the lower surface of the leaf blade as white downy growth consisting of conidia and conidiophores of the pathogen, which later progresses upward. Barren inflorescence develops in pearl

millet due to systemic infection. In finger millet, affected plants are generally stunted with shortened internodes, profuse tillering and plant assumes a bushy appearance known as crazy top or green ear symptoms. These green ear symptoms are also common on pearl millet. A cool environment and high humidity favour the production of spore and disease development.

Management: Crop rotation with other crops viz., pulses and oilseeds can minimize the primary inoculum of the pathogen. Use of resistant cultivars is the best option. Avoid the secondary spread of the disease by rouging out the infected plants. Seed treatment with Metalaxyl @ 2 g a.i.kg^{-1} seed controls the disease for about a month after sowing. However, seed treatment coupled with a single foliar spray with Metalaxyl or Mancozeb (0.2%) was found superior. A new formulation of metalaxyl Apron Star 42 WS for seed dressing is cost effective. Seed priming with chitosan gave systemic protection against downy mildew of pearl millet.

4. Ergot: Ergot or sugary disease is common on pearl millet (*Claviceps fusiformis*) as well as on sorghum (*Claviceps sorghi* and *C. africana*) and has quarantine implications. The disease is also reported in kodo millet. First visible symptom of ergot infection appears as exudates of viscous pinkish to brownish sweet liquid known as honey dew from the florets. The symptoms can be seen on a single, few or all florets of a panicle depending on severity of infection. Infected florets do not produce grain and adjoining grains from infected panicles show reduced germination. Ergot infection causes loss in seed yield as well as seed quality parameters. About 58 to 70 percent loss in grain yield of pearl millet and 10 to 80 percent in sorghum was reported due to ergot. The pathogen survives in the infected panicles left in the field and sclerotia that are mixed with the seed during harvesting, threshing and processing. Sclerotia contain alkaloids that affect the human and animal health.

Management: Use of resistant varieties, crop rotation with leguminous crops, Inter-cropping with pulses (Red gram) and removal of weeds from field are the eco-friendly management strategies. Early sown crop escapes as compared to late sown crops. Use of 10 percent brine solution is recommended to separate the sclerotia. Foliar spray of Ziram or a mixture of Copper oxychloride + Zineb (1:2), applied 2-3 times at 5-7 days interval started prior to ear head emergence is effective. Foliar spray of Captan @ 0.2% is also effective. Soil application of *Trichoderma viride* @ 500g/acre is also recommended. In pearl millet, the disease can be managed by continuous supply of pollen by maintaining heterogenous plant populations of open pollinated varieties.

5. Smut: Four types of smut namely head smut (sorghum, kodo millet, barnyard millet), grain smut (sorghum, little millet, barnyard millet, finger millet, proso millet), loose smut (sorghum) and long smut (pearl millet) were recorded in millets. Sorghum is infected by all the four types of smuts. Head smut is soil borne, while grain smut and loose smut are primarily carried on the seed surface. Spores get adhered to the seed and germinate in the soil along with the seed. In long smut, the fungus survives as teliospores in infected seed as well as in soil. Teliospore germinates in optimum moisture and temperature and produce sporidia. They becomes air borne, falls on stigma and cause infection. In grain smut few to most of the grains of an infected ear head are transformed into smut sori covered with a membrane. The loose smut infected plants flower earlier than the healthy plants. All the spikelets of an infected ear head get malformed and hypertrophied. In case of head smut, a smut sorus entirely covered with a grayish white membrane emerged from the boot leaf in place of normal inflorescence. At maturity, fungal membrane ruptures releasing spore masses in the air leaving filamentous vascular tissues of the host. In case of long smut, the sorus is covered by a whitish to dull yellow thick membrane. The sorus is larger than grain and appears as enlarged body in place of grain. Grain losses up to 30% have been reported due to long smut in pearl millet. In India, generally smuts are observed sporidically on millets and are of minor importance.

Management: Use of resistant cultivars, removal of infected heads, shallow sowing and application of nitrogenous and phosphate fertilizer minimize the incidence of smut in millets. Seed treatment with *Trichoderma viride, T. harzianum* @ 4-6 g k^{g-1} seed or Seed treatment with Carboxin, Carbendazim, mixture of Carboxin + Thirum, Carbendazim + Mancozeb @ 2 g kg^{-1} seed is economical. Seed treatment

& foliar spray of Triozol (Triadiminol) @ 0.2% at 5-7 days interval is effective. For grain smut of barnyard millet, seed treatment and foliar spray of Carbendazim or Tebuconazol @ (1%) is recommended. Seed treatment with *T. viridae* + 1 foliar spray of Carbendazim is very effective against grain smut of barnyard millet. Seed treatment with Carbendazim, Carboxin, Chlorothalonil @ 2 g per kg seed is effective for the control of kodo millet head smut.

6. Rust: Almost all the millets are infected by rust causing pathogens namely *Puccinia purpurea* (sorghum), *P. subtriata* var. *indica* (pearl millet), *P. substriata* (kodo millet), *Uromycrs linearis* (little millet), *U. setariae italicae* (foxtail millet) and *U. eragrastidis*). In most of the cases, incidence occurs sporadically towards the end of the season and cause little damage to the crop. If rust appears before the ear formation, the disease become serious and destroyed the crop. The rust symptoms appear as minute reddish to dark brown broken postules on both the surfaces of lower leaves. The rust is more severe in upper half of leaves as compared to the lower half. As the disease advances the infection spreads to the younger leaves. The disease may become severe under cool humid weather. Tan type varieties of sorghum and hybrids exhibits good amount of resistance to rust.

Management: Use of resistant varieties, removal of alternate and collateral hosts reduces the rust incidence. Early sown crop escapes from rust incidence. Foliar sprays of Chlorothalonil (0.1%) or Mancozeb (0.2%) or Hexaconazol (0.1%) or Difenconazol (0.1%) or Propiconazol (0.1%) just after initiation of symptoms can control rust incidence effectively. Two sprays at 15 days interval immediately after appearance of symptoms is recommended for better management of the disease.

7. Anthracnose : Anthracnose caused by *Colletotrichum graminicola* is an important disease of grain forage and sweet sorghum but not observed on any other millets. The symptoms can appear as seedling blight, leaf blight, stalk rot and head blight. The disease has adverse effect on grain and stover yield, stover quality of forage sorghum and sugar accumulation in sweet sorghum. Grain yield losses may be up to 20 to 50% under severe conditions. Symptoms first appear on the leaf as minute elliptical to circular spots with straw colour centre and wide margin. Several spots may coalesce to give a blighted appearance on the leaf. Formation of a black dot like acervulus at the centre of necrotic spot is the characteristic symptom of the leaf anthracnose. The disease is more severe during extended periods of cloudy, warm, humid and wet weather.

Management: Deep summer ploughing, clean cultivation and use of resistant cultivars reduces the disease incidence. Seed treatment with Carbendazim, Benlate, mixture of Carbendazim + Mancozeb @ 2 g kg^{-1} seed is effective. Foliar spray with Carbendazim (0.1%), Captafol, Chlorothalonil, Mancozeb, Zineb (0.2%) is also recommended. Seed treatment with Apron-plus (metalaxyl+carboxin+furathicarp) @ 1 g per kg seed along with foliar spray of Carbendazim+Maneb @ 0.2% or Mancozeb (0.2%) is effective.

8. Charcoal rot : Charcoal rot caused by *Macrophomina phasiolina* is an important soil borne disease of rabi sorghum in Maharashtra and Karnataka. The premature lodging of plant is the most apparent symptom of the disease. The pathogen infects root, destroying cortical tissues and may block water movement through vascular bundles. Rotting and breaking of the basal internodes cause lodging of the crop. Extensive lodging can cause 23 to 64% loss in grain yield depending on weather conditions and growth stage of cultivar at the time of infection.

Management: Seed treatment with *Trichoderma* @ 4 g per kg seed or talk formulation of *Pseudomonas chlororaphis* SRB127 reduces the charcoal rot incidence and increases seed weight.

9. Grain mold: Grain mold of sorghum is an important grain disease of sorghum resulted 30 to 100 percent production losses depending on cultivars and prevailing weather conditions. Pearl millet, kodo millet, finger millet and barnyard millet are also infected with mold fungi occasionally. The disease reduces seed value, nutritive value of food as well as feed and cooking quality of the grain. Mold infection becomes visible in pink, orange gray, white or black colour fungal bloom on the grain surface. The severely infected grain becomes soft and disintegrates under slight pressure. The most common species

causing mold are *Fusarium moniliforme, Curvularia lunata, Alternaria alternata* and *Phoma sorghina*. Besides, many saprophytic fungi may also colonize mature grains. Moderate temperature (25-35^{0}C) and >90% relative humidity favours infection and subsequent disease development. In Kodo millet, a number of fungal species i.e. *Phomopsis paspali, Fusarium gramearum, Aspergillus flavus* and *A. tamari* were found associated with kodo millet grains. Consumption of infected grains causes giddiness, vomiting, unconsciousness, difficulty in swallowing in humans and cattles, popularly known as kodo poisoning. Mycotoxins namely Paspalin P-I and P-II, Afla-toxin B 1 and Cyclopiazonic acid were isolated from kodo millet seeds.

Management: Avoid harvesting and threshing of unripe or pre-mature grains. Protect the harvest with rains/moisture, because it makes the grains moldy. Two to three sprays of Mancozeb + Captan (0.2%) or Thirum + Carbendazim (0.2%) or Propiconazol (0.1%) should be taken to reduce the grain mold in sorghum. Pre-harvest foliar spray of Mancozeb (0.25%) also reduced the grain mould. Spraying with talk based formulation of *Pseudomonas* (0.2%) two times increase the seedling growth and reduce the grain mold in sorghum. In case of kodo poisoning, treat the infected grains with cow dung before consumption

10. Banded blight: Banded blight or banded leaf and sheath blight (BLSB) caused by *Rhizoctonia solani* is an emerging soil borne disease of all the small millets. The disease is characterized by oval to irregular light gray to dark brown lesions on the lower leaf and leaf sheath. The central portions of the lesions subsequently turn white with narrow reddish brown margins. Under favourable conditions, lesions enlarge rapidly, coalesce to cover large portions of the sheath and leaf blade. At this stage, the disease symptoms are characterized by a series of copper brown colour bands across the leaves and sheath giving a characteristic banded appearance. In severe cases, irregular to oval dark brown to purplish brown necrotic lesions appear on peduncles, fingers and glumes. The white mycelial growth along with sclerotia of the fungus can be observed on and around the lesions (Jain et al, 2021).

Management: Clean cultivation, draining out of excess water, removal of grass weeds and use of resistant cultivars can prevent the disease. One spray of Propiconazole @ 1 ml/litre of water is cost effective against BLSB in finger millet. Seed treatment with Validamycin or Hexaconazole @ 2ml/lit. of water + 1 FS of same fungicide is very effective against BLSB in kodo millet and little millet. One foliar spray of salicylic acid or sodium fluoride @ 200 ppm induced the resistance against BLSB in kodo millet & little millet. Soil application of farm yard manure/vermi compost enriched with *Pseudomonas fluorescence* + *Trichoderma viride* + *Bacillus subtilis* or only T. viride @ 2 kg /t of manure is very effective.

11. Foot rot of finger millet : Foot rot of finger millet caused by *Sclerotium rolfsii* is a soil borne sporadic disease observed in all finger millet growing areas. The infection occurs in and around the collar region restricted to 2-3 inches above ground level. The basal portion of affected plant appears water soaked that turn brown with a concomitant shrinking of the stem in the affected region. Profuse white cottony mycelia growth occurs in the affected areas with small global white velvety mustard seed like sclerotial bodies. Finally the leaves lose their luster, droop, dry and the plant dries up prematurely. Sandy loam soils, low soil moisture and warm humid conditions favour the disease development.

Management: Use of resistant varieties is the best cost effective management option. Soil treatment with Vitavax @ 10 kg /ha is effective against foot rot of finger millet. Soil application of *Trichoderma viride* + *Pseudomonas fluorescence* 500 g each mixed with 25 kg compost incubated for 15 days and spread over an acre at the time of weeding results least foot rot incidence and higher yield.

12. Narrow leaf spot of finger millet : The disease caused by *Cercospora eleusinis* and appears in June in early sown crops. Disease is restricted to cooler regions, where mean temperature does not exceed 20^0 C. The disease can occur during all stages of plant growth from seedling to grain filling. It disease occurs immediately after heading, it can reduce the yield up to 40%. Reddish brown speaks with yellow halo are formed on leaves. Symptoms also produced on stem, leaf sheath and fingers. Delayed sowing in the month of July decreases the disease incidence and severity. Foliar spray of carbendazim (0.05%) reduces

the disease incidence.

13. Udbatta : Udbatta caused by *Ephelis oryzae* is a seed borne panicle disease commonly observed on foxtail millet, kodo millet and little millet. It is a minor disease of small millets and reported in paddy growing areas (1931). The disease was reappeared in kodo millet in sporadic way during rainy season of 2008 and in foxtail millet during 2013. Infected plants are usually stunted and occasionally narrow stripes are formed on the flag leaf along the veins. Affected panicles are transformed into a compact silver coloured cylindrical spike that looks like an incense stick resembling an *Agarwatti*. Hence, the name Udbatta. Infected panicles fail to produce normal grain and become sterile.

Management: Removal & burning of affected panicles, Keeping bunds & field free from graminaceous weeds, Seed treatment with Carbendazim @ 2 g/kg seed

II. Bacterial diseases

Few minor bacterial diseases were reported in millet crops. Bacterial leaf stripe or bacterial blight (*Pseudomonas andropogonis*), bacterial leaf streak (*Xanthomonas axonopodis* pv *holcicola*), bacterial stalk rot (*Erwinia chrysanthemi*) and bacterial leaf spot (*Pseudomonas syringae* pv *syringae*) were reported to cause sustainable yield loss in sorghum. Leaf streak of sorghum caused by *Klebsiella variicola* was first time reported in sorghum from Hisar (Haryana) during 2019 to 2022. The reddish brown slightly wavy streaks surrounded by bright yellow halo were observed in the inter- veinal spaces of lower and upper leaves and about 20-30 percent plants were found affected with the bacterium. As the disease progressed, the number and size of streaks increased on the leaf blade, coalesced to form large necrotic areas. Bacterial spot caused by *P. syringae*, bacterial leaf streak caused by *X. campestris* pv *pennamericanum* and bacterial leaf stripe caused by *Acidovorax avenae* were reported in pearl millet. In finger millet, bacterial leaf spot (*Xanthomonas eleuisinae*), bacterial blight (*X.axonopodis* pv *coracanae*) and bacterial leaf stripe (*Pseudomonas eleusinae*) were reported. Bacterial stripe (*Pseudomonas syringae* pv *panici*) in proso millet, Bacterial blight or spot (*Pseudomonas alboprecepitans*) and bacterial brown stripe (*P. setariae*) in foxtail millet, bacterial leaf streak (*Xanthomonas* sp.) and bacterial leaf blight (*Xanthomonas campestris* pv *oryzae*) in kodo millet were reported from few localities.

III. Viral diseases

Maize stripe virus and maize dwarf mosaic virus and maize chlorotic dwarf were reported to infect sorghum. In pearl millet, black streaked dwarf virus, guinea grass mosaic virus, maize dwarf mosaic virus, maize streak virus, panicum mosaic virus, satellite panicum mosaic virus and wheat streak mosaic virus were reported. Three viral diseases namely severe mosaic caused by sugarcane mosaic virus, mottle streak caused by mottle streak virus and finger millet streak caused by *Eleusine* strain of mosaic streak virus were recorded in finger millet. Wheat streak virus, sugarcane mosaic virus and *Eleusine* virus 2 infects the barnyard millet crop. Wheat streak virus was also reported to infect foxtail millet and proso millet. Other viruses like rice dwarf or stunt virus and leaf streak virus of maize have been recorded on proso millet.

IV. Nematode diseases

A number of plant parasitic nematodes have been reported in millets and some of them are of economic importance. However, information on the occurrence, distribution, biology, relationship with other plant pathogens and management aspects is meager (Jain, 2009 and Jain *et al*, 2022). Sorghum, finger millet, foxtail millet and barnyard millet were found good host for cyst nematode, *Heterodera delvi* (*H.gambiensis*). barnyard millet was reported good host for *H. avenae* and foxtail millet for *H.zeae* . Association of finger millet and barnyard millet with *Rotylenchulus reniformis* was reported. General stunting and brown to black discolouration on roots were observed in nematode infected plants. Increased population of *R. reniformis* had positive correlation with reduction in plant height, top weight, root weight and grain yield in finger millet. Foliar nematode, *Aphelenchoides besseyi* was reported on foxtail millet as well as on proso millet and causes light ear disease. This nematode pest is of quarantine importance.

Nematodes were found localized beneath the glumes in anhydrobiotic state and up to 16 nematodes with an average of 1.8 per seed were recorded in proso millet. Seed borne nematode can be eradicated by pre soaking of seeds in 1%H_2O_2 for 3 h followed by hot water treatment at 48^{0}C for 15 minutes. Exposing of seeds at 50^{0}C for 15 minutes can eradicate seed borne nematode completely. Concomitant infection of *A. besseyi* and a fungus *Phoma* species was observed in the panicles of foxtail millet under field conditions. Association of *Aphelenchoides* species with finger millet was also reported from Odisha. Two species of spiral nematode, *Helicotylenchus dihystera* on little millet and *H.abunaamai* on little millet, finger millet, proso millet and foxtail millet were recorded. Five species of root knot nematode namely *Meloidogyne incognita, M. javanica, M.arenaria, M.acronea* and *M. graminicola* were recorded on small millets. Foxtail millet was reported suitable host for *Pratylenchus brachyurus*. Whereas, barnyard millet supports the growth and reproduction of *P. penetrans*. Finger millet was also found infested with *P.indicus* in rice field at Cuttak (Odisha). During survey, sorghum, pearl millet and finger millet were found good host for ring nematode, *Macroposthonia oranata*. Stunt nematode, *Tylenchorhynchus vulgaris* reproduced well on kodo millet, little millet, barnyard millet and finger millet and proved good host. Association of *T. mashhoodi* with finger millet was also reported from Odisha. Some other plant parasitic nematodes like *Dolichodorus* spp, *Xiphenema americanum, Pratylenchus* spp., *Longidorus africanus, Paratylenchus* spp., *Rotylechus* spp., *Criconemella* spp., *Meloidogyne* spp., *Helicotylenchus* spp., *Belonolaimus longicaudatus, Paratrichodorus minor* and *Tylenchorhynchus* spp in sorghum, *Radopholus similis, Heterodera gambiensis, Xiphenema americanum, Hoplolaimus indicus, Panagrolaimus* spp., *Criconemella ornata, Meloidogyne incognita*, *M. javanica , M. arenaria, Pratylenchus mulchandi, P. brachyurus, P. zeae, Belonolaimus longicaudatus, Paratrichodorus minor, Tylenchorhynchus vulgaris, T. phaseoli* and *T. zeae* on pearl millet, *Trichodorus* sp., *Criconemoides ornatus, Hoplolaimus indicus* and *Caloosia exilis* on finger millet, *Hemicriconemoides cocophilus* on foxtail millet, *Hemicycliophora* sp. and *Hirschmanniella oryzae* on barnyard millet were recorded and are of minor nature.

V. Phanerogamic partial root parasite

A partial root parasite popularly known as witch weed **(***Striga* spp.) is a serious problem in majority of millets including sorghum, pearl millet, kodo millet and finger millet in light and low fertile soils. Three species of *Striga* namely *S. asiatica, S. hermonthica* and *S. densiflora* have been reported to attack the millets and produces a variety of debilitating symptoms like increase in the host root:shoot ratio, and reduction in photosynthetic efficiency. It damages its hosts by withdrawal of water, nutrients and assimilates. Infestation of *Striga* establishes the close biological association with host plant and inhibits the normal growth resulting devastating yield loss.

Management: The weeding or hand pulling of *Striga* plants before flowering is the cheapest and effective method for its eradication. Application of nitrogenous fertilizers also reduces the infestation of *Striga* species. Soil application of 100% RDF is best for *Striga* management in kodo millet. Soil application of farm yard manure (FYM) + vermi-compost (VC) enriched with *Trichoderma* + *Azospirillum* @ 2 kg/t of manure and application of FYM + VC enriched with *Trichoderma* @ 2 kg/tones of manure before sowing is also effective to minimize the infestation,

Table. 1. Disease resistant/moderately resistant varieties of millets

Crop	Disease	Resistan t sources
Sorghum	Anthracnose	CSH 1,2, SPV 1531, 1533, SPH 1148,1268 , CSV 17, CSV 31
	Ergot	CSH 3,6,9, GSH 1, CSV 4,10, CO 25, Swati ,CSV 17
	Grain mold	CSV 25, CSV 27, CSV 28, CSV 31
	Smut	CSH 9, SPV 102, 104, 115, 245, Jawahar Jowar 8, 1022,1041
	Leaf spots	CSV 17, CSV 18
	Charcoal rot	CSV 17, CSV 22, CSV 36, CSV 29R
Pearl millet	Downy mildew	WCC 75, ICM 7703, ICTP 8023, ISMV 155, RHB 233, RHB 234, H HB 299, ABH 1200Fe , ABH 1269Fe, HHB 311
	Ergot	HB 5, BD 763, MBH 110, PSB 8,JBB 4 , RHB 233, RHB 2 34, HHB 299, HHB 311
	Long smut	Jawahar Bajra 2, MH 179, MBH 188, WCC 75, JBV 3, 4, RHB 233, RHB 234, HHB 299, HHB 311
	Blast	RHB 233, RHB 234, HHB 299, HH B 311
Finger millet	Blast	GPU 28,GPU 45, GPU 48, OEB 10 (Chilika), OEB 526, OEB 532, PPR 2700 (Vakula), VL 315, VL 352, GN 5, GN 6, VL 149, VL 348, VL 379, PRM 1, VR 762 (Bharathi), Srichaitanya, KMR 301, KMR 340, KOPN 235, Dapoli 2, Vegavathi (VR 929), Birsa madua 3, CFMV 1, CFMV 2, CFMV 3 (Ekvijay)
	Brown spot	Vegavathi (VR 929),Birsa madua 3, G owthami, CFMV 2
	Foot rot	Indaf 3, Indaf 6, Indaf 7, GPU 28, MR 6, GN 4 , PR 202 Vegavathi (VR 929), Birsa madua 3, CFMV 1, CFMV 2, CFMV 3 (Ekvijay)
	Ban ded blight	GPU 28, VL 379, Vegava thi (VR 929), Birsa madua 3, VR 988,CFMV 1, CFMV 2, CFMV 3 (Ekvija y), Gowthami
	Smut	VL 149, GPU 28, GPU 45, GPU 67
Kodo millet	Head smut	JK 41, JK 48, JK 439, KK 1, KK 2, JK 106, JK 13, JK 65, JK 98, TNAU 86, JK 137, ATL 2, JK 9 -1, CKMV 2
	Banded bligh t	JK 13, CKMV 2, ATL 1
	Striga spp	JK 41, JK 155 and GPUK 3
Little millet	Grain smut	OLM 20, OLM 203 (Tarini), OLM 217, GNV 3, GV 2, JK 4
	Banded blight	OLM 36 (Kolab), OLM 217, Chhatisgarh Sonkutki, CLMV 1, JK 95, GV 2
	Blast	GNV 3, OLM 203 (Tarini), JK 95, GV 2
	Rust	OLM 217, Chhatisgarh Sonkutki, CLMV 1, JK 95, GV 2
Foxtail millet	Blast	SiA 3085, RAU 2, SiA 3223 (Renadu), SiA 3088 (Suryanandi)
	Brown spot	RAU 2
	Banded blight	RAU 2
	Downy mildew	SR 16 (Meera),Si A 3085, RAU 2, SiA 3223 (Renadu), SiA 3088 (Suryanandi)
	Rust	TNAU 196, RAU 2
Barnyard millet	Gra in smut	VL 29, VL 172, VL 207, K1 , ER 64 (Pratap Sawan 1), TNAU 143
	Banded blight	IIMRBM 8 -1920, VMBC 335
Proso millet	Banded blight	TNAU 202
	Leaf blig ht	PMV 442, TNAU 202, PRC 1, TNAU 143
	Leaf spot and blight	GPUBT 2, HBR 2

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Possibilities of Use of Drones for Spraying Pesticides in Precision Agriculture

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ABSTRACT
Today, everybody is talking about practical use of drones in agriculture. In precision farming, drones may be used for mapping soil fertility, devising production agronomy, study of natural resources and vegetation, weed control, insect-pest and disease control and grain yield forecasting. Conventionally, the spray of pesticides or application of liquid fertilizers is done with knapsack sprayer which is laborious, time consuming and increases drudgery. To save time, farmers resort to use tractor operated power sprayer with long hose pipe ending into a spray gun. However, complaints of poor pest control and damage to non-target organisms are often recorded with this practice. In Punjab, use of drones for pesticide spray looks very lucrative to farmers with big land holdings. But, relatively a greater number of small and marginal land holdings of farmers and alternate land use is posing a great challenge to mechanization of agriculture. Drones can scan the ground and spray the correct amount of liquid with even coverage, resulting in increased efficiency with reduction in pollution of underground water. The drone operations are being permitted by Ministry of Civil Aviation (MoCA) and Director General of Civil Aviation (DGCA) through the conditional exemption route. The use of drones for spray of pesticides and safety of drone operations is under testing phase and guidelines have been framed for spray of some insecticides and fungicides. We are hopeful that the agricultural industry will use this new machinery for precision agriculture.

INTRODUCTION
In modern agriculture, pesticides are critical components and the traditional practice of spraying pesticides by knapsack sprayers causes uneven distribution in the fields. Injudicious use of pesticides and their faulty spraying methods is reported to cause tumors, hypersensitivity, allergies, and other illnesses in users (Souvanhnak hoomman, 2021). Hence, Drone can be used to automate the pesticide spraying that will save time, cost, ensures uniform application. The smaller diameter of droplet makes the pesticide more well-distributed which improve the pesticide efficacy (Biswas *et al*, 2023).

A drone is an unmanned aerial vehicle used commercially since the early 1980s. Today, however, everybody is talking about practical use of drone in agriculture. Agricultural drones are expected to revolutionize the way we conduct agronomic procedures. Agricultural producers must embrace new and innovative strategies for producing food for feeding 9 billion people by 2050. The major advantages of drones in agriculture are firstly, monitoring agricultural fields or bare soil or water bodies with in-built sensors or camera, and second, geo-tagging of agricultural fields for digitization of revenue records. Now, we have advanced sensors and imaging capabilities of drones. In precision farming, drones may be used for mapping soil fertility, devising production agronomy, study of natural resources and vegetation, maintenance of adequate irrigation, weed control, pest & disease control, grain yield forecasting and economic advantages (Nukala *et al,* 2016*)*. The bird' eye view can reveal many issues such as irrigation problems, soil variation, and pest problems. Multi-spectral images at periodic intervals show both near infra-red and visual spectrum view, and this combination is very helpful in differentiating healthy crop from unhealthy ones.

In developed nations like USA and Australia, where agriculture is fully mechanized, some vacant space is kept for movement of traffic wheels. So, tractor operated machinery can be used for interculture or application of various pesticides and fertilizers in standing crop. However, in developing nations like India, agriculture mechanization is still in nascent stage. In some states like Punjab, mechanization of agriculture is stressed upon because of labour shortage. But, relatively a greater number of small and marginal land holdings of farmers and alternate land use is posing a great challenge to mechanization of agriculture. Further, mobility of vehicle in standing dense crop stand especially in solid drilled crops like rice and wheat is not feasible. Conventionally, the spray of pesticides or application of liquid fertilizers is done with knapsack sprayer. This method is laborious, time consuming and increases drudgery. To save

time, farmers resort to use tractor operated power sprayer with long hose pipe ending into a spray gun. The spray liquid blows through PVC tube and reach the nozzle where the speedy air from blower, blasts the liquid into very fine droplets through small opening on mouth of spray gun. But this practice is wrong as spray is not done in proper method and very often, complaints of poor control are recorded.

Scope of drone usage for pesticide spray

In India, the use of drones in agriculture (especially agriculture spraying) needs special permission. The Indian government initially approved the use of drones for agricultural research for the International Crops Research Institute for the Semi-Arid Tropics, Hyderabad (Prakash *et al*, 2022). Ministry of Civil Aviation (MoCA) has published 'Drone Rules 2021' vide GSR No. 589(E) dated 25th August 2021 to regulate the use and operation of Drones in India. The additional guidelines for providing agricultural services through drone technology under Sub-Mission on Agricultural Mechanization (SMAM) has been released by Department of Agriculture & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India on 17th January, 2022. MoCA and Directorate General of Civil Aviation (DGCA) have granted conditional exemption from Unmanned Aircraft System (UAS) Rules, 2021 to 10 organizations. These exemptions are valid for a period of one year from the date of approval or until further orders, whichever is earlier, and shall be subject to the terms and conditions of the SOP issued by DGCA. Currently, 90% of drones in use in India are imported. There is no component ecosystem in the country and most of the major components are imported, especially from China (Anonymous, 2021).

Factors affecting use of drones for pesticide spray applications

The use of drone for pesticide application can reduce the shortage of labour and increase the spraying efficiency. Drone can perform pesticide application in a short period of time without destroying the soil and the crop (Berner and Chojnacki, 2017). The movement of drones is very quick over the field crops and spraying height above the plants can also be adjusted easily (Faiçal *et al*, 2017). It also minimizes the risk of non-target pesticide poisoning (Kedari *et al*, 2016; Vardhan *et al*, 2014). Use of drones for pesticide application looks very lucrative to farmers with big land holdings. Drone use in agriculture can increase their farm efficiency. According to an estimate, aerial spraying can be completed five times faster with drones than with traditional spraying. Aerial spraying can be done and offers new fronts for crop mechanization. There is a lot of room for growth with agricultural drones. But this should be practiced with utmost care and certain points must be kept in mind before opting for use of drone:

1. A pesticide needs to be applied to a particular 'Target' area occupied by pests - an insect, disease or weed. Aerial spraying because of its inherent nature is very risky affair. It can drift away to non-target sites and pollute the environment.
2. A drone, when used in field, causes a lot of turbulence and thrust with their circular motion. This turbulence may be beneficial as it can cause pesticide to reach the target disease organism or herbicide at ground. But this turbulence may be harmful to crop at maturity stage.
3. According to the volume of spray applied per unit area, pesticide spraying techniques are broadly classified as High Volume (HV), Low Volume (LV) and Ultra Low Volume (ULV). The spray volume of more than 150 L/ha, 10-150 L/ha and 1-5 L/ha is used in HV, LV and ULV, respectively. To ensure effective and uniform spray, 200-250 L/ha for insecticides while, 375-500 L/ha of spray volume is required for effective spray of fungicides and herbicides. A drone is equipped with spraying tank of 10-15 L capacity only. Therefore, either we must refill the spraying tank very frequently or resort to use of LV or ULV spray application technology for spray over one acre area.

   It is worth to mention here that in developed nations, initially high-volume spraying technique was used for pesticides application. The advent of equipment with improvement in the technique of producing smaller droplets, now the trend is to use minimum amount of carrier or diluent liquid with usage of low volume and ultra-low volume technique. The quantity of pesticide per unit area remains the same regardless of the volume of water used for HV or LV or ULV.
4. Pesticides are mostly applied on the target in the form of spray droplets. They are defined in term of their diameter and density on the target. The droplets diameter of a given spray can be measured as the median of either the volume or number of droplets. Droplet size is most important for efficient application with minimum contamination of environment, and correct droplet size, density and distribution is primary criteria for successful application of pesticide. The droplets are classified according to their Volume Mean Diameter (VMD) by American Society of Agricultural Engineering (ASAE) standards (Table 1).

Table 1. Classification of droplets according to volume mean diameter

Symbol	Category	VMD (micron)	Comparative size (micron)	Atomization
VF	Very Fine	< 100	25	Fog
F	Fine	100 -175	100	Fine Mist
M	Medium	175 -200	150	Fine Drizzle
C	Coarse	250 -375		Light Rain
VC	Very Coarse	375 -450	420	
EC	Extremely Coarse	> 450	2000	Thunderstorm

5. The fate of droplets from the time of their formation by a nozzle until their deposition onto a target is influenced by several factors such as: velocity of droplet ejection, gravitational force, wind velocity, air turbulence caused by thermal movement, volatility of the spray liquid and characteristics of target surface.

6. Small droplets of pesticide have low terminal velocity and remain suspended in the air for longer times. This can lead to major environmental hazards in the form of air pollution and risk for non-target flora and fauna. The suspension time of droplets can significantly impact their effectiveness in various applications. The time it takes for droplets to fall a distance of 10 feet varies dramatically based on their size. Droplets with a diameter of 1 micron take approximately 28 hours to descend while droplets with a diameter of 100 and 1000 microns take just 11 and 1 second, respectively (Ross and Lembi, 1985).

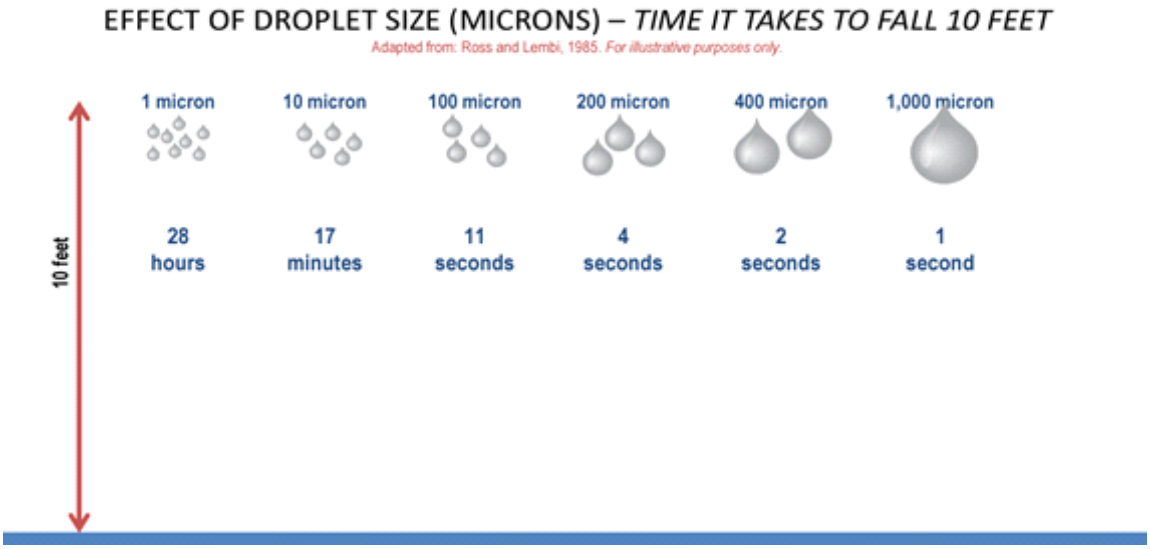

Figure 1: Effect of droplet size on suspension time (Adapted from Ross and Lembi, 1985)

7. There will be considerable loss of spray volume due to drip and drift, the deposition of spray on non-target areas and due to erratic distribution of droplets on target surfaces. Loss of spray by drip and drift are more prominent in HV and ULV spraying technique, respectively. HV spraying techniques led to coarser spray particles. Coarse droplets are largely influenced by gravitational force and relatively unaffected by turbulence. The drift depends upon nozzle type, application volume rate, orifice size, and formulation. Fine droplets will be influenced by wind and turbulence and tend to drift. Droplet sizes more than 300 microns are lost by drip whereas the droplet sizes less than 100 microns are lost by drift. The relationship between droplet size and drift reduction is crucial for effective application. Smaller droplets may enhance herbicide efficacy due to better coverage while larger droplets reduce drift potential but may compromise coverage.

Technical and operational challenges while working with drones for pesticide application

1. Drone ownership is restricted to Indian only and there is need of registration with Digital Sky Platform App and Unique Identification Number (UIN) is required for UAV>250g. This UIN shall be linked to the unique serial number provided by the manufacturer. Safety and security features like 'No permission - no take-off' (NPNT), real-time tracking beacon, geo-fencing, capability *etc.* to be notified in the Official Gazette in future.
2. Flying in the densely populated areas or large crowds must be avoided. The drones must be used during daylight hours and under good weather conditions.
3. In India, only remote pilot license (RPL) holding person enlisted in digital sky platform can operate a drone. In RPL, category, sub-category and classification of the unmanned aircraft system or a combination of these should be mentioned. No remote pilot license shall be required for operating a nano and micro UAS for non-commercial purposes. Drone user must be trained drone pilot and should have attained the age of 18 years and not more than 65 years. Training in UAV Operations is being run at only 23 centres or areas. All drones (except nano drones) must have valid third-party insurance policy to cover the liability that may arise on account of mishap. Basic drone laws must be followed while flying a drone over 250 grams weight.
4. UAVs available today can only fly for a limited time (15-30 min) and for the uninterrupted operation of the drone, frequent charging is required. Unmanned aerial vehicles can be used to their full potential and economic impact only when they are capable to stay in flight for a longer duration.
5. The drone can be flown based on interactive airspace maps which include green, yellow and red zone. The airspace map is available on DGCA's digital sky platform. No one can operate a drone in the yellow or red zone without prior permission and follow Carriage of Dangerous Goods Rule, 2003.
6. There is payload Limitations as well. The tank cannot be filled beyond 20-30% of the total weight of the system.

Standard Operational Procedures (SOPs) for Application of Pesticides with Drones

To widen the scope of drone assisted pesticide application for different crops grown under diverse climatic conditions, the Government of India has brought Standard Operating Procedures (SOPs) for use of drones in pesticide and nutrient applications that provide concise instructions for effective and safe operations of drones (Anonymous, 2022). SOPs were prepared by taking into considerations the relevant parameters like temperature, humidity, wind speed, terrain and crop as well as other environmental parameters. The SOPs for use of drone for pesticide application for crop protection in agricultural, forestry, non-cropped areas, etc cover important aspects like statutory provisions, flying permission, area distance restrictions, weight classification, overcrowded area restriction, drone registration, safety insurance and piloting certification, operation plan, air flight zones, weather conditions, SOPs for pre, post and during operation, emergency handling plan etc. The critical parameters have been also considered for drone-based pesticides application such as drone related, pesticides, environment limitations, pilot training, drift management, critical operational parameters, safety precaution during operation, registration requirements of pesticides for drone application, spray monitoring form and data submission, etc. The data was received for nine major crops i.e. rice, maize, cotton, groundnut, pigeon pea, safflower, sesame, soybean, and sugarcane. Based on the available information, the crop specific SOPs were developed for application of different insecticides/ fungicides through use of drones. The crop specific SOPs were developed considering a standard drone with tank capacity of 10 liters and overall weight of the drone less than 25 kg. The SOPs for herbicide spraying are still not finalized.

Way Forward

The use of drones may help increase crop production and monitor crop growth with sensors and digital imaging capabilities. There is a lot of room for growth with agricultural drones and use of drones for spray of pesticides and safety of drone operations is under testing phase. We are hopeful that the agricultural industry can actually use this new machinery. Pesticide application from air may be used to treat aquatic weeds like water hyacinth, paddy fields, large sugarcane plantation, orchards where other methods cannot be employed. Presence of various obstacles like trees, small land holdings and diversified

farming in India are bottle necks in its use. The drift hazards may lead to environmental pollution and damage to non-target organisms.

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KVK Model for Technology Transfer and Dissemination

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INTRODUCTION

India's economy depends on agriculture being agrarian economy. About two-thirds of the population here is sustained by agriculture. Today we are self-sufficient in food grain production and are capable of agricultural production as per requirement. In fact, the National Agricultural Research and Extension System has a significant contribution in this success. Field extension in India is mainly provided by five departments such as Department of Agriculture and Cooperation and its related Rural Ministry, Krishi Vigyan Kendra, Indian Council of Agricultural Research and State Agricultural Universities, Frontline extension, commodity boards and input agencies and non-governmental organizations.

Extension System in India

After India's independence, various projects were started, the objective of which was to increase agricultural production as well as rural development. However, some rural development projects were initiated by social workers before British rule/independence in India. Extension programs have been developed at two levels-

Before Independence (1866–1947)

At the time of dependence, many efforts for rural development were made by individuals and private agencies, such as the Gurugaon Project, Sriniketan project, Sevagram project, Marthandam project, Sarvodaya Program etc. were started. In June, 1871, the Government of India established the Department of Agriculture and in 1882, the Agriculture Department started working structurally in almost all the areas. In 1905, the Government of India established the Imperial Agricultural Research Institute in Bihar for the development of new methods of production, which was changed to the Indian Agricultural Research Institute, New Delhi in 1936. Although agriculture is a state related subject, Indian Council of Agricultural Research has an important contribution in increasing agricultural production by incorporating new technologies in agriculture.

After independence (1947–1966)

After independence, Etawah project was started by Albert Mayer as an experimental project for intensive all-round development. This project laid the foundation of community development project and led to the development of the concept of multipurpose village-level worker. This project was based on principles like self-help, democracy, integrated approach, people's needs and cooperation. Further, during 1960, Intensive Agricultural Development Program was started, whose main objective was to solve the problems faced in agricultural production by adopting advanced agricultural techniques through coordinated and intensive approach.

Extension Approaches after green revolution

In the year 1966, the High Yield Varieties Program was started whose objective was to achieve self-sufficiency in food grains in the country. Under this program, along with high yielding varieties, balanced fertilizers, proper irrigation, crop protection and use of advanced equipment were recommended, as a result of which Green Revolution became possible in the country. In the year 1971, the headquarters of Extension Education was created in the Indian Council of Agricultural Research, which was converted into the Department of Agricultural Extension. Its objective was to establish functional relationships among research institutes, agricultural universities and related institutions.

Further, ICAR launched four main technology transfer projects namely National Demonstration Project, Operational Research Project, Krishi Vigyan Kendra and Lab to Land Project. National Demonstration Project was started on main food crops at the national level in the year 1964 which had a

similar outline and its objective was to demonstrate the genetic production potential of major crops.

The Operational Research Project was started in the year 1974-75. This project was mainly started in watershed areas. It covers various subjects like cultivation of food crops, mixed farming, integrated coordinated pest management, plantation crops, post-harvest techniques, tillage and tillage reclamation, land reclamation, dry land management, fisheries etc.

Krishi Vigyan Kendra

(Farm Science Center and Trainers' Training Center was established in the year 1974. Whose main objective was to increase the technical knowledge among the farmers and it was based on the principles of "learning by doing" and "seeing by doing".

Lab to Land Program was started in the year 1979 on the occasion of the Golden Jubilee of the Indian Council of Agricultural Research, through which practical technologies were to be taken from the laboratory to the fields of farmers.

In the year 1992, national demonstration, operational research, and lab to land projects were merged into Krishi Vigyan Kendra. In the research system, Krishi Vigyan Kendra is a center working at the grassroots level through which assessment and refinement of technologies based on farmers' problems and place is done.

Agricultural Technology Information Center (ATIC) was established by the Indian Council of Agricultural Research which works like a single window system. Through this, technical information, diagnostics, advice and technical inputs are provided to the farming community. Kisan Melas are organized by them to showcase new technologies at the state and regional level.

Institution Village Linkage Program (IVLP) was started in the year 1995 under technical assessment and refinement to introduce technical measures to achieve stability and sustainability with high yield in small agricultural production system.

National Agricultural Technology Project was launched on 30 June 1998 by the Indian Council of Agricultural Research, New Delhi with the assistance of the World Bank to increase the output of the National Agricultural Research System and to strengthen and complement the existing resources.

Further, **National Agricultural Innovation Project** was launched by the Indian Council of Agricultural Research in the year 2007 for rapid and sustainable transformation of Indian agriculture through poverty alleviation and income generation. Through this, the main objective was to expand the technologies developed through innovation system in neglected areas to improve the livelihood of villagers and change the social and economic situation.

Agricultural Technical Management Agency (ATMA)

Agricultural Technical Management Agency is a society of important stakeholders whose objective is to carry out agricultural activities for sustainable agricultural development in the district. It is a focal point for integrating research and extension activities and decentralizing the day-to-day running of the public agricultural technical system. District level agricultural technical management agency was started with the help of the World Bank. It was started as a pilot project in 28 districts of seven states between 1998-2003. In the year 2007, it became fully functional in all the districts. It is a registered society responsible for technology dissemination at the district level. Extension activities are carried out at the grassroots level through Block Level Technical Teams (BTTs) and Farmer Advisory Committees (FACs), farmer groups and self-help groups.

Research-Extension-Farmer Linkage

There is a need for a strong research-extension-farmer linkage to deliver agricultural technologies to the farmers as per the location specific and need of the farmers, in which all three together identify and solve the problem and their participation is required more in this. In line with this, efforts were made to institutionalize research and extension linkages at the national, regional, state and zonal levels.

Front line Demonstration

The concept of frontline demonstration was introduced by the Indian Council of Agricultural Research in the mid-eighties in the beginning of the Technical Mission on Oilseed Crops. Under the

supervision of scientists of the National Agricultural Research System, field demonstration is conducted which is called frontline demonstration. In this, the technology is demonstrated for the first time by scientists, after which it is expanded by the agriculture department of the state to further disseminate at wider scale.

Showcasing of advanced technologies by Krishi Vigyan Kendra

(a) Advanced technologies and dissemination for enhancing the income of farmers

Continuous efforts are being made in this direction by the ICAR and KVKs. For this, it is also necessary that as production increases, the cost of inputs should also be reduced. Keeping these facts in mind, there is a need for such technologies/systems in which the product of one system acts as an input for the other system and they complement each other.

Integrated farming system is capable of enhancing the income of farmers. The IFS is an interdependent, interrelated and interconnected production system based on a few crops, animal husbandry and related supporting enterprises, which maximizes the use of nutrients of each system. The components of an integrated farming system should be in accordance with the situation of the farmer and the resources available to him, so that maximum profit can be earned without harming the environment.

(b) Climate friendly agricultural techniques and dissemination

To reduce the effect of climate change, new technologies are being demonstrated by the ICAR through Krishi Vigyan Kendras. National Initiative on Climate Resilient Agriculture was launched as a network project in February 2011 by the Indian Council of Agricultural Research. Its main objective is to adapt Indian agriculture to climate change and reduce the impact of climate vulnerability through strategic research and technology demonstration. Climate smart villages have been established for this. In which the focus was on appropriate crops, varieties, natural resource management, agricultural mechanization and custom hiring centers and the concerned farmers were also made aware of problems like drought, flood, frost, soil related problems and depletion of underground water.

Water management techniques and dissemination for rainfed farming.

In rainfed agriculture, some techniques have been recommended to protect crops from the adverse effects of water shortage, such as conserving moisture in the fields (zero ploughing, ridge and drain method, land leveling by laser method, etc.), collecting rain water and reusing it, using ground water. Water management can be done effectively through recharge etc. The collection of rain water also increases the underground water level and in case of no rain, this water is used for irrigation. This also conserves the soil.

Nutrition Sensitive Agriculture and Extension

Nutrition sensitive agriculture is a food-based approach that focuses on nutrition-rich foods, dietary diversity and fortified foods to address malnutrition and micronutrient deficiencies. Nutrition Smart villages are being developed by Krishi Vigyan Kendras so that malnutrition can be eliminated. Nutrition Smart Village is a mini laboratory through which nutrition security, nutrition literacy can be achieved through available means. First of all, motivation and behavioral change is done among the farmers towards nutrition. Poshan Smart Village is based on the concept of "Grow what you eat and eat what you grow". It was first started by Agricultural Technical Application Research Institute, Jabalpur, Madhya Pradesh, which is now being promoted in the entire country. Through this method, a nutritious thali rich in traditional dishes has been prepared to overcome the deficiency of nutrients. For nutritional security, demonstrations are being given on nutrition garden/home garden, rooftop gardening, seven days seven beds and bio-fortified crops.

Kadaknath poultry farming technology and propagation

Kadaknath rearing is a technique of poultry farming that generates more income. Kadaknath is the only Indian breed of chicken which has received the G-I tag. Whose main origin is Jhabua district of Madhya Pradesh. Its speciality is that the color of its meat as black and it is rich in protein (about 25 percent) and it also has many medicinal properties. This breed lays an average of 80-90 eggs in a year and its chicken also fetches a high price in the market. Kadaknath chicken has spread to 117 districts of 20 states of the country and is being exported to Asian countries.

Self-help group or farmer producer organization

Krishi Vigyan Kendras have an important role in motivating farmers to work by forming groups. They form groups of farmers and provide guidance to carry out agricultural activities and take agricultural products to the market, because working in a group brings more profits and also increases the efficiency of using available resources. Through these centres, farmers are being organized and made entrepreneurs through self-help groups, farmer producer organizations **(FPOs)**, seed production units etc.

Information and communication technology:-

Krishi Vigyan Kendras provide timely agricultural advice to farmers through agricultural mobile advice and social media (Whats App, Facebook and Twitter etc.). Through mKisan portal, agricultural advice is given to the farming communities on weather, market, agricultural activities, pest and disease management as per time and requirement.

KVK Ring for better Resource Utilization

This KVK-Ring works on3 Ms i.e. Manpower, Materials and Machinery sharing among the ring partners.

System of Resource Sharing

1. Verbal agreement 2. Written contract and 3. Formal co-operative

Degree of Resource Sharing

- Sharing of a full/part of the implement/ equipment
- Share a set of machinery with labour
- Sharing men and machines with group buying & selling of the input and output
- Sharing men, machine and money with group recording system

Net Zero Farm Science Centre

In future, we should also focus on the use of renewable source of energy so that along with cost, more green energy could be harvested and used for healthy environments. Government of India initiated roof top solar system along with other similar options for making it further popular.

Revolutions in Agriculture Sector -

1. Agriculture 1.0 (Year -1700; Traditional agriculture with use of human and animal resources)
2. Agriculture 2.0 (Year -1950; Mechanized agriculture with use of power and machinery)
3. Agriculture 3.0 (Year -1992; Automated agriculture with use of high-speed machines)
4. Agriculture 4.0(Year -2017; Smart agriculture with use of internet of things, artificial intelligence, big data analytics, unmanned vehicle, robotics)
5. Agriculture 5.0 (Next generation agriculture as Precision Agriculture and Livestock System, Robotics and Automation in Agriculture, Public Private Partnership Ecosystem, etc.)

CONCLUSION AND POLICY SUPPORT

In nutshell, we can say that KVKs are striving hard to support the farming community with the financial support of ICAR, Govt. of India but now there is need to make planned investment in this sector to make the forthcoming agricultural revolution in reality. The present Government of India has started new schemes for the benefit of farmers like - Prime Minister Crop Insurance Scheme, Prime Minister Irrigation Scheme, Prime Minister Kisan Samman Nidhi, Prime Minister Agricultural Infrastructure Fund, etc. so that the farmer families can live a happy life with proper benefits. Krishi Vigyan Kendras act as a bridge in taking these schemes to the farmers and play an important role in increasing the income of farmers in convergence with the state departments and NGOs working in the region.

Significance of Protein Metabolism and Other Factors in Milk Production in Dairy Animals

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INTRODUCTION

The milk production and reproduction are imperative for sustainable dairy farming. This can be achieved through the adoption of scientific feeding practices. Interventions pertaining to 'feed and fodder' can play a pivotal role in making dairying more remunerative to the milk producers in both, the short term as well as the long-term situations. Lactating dairy cows need a variety of nutrients like carbohydrates, protein, fatty acids, vitamins and minerals in addition to water so that the demands of mammary gland can be met for the production of milk and various milk components. It is worth to note that development of a high milk yielding cow requires proper nutrition of the young calf as well as heifer. However, in order to develop the cow that will produce a high milk yield, proper feeding and management of both calf and heifer is of utmost importance during early growing stages. The cost of raising heifers is approximately 20-25 per cent of the expenses on a dairy farm where the highest expense is incurred on feed while the second or third highest is on labour. Sharma and Shelly (2023) reported that the average milk production of dairy animals per day per animal in the rural area was very low whereas it is perceived that there is marketing problem of milk. Further, with so little milk production, keeping of dairy animals can never be remunerative. Thus, there is need to educate the farmers about various management practices to be followed in order to enhance the total milk production per animal per day so that livelihood security can be ensured.

Major consideration for a dairy farmer

In the production cycle of a cow, a 100 days period is very crucial. This period begins 30 days prior to calving and 70 days post-calving. During this period, it is very essential to ensure the birth of a healthy calf, maintain the health of the dam without any incidence of metabolic disorders during the transition period, achieve peak milk production in line with the genetic potential, prevent excessive loss of body condition as well as achieve high fertility at first breeding.

Conservation of green fodder in the form of silage

The non-availability of green fodder, particularly during summer, increases the cost of feeding and also hampers animal productivity. It is therefore important to conserve green fodder during seasons of surplus to ensure regular supply during lean periods.

Feed supplement for improving Fat and SNF content in milk

Fat and SNF content in milk directly impacts the price realization by the dairy farmers. Fat and SNF content of milk depends on many factors such as species of the animal, breed, lactation stage, season, milking practices, and nutrition. The various nutritional factors affecting fat and SNF content in milk are imbalanced feeding, feeding energy-deficient rations, low body condition score (BCS), improper rumen function, excessive concentrate feeding, improper roughage to concentrate ratio, deficiencies of minerals, etc. Several feeding strategies can be adopted and may include the maintenance of an appropriate roughage-concentrate ratio, supplementation of appropriate additives as well as the avoidance of negative energy balance.

Heat Stress

Dairy cattle start experiencing heat stress at a temperature humidity index (THI) of 72 and above. Beginning in the month of April and extending up to September moderate (72 THI) to severe heat stress (85 THI) has been reported in most states in India. Heat stress can lead to substantial economic losses for farmers owing to reduced milk production (up to 20%) in the immediate term and sub-optimal fertility in the medium term. Heat stress can be mitigated by nutritional and management strategies. Supplementation of appropriate nutrients or additives can reduce the negative effect of heat stress on animals and stabilize the income of dairy farmers during the summer months.

Replacement of low producing animals

One of the important aspects of profitable dairying is the regular replacement of low productive

or unproductive animals with high producing animals. It is recommended that dairy farmers should raise own replacement animals rather than procure from outside to enable accurate assessment of milk yielding potential and mitigate the disease burden. A properly managed program for the rearing of calves on the farm can reduce mortality rates in new born calves, reduce the age at sexual maturity and ensure the desired age at first calving.

Feeding of colostrum to young animals

The dairy animals produce colostrum as the first secretion from mammary glands which is very important for the calves as it provides immunoglobulins soon after the birth of the calf. Feeding of the calf defends the calf against the disease causing infectious agents like viruses and other pathogens. However, the quality of colostrum start diminishing as the time advances and the mammary gland starts to milk secretion. Fig. 1 (Morin *et al,* 2010).

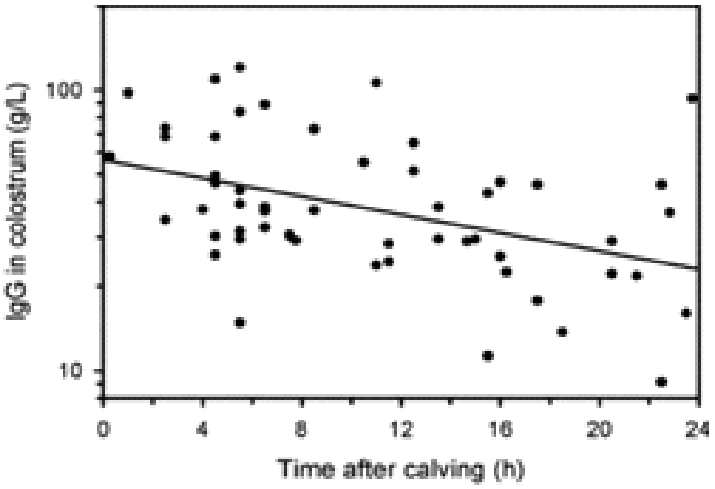

Fig. 1 *Colostrum quality diminishes as harvest time after calving increases*

With the increase in time after calving, immunoglobulin absorption by the calf gut is reduced and therefore, efforts should be made to feed good quality colostrum @ 1/10th of the birth weight of the calf just after the birth of calf as soon as possible and feed another 2 litres within twelve hours of the calving of dairy animal.

A balanced and palatable calf starter grain is important for the proper development of calf rumen. The volatile fatty acids (VFAs) produced in the rumen help in its development and the butyrate VFA is especially important for the development of rumen papillae (rumen epithelium) in calf. Chester-Jones *et al* (2017) reported that if there was approximately 1 kg of daily gain in young calf during the first 6-8 weeks of life, it led to increased milk production in first lactation but for that proper feeding of post weaned heifer is very essential. The major objective should be to feed the heifer animal in such a way so that at least 55 percent of the calving weight at 15-16 months (the time of breeding) and about eighty percent of the weight at 24-25 months (time of parturition) can be achieved.

Concept of precision feeding

The concept of precision feeding aims at providing exactly the required nutrition for its growth and other body functions. It is very beneficial for the dairy farmer as it prevents over feeding, reduces the feed costs involved and also there is less wastage. The farmer should fix a growth target of 0.8 kg/d in addition to fulfilling all the other requirements of a weaned heifer. For the growing heifer, crude protein should be between 14-15 percent while the metabolizable energy from 2.84 Mcal/kg to 3.01 Mcal/kg of intake (Table 1), neutral detergent fiber varies from 25-35 percent and all other requirements of minerals, vitamins etc. are as per NRC (NRC, 2001).

The ration formulation of a high yielding dairy cow is possible only with the knowledge of nutrients involved and their physical and combined interactions with each other, understanding these interactions is essential to carry out a successful dairy feeding programme for cattle.

Table 1. Nutrient recommendations of precision-fed dairy heifers fed to gain 0.86 kg/d.

Age, month	Body weight, kg	DMI, kg/d	ME, Mcal/d	CP, kg/d	NDF, %
4	113	2.59	7.8	0.41	23
6	159	3.38	10.1	0.50	24
7	204	4.11	12.2	0.63	26
9	249	4.82	14.1	0.72	27
11	295	5.49	16.0	0.82	28
13	340	6.14	17.9	0.91	29
14	385	6.78	19.6	1.00	30
16	431	7.40	21.3	1.09	30
18	476	8.00	23.0	1.18	31
20	521	8.60	24.6	1.27	32
21	567	9.18	26.2	1.32	32
23	612	9.76	27.7	1.40	33

Note- Adapted from Penn State Extension. Precision Feeding Dairy Heifers: Strategies and Recommendations

Provision of drinking water

In a dairy cow, of the total body weight, 56-81 percent is water while for the calf this range stands at 68-72 (Chapman *et al*, 2017). This shows the importance of water which also forms aboult 85 percent of milk, carries out transport of various substances in the body and is required for insulation as well as temperature regulation, it also helps in waste excretion from the body. Dairy farmers must take care to provide free choice drinking water for dairy cattle at all times so that production level can be maintained. Water also helps in microbial development of rumen in calf.

Protein sources

Dairy cows need a wide range of protein sources instead of only one so that amino acids can be balanced and the deficiency of particular amino acid in one source can be fulfilled by including another source. As per NRC 2001, rumen degradable protein (RDP) can be 10 percent while the rumen undegradable protein (RUP) is 5-6 percent of the dietary dry matter.

Harvesting of forages

Farmers should harvest forages at optimum time so that nutrient concentration and digestibility in these can be proper. Lignin in addition to ADF lower digestibility, keep NDF in range of 26-28 percent of diet dry matter for the lactating dairy cow as per NRC 2001. Sufficient forage level in ration keeps the rumen in proper health and microbes can flourish for ruminal digestion. Non-structural carbohydrates (NSC) comprising starch, simple sugars and disaccharides must form at least 35 percent of dietary dry matter in dairy cow while it is far less for the dry cow or post weaned heifer as nutrient requirements varies in all animal categories and life phases.

Use of fat

Hydrogenation of fats in rumen is deleterious for rumen microbes as it leads to reduced content of milk fat, decreases dry matter intake and milk yield. Slow releasing fats from cottonseed or cracked soybeans will not have negative impact on rumen fermentation however rapidly releasing fats from highly processed feedstuffs can be dangerous and harmful for rumen fermentation as the oil forms a coating on fiber reducing its digestibility in addition to harming microbes involved in digestion. Many dietary factors like reduced NDF (neutral detergent fibre), small fiber particle size, high starch unsaturated fat content in ration, the inadequate biohydrogenation can cause increase in production of isomers of C18:2 and C18:1 in rumen causing decreased synthesis of milk fat in dairy cow mammary gland (Bauman *et al*, 2011).

Fat is utilized for milk fat formation in early lactation while in later lactation phases, it is stored in adipose tissue so that it may prove useful in future lactation requirement. Fat is recommended to be fed at only 8 percent of total dry matter only. A typical ration with no supplemental fat already has 4 percent fat. If fats are given in correct form and concentration, higher milk yield is there in early lactation cows but milk protein concentration is lowered. With proper fat inclusion in ration after peak lactation, body condition improves in cow as well as fertility improves through better energy balance or more hormone production.

Use of minerals

For correct performance of many body functions, minerals (osmotic balance, nerve impulse, catalysts for enzymes in body etc. They are also a part of body structure like calcium in bones. Macrominerals (including Calcium, Phosphorous, Magnesium, potassium, Chlorine, Sodium, and Sulphur) which are required in gram quantities. Microminerals also known as trace minerals are required in milligram or microgram quantities.

Available Feed Resources

The small farmers of developing countries have limited resources available for feeding to their ruminant livestock. They do not have the luxury of being able to select the basal diet but use whatever is available at the household level. The available resources are essentially of low digestibility forages, straws and other crop residues and agricultural by-products which are generally low in protein. The major criterion for improvement in production is to optimize the efficiency of utilization of the available fodder resource and not to attempt to maximize animal production.

Basic Philosophy

The question is how to optimize the utilization of the available forages for dairy animals? Two basic concepts must be applied as follows:

- To make the digestive system of the cow as efficient as possible by ensuring optimum conditions for microbial growth in the rumen.
- To optimize production by balancing nutrients so that these are used as efficiently as possible for milk production without jeopardizing the reproductive capacity of the cow.

Protein digestion in ruminants

Ruminants consume many types of carbohydrates, proteins and other plant and animal constituents. All digestible carbohydrates are fermented to volatile fatty acids (VFA) plus methane and carbon dioxide by microbial action. Proteins are degraded by microbial enzymes in the rumen to give the same three end-products (VFA, CO_2 and CH_4) plus ammonia. In all cases a proportion of the substrate metabolized by microbes is used for synthesis of the microbes. The microbial fermentation of soluble protein in the rumen is an unavoidable consequence of the ruminant mode of digestion. In the absence of other forms of N, it ensures a supply of ammonia nitrogen for micro-organisms from which they synthesize the protein in their cells. Under many circumstances, it is a wasteful process because high quality proteins are broken down to ammonia, absorbed as such, converted to urea in the liver and this is excreted in the urine.

Microbial growth on protein

Protein degradation to VFA leads to a relatively low availability of energy to rumen microbes and therefore protein that is degraded in the rumen is inefficiently used for the growth of micro-organisms. In comparison with carbohydrate when protein is degraded in the rumen, only half the ATP (the energy currency of the microbes) is produced in fermentation of protein relative to the same amount of carbohydrate. The breakdown of carbohydrate in the presence of adequate ammonia and sulphur and other minerals supplied by, for instance urea molasses mineral blocks, results in more microbial protein being produced than from an equal amount of protein fermented in the rumen.

Factors influencing the availability of by-pass protein

A proportion of the dietary protein passes from the rumen into the small intestine without alteration. On reaching the small intestine this by-pass protein is digested by enzyme hydrolysis and absorbed into the body as amino acid. The conditions under which some dietary protein may escape the rumen for digestion in the lower alimentary tract include:

- When a protein meal has been made highly insoluble by heat treatment.

- The protein meal contains tannins (2–4%) which bind to make an insoluble tannin - protein complex which is not degraded in the rumen but is degraded in the abomasum/small intestine.
- Chemical treatment has been applied *e.g.,* formaldehyde treatment (Scott, 1970).
- When a relatively soluble protein meal is fed in very high quantities and is either in a finely ground form or is rapidly fragmented into small particles which move quickly through the rumen. For example, when clover or lucerne ,that do not contain tannins, are fed at levels below 2.5% of liveweight, on a dry matter basis, it is probable that no dietary protein escapes to the lower tract. However, at levels above this, some protein escapes because of the rapid movement of digesta out of the rumen. The amount of by-pass protein can be as high as 30% of the total protein in the feed if this is highly digestible (Nolan and Leng, 1989.).
- When heat is applied to a mixture of soluble protein and xylose, when a modified browning reaction can insolubilize the protein.

Microbial protein synthesis in the rumen

Ammonia, peptides, amino acids and amines form the nitrogenous substrate for the synthesis of microbial cells but ammonia is the most important source of N for the microbes that ferment forages. Ammonia is used by many species of rumen micro-organisms as their sole source of nitrogen for protein synthesis. A deficiency of rumen ammonia results in a low microbial growth rate which may reduce digestibility of fibre and lower intake of feed. Estimates of the critical level of ammonia in the rumen fluid for efficient digestion has been reported to be as low as 50 mg N/1 or as high as 200 mg N/1. Intake of straw by cattle has been shown to be increased by increasing urea levels in the diet until the level of ammonia reaches 200 mg N/1 (Boniface et al., 1986; Perdok and Leng, 1989).

Can the rumen microbes supply all the protein needs of the ruminant?

Even when ammonia and other nutrients are supplied, the quantities of microbes that leave the rumen in digesta do not supply sufficient protein to meet the needs for productivity in ruminants (moderate to high growth rate and milk yield). In such a situation, the deficiency symptoms indicate an insufficient supply of essential amino acids to the tissue. Under these conditions supplementation with a protein meal (which has a high content of by-pass protein) to supply additional dietary amino acids increases both the level and efficiency of animal production (Preston and Leng, 1987).

Protein Requirements of Ruminants

The protein requirements of ruminants and evaluation of the protein value of feeds for ruminants have been based on digestible crude protein (N × 6.25). This is now recognized as a misleading concept. The use of digestible crude protein has arisen largely because it was considered that cattle and sheep could obtain their essential amino acids from microbes produced in the rumen. This in turn led to suggestions that extensive use could be made of non-protein nitrogen in high carbohydrate feeds and that a special role of ruminants could be to convert non-protein nitrogen to high quality animal protein.

These have now been superseded by new concepts which take into consideration that when amino acid requirements are high, insufficient digestible microbial protein is available from the rumen to meet these needs. It is now necessary to assess the requirements for N by ruminants in terms of the amount of ammonia (or NPN) and amino acids needed by the rumen microbes, and the amount of digestible by-pass protein needed by the animal to augment the total protein (amino acids) available to the animal and to create an efficient metabolism.

Protein or amino acid requirements relative to energy requirements of ruminants are, however, influenced by a number of factors and cannot be stated with any degree of accuracy. The requirements are influenced by:

- physiological state of the animal,
- rate of growth and milk production,
- body composition as influenced by previous dietary and health history,
- basal feed (particularly fat content),
- proportions of the different amino acids absorbed,
- patterns of rumen fermentation
- availability of volatile fatty acids,
- requirements for glucose for essential purposes,
- environmental heat or cold stress, and

- the extent of the work load of the animal.

Availability of metabolizable protein to ruminants

Metabolizable protein available is the sum of digestible dietary by-pass protein plus digestible protein from microbes reaching the lower tract. On most straw based diets, the metabolizable protein is mainly of microbial origin. The amount of protein available therefore depends on the efficiency of microbial growth in the rumen. This in turn depends on several factors such as

- the presence of all the essential nutrients in the balances and amounts needed by the rumen microbes to grow e.g., ammonia, sulphur, phosphorus, trace minerals, amino acids, peptides, etc.,
- a source of fermentable dry matter
- to a small extent the rate of digesta turnover and therefore feed intake. However, this depends on degradability of the feed, type of carbohydrate and the physiological status of the animal.
- buffering capacity of the rumen and pH of the rumen fluid which largely depends on diet, and
- the balance of micro-organisms in the rumen. If supplementation with carbohydrate promotes protozoal population this can actually decrease the protein to energy ratio in the nutrients available from the rumen (Bird and Leng, 1985).

More recently it has been demonstrated that feeding a meal high in by-pass protein (low in grain) as compared to a cattle feed concentrate based on traditional requirements increased milk production and live-weight gain without substantially influencing basal feed intake.

Suggestion

The efficiency of feed utilization is enormously improved if the rumen of the animal has a healthy microbial population adequately supplemented by providing a urea molasses mineral block which often increases the intake of a basal diet. Adding a by-pass protein supplement will further improve the efficiency of utilization of the basal feed resources but will also allow animals to maintain feed intake at high environmental temperatures and humidity. Conversely, the productivity of lactating animals can be maintained at a lower feed intake provided the rumen and animal's metabolism is made efficient.

Amelioration of anoestrous

A major problem associated with milk production in villages is that the non-descript animals which are by far the majority of dairy animals are often fed the poorest feeds particularly in early life and between lactations. The reason is that without the cash flow that comes from milk and with no rapid cash return on their outlay, dairy farmers are not prepared to purchase supplements. In general, in developing countries, cattle and buffalo often calve for the first time at 4–5 years of age and have an inter-calving interval of up to two years. Infertility is therefore a major problem.

What can be done?

The feed processing technology should be modified in view of the new system with a view to increasing, in processing, the by-pass protein content of a pelleted feed. A suitable feed formula based on the nutrient supply, processability and economics of feeding needs to be developed, for use with the important basal feeds available to small-farmers. There is a wide gap today in this technology between the research nutritionists who use only single ingredients or a combination of two or three protein meals and the practical feed manufacture who uses a variety of feeds compounded on least-cost basis. Since many developing countries have large quantities of protein meals in the country then technology development to ensure its efficient utilization should be a matter of priority. In countries where the oilseed meals are unavailable, the potential of forage trees containing tannins, or the treatment of forage tree leaves to protect the protein need to be developed.

The Future

The challenge for the scientist in many developing countries is to how best combine in a diet for dairy animals the available green forage, crop residues and agro-industrial by-products with the available protein resources and molasses/urea block to optimize milk production. It is likely that the availability of protein for dairy animals is likely to be the primary economic constraint, it is therefore necessary to develop new protein resources and to find ways and means of protecting the protein from degradation in the rumen whilst remaining of high digestibility is an urgent priority.

Increasing milk production following optimization of the efficiency of utilization of the basal

feed resource. The greenhouse effect that is the warming of the Earth's atmosphere because of increased content of carbon dioxide and methane, will in the future require a reduction in production of these gases. Methane produced by ruminants probably contributes about 25% of the increase in global methane concentration in the atmosphere (which is 1 % per year at present) and this source of methane can be reduced by decreasing the number of ruminants in the world. This will necessitate a move to increase production per animal to maintain and increase this source of human food. This increase per animal will need to be made within the constraints of the available feed resources.

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Suggestions for Strengthening the Functioning of KVKs as per Emerging Needs

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ABSTRACT

KVK appears to be the only institutional system at the district level for technological backstopping in agriculture and allied sectors. The first KVK, on a pilot basis, was established in 1974 at Puducherry (Pondicherry) under the administrative control of the Tamil Nadu Agricultural University (TNAU), **Total KVKs established till Feb 2024 is 731.** Currently, the KVKs are performing multi-dimensional roles, starting from core activities such as technology backstopping, resource-conservation methods, introduction of cutting-edge techniques, and up-scaling at one end, and envisioning entrepreneurial opportunities in rural areas, providing vocational/skill training to rural youth, women folks on the other end. There is no provision of Medical allowance/medical reimbursement/health insurance facilities to KVK staff and their family members Since the establishment of the KVK, Staff are facing many problems due to lack of uniform policy on KVK. To overcome this ambiguity implementation of High power committee recommendations is the only solution

INTRODUCTION

Krishi Vigyan Kendra (KVK) is an institutional project of the ICAR to demonstrate the application of Science and Technology input of agricultural research and education at the farmer's field and in the rural area with the help of a multidisciplinary team of scientists. It is a research oriented extension project to test, validate, refine and disseminate agriculture and allied technologies in the rural areas.

At present, KVK appears to be the only institutional system at the district level for technological backstopping in agriculture and allied sectors.KVK is front line extension system in the district. KVK a plan scheme designed and managed by ICAR for over 5 decades, is playing vital role because of its fallowing Unique features:

1. Creation of valuable resources in terms of technical manpower and assets
2. Confirmation of technologies to suit local specificity
3. Showcasing the frontier technologies
4. Capacity building among stakeholders
5. Front runner in technology application, information and inputs
6. Participatory approaches in planning, implementing, executing and evaluation

Vision

Science and technology-led growth leading to enhanced productivity, profitability and sustainability of agriculture.

Mission

Farmer-centric growth in agriculture and allied sectors through application of appropriate technologies in specific agro-ecosystem perspective.

Mandates

Technology Assessment and Demonstration for its wider Application and to enhance Capacity Development (TADA-CD)

Activities

To implement the mandate effectively through creation of awareness about improved agricultural technologies, the following activities be defined for each KVK.

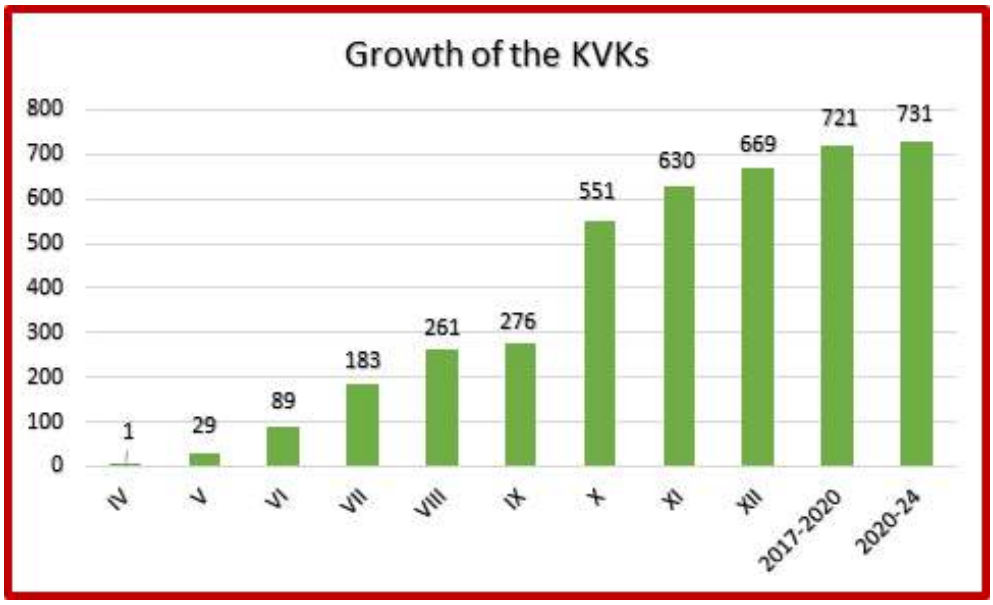
- Assessment and demonstration of agricultural technologies on the farmers field for their application and feedback.

- Capacity development through skilling and training of farmers, farm women, youth and extension functionaries.
- Act as an information and knowledge centre for providing diagnostic and farm advisories to farmers and other stakeholders
- Production of quality seeds, planting materials and other technological inputs for availability to the farmers
- Develop convergence and partnership with agriculture related ongoing schemes and programs of different departments and organizations on national priorities.
- Awareness creation and community mobilization on various issues related to agriculture & allied sectors through innovative extension activities including use of ICT and other media.

Genesis of KVK

- ✓ The Education Commission (1964-66) recommended that a vigorous effort be made to establish specialized institutions to provide vocational education in agriculture and allied fields at the pre and post-matriculate levels to cater the training needs of a large number of boys and girls of rural areas.
- ✓ The Commission, further, suggested that such institutions be named as Agricultural Polytechnics. The recommendation of the Commission was thoroughly discussed during 1966-72 by the Ministry of Education, Ministry of Agriculture, Planning Commission, ICAR and other allied institutions.
- ✓ Finally, the ICAR mooted the idea of establishing KVKs as innovative institutions for imparting vocational training to the practicing farmers, school dropouts and field level extension functionaries.
- ✓ ICAR Standing Committee on Agricultural Education, in its meeting held in August, 1973, observed that since the establishment of KVKs was of national importance which would help in accelerating the agricultural production and also in improving the socio-economic conditions of the farming community, the assistance of all related institutions should be taken in implementing this scheme.
- ✓ The ICAR, therefore, constituted a committee in 1973 headed by Dr. Mohan Singh Mehta of Seva Mandir, Udaipur (Rajasthan), for working out a detailed plan for implementing this scheme. The Committee submitted its report in 1974.
- ✓ The first KVK, on a pilot basis, was established in 1974 at Puducherry (Pondicherry) under the administrative control of the Tamil Nadu Agricultural University (TNAU),

Growth of the KVK



Total KVKs established till Feb 2024: 731

Distribution of KVK

Host Organization	KVKs
State Agricultural University	480
Central Agricultural University	22
ICAR Institutes	66
Non-government Organization	104
Public Sector Undertaking	3
State Govt.	38
Central University	3
Deemed University	8
Other Educational Institution	5
Total	**731**

Over a period of four decades, since the set-up of KVK system at grass-root level, spectrum of the mandated and core functions of KVKs are enlarged to address all the day-to-day issues of farming community in a seamless manner. Currently, the KVKs are performing multi-dimensional roles, starting from core activities such as technology backstopping, resource-conservation methods, introduction of cutting-edge techniques, and up-scaling at one end, and envisioning entrepreneurial opportunities in rural areas, providing vocational/skill training to rural youth, women folks on the other end. These Institutions are also effectively using the latest tools of ICT in dissemination of information for extended reach with richness.

Time and again, there were empirical evidences to prove that the KVK System has positively impacted the quality of life of farming community in terms of income, yield, productivity, and above all capacity for optimal utilization of resources etc. It also made a tangible impact in the areas of integrated farming, crop diversification, value addition, biodiversity, organic farming, horticulture, dairying, veterinary & animal husbandry, fisheries etc. However, the inter-state diversities due to agro-climatic conditions, non-uniform agrarian dynamics of each district, dissimilar institutional framework are reasons for non-uniform outcomes and efficacies from each KVK

Irrespective of any Host organization Funding pattern, Staffing Pattern and working pattern is same for all KVKs but service conditions are as per host organization rules and regulations not to exceed ICAR provisions. KVK staff are not the ICAR employees as per ICAR F.No.A.Extn.1/2/2015-AE-1 Dated 17-06-2015.

Problems in KVKs

1. Service conditions of KVK staff differ from one host organization to another host organization
2. KVK staff do not have approved promotion policy except ICAR KVKs
3. Retirement age is differ from one host organization to another host organization
4. There are no retirement benefits like Gratuity, ELs etc.,
5. There is no pay protection during lateral entry from one KVK to another entry
6. Grade pay SMS is differ from one host organization to another host organization
7. There is no provision of Medical allowance/medical reimbursement/health insurance facilities to KVK staff and their family members
8. No benefit of study leave if staff undergone for higher education
9. In case the host organizations discontinue to host the KVK, employee protection is not there

In order to make the KVK more relevant and effective under the changing scenarios over the years, various committees had been constituted to review the progress of KVKs and suggest much needed improvements in their functioning. The details of such Committees constituted in the past are provided as under:

1980: High level Evaluation Committee under the Chairmanship of Dr. P. Bhattacharya

1986: Joint Food & Agricultural organisation (FAO) – ICAR Mission under the Chairmanship of Dr. M.L. Dewan

1988: ICAR Review Committee under the Chairmanship of Dr. G.V.K. Rao

1993: Nine Quinquennial Review Teams (QRTs) for different Agro-Climatic Regions 3 Introduction

1995 : Committee regarding financial and administrative management, financial support and pattern of funding etc., under the Chairmanship of Dr. M.V. Rao

1995 : Committee under the Chairmanship of Shri S.S. Surjewala

1996 : Committee on Human Resource Development (HRD) through KVKs and Trainers Training Centres (TTCs) under the Chairmanship of Dr. S.C. Mudgal.

2001 : Committee on streamlining the functioning of KVKs in the country under the Chairmanship of Shri Acharya Ramamurti

2005 : Committee for Independent Evaluation and Impact Assessment under the Chairmanship of Shri J.N.L. Srivastava

2006 : QRT under the Chairmanship of Shri J.N.L. Srivastava

2011 : Eight QRTs for Zonal Project Directorates (ZPDs) in 8 Zones

2011 : High power committee under the chairmanship of Dr R.S Paroda

2015 : High level panel under the Chairmanship of Shri J.N.L. Srivastava

2017 : Evolution of KVKs by NILERD

2018 : Eleven QRTs for ATARIs in 11 Zones

The relevant suggestions of the above committees at various points of time had helped in strengthening the functioning of KVKs as per emerging needs.

Even though many committees were formed and given recommendations for strengthening of the KVK system but not yet resolved the issues of KVK staff.

In addition, the existing guidelines for KVK, which were developed during 1999, no longer address clearly the management and technical issues nor they address precisely the decisions revised from time to time. Besides, Performance Audit of Agricultural Extension activities of ICAR by the Comptroller and Auditor General (CAG) also suggested updating of guidelines for KVK. Hence, for a vibrant KVK system, a pre-requisite is to have detailed and precise guidelines with clarity and precision, which touches upon all important, related issues.

Under this backdrop, Hon'ble Union Minister of Agriculture and Food Processing Industries and the President of ICAR Society decided to constitute a High Power Committee (HPC), under the Chairmanship of Dr.R.S.Paroda, former Secretary, DARE & Director General, ICAR to review all issues pertaining to KVK system and suggest measures for improving their efficiency and relevance so as to meet the current expectations of stakeholders vide ICAR office order F.No.5-5/2011-A.E-II/173-179 dated 02-05-2011.

High power committee headed by Dr. R.S. Paroda given clearcut recommendations to remove the disparity among the KVK staff in different host organizations

1.All Krishi Vigyan Kendras established up to XI Plan must be converted from Plan to Non-Plan scheme, as per the existing procedure of the Government for required sustainability and effective functioning. Likewise, new Krishi Vigyan Kendras to be opened in subsequent Plans be converted into Non-Plan Scheme, when they complete 5 years of establishment.

2. In view of increasing expectations from Krishi Vigyan Kendra, its Vision be now defined as "Science and technology-led growth leading to enhanced productivity, profitability and sustainability of agriculture", where as the Mission should be "Farmer-centric growth in agriculture and allied sectors through the application of appropriate technologies in specific agro-eco system perspective". Also, the Mandate should be "Technology Assessment and Demonstration for its wider Application and Capacity Development".

3. Additional Krishi Vigyan Kendra in the district be established only based on specific criteria such as: large rural population, bigger geographical area, higher net sown area, relative xiv Report of the High Power Committee on Management of KVK backwardness norms of the district, more Tribal/Scheduled Caste/Scheduled Tribe population, and those in mountainous (above 5000 feet above mean sea level) and difficult/border areas.

4. The position of Programme Coordinator of Krishi Vigyan Kendra should be re-designated as 'Chief Scientist- cum-Head', in the cadre of Principal Scientist/Professor (PB-4, ` 37400-67000 with GP ` 10000), for effective management, implementation of mandated activities through proper coordination and convergence with line departments, including the district administration.

5. Further, all Subject Matter Specialists in Indian Council of Agricultural Research/State Agriculture Universities/Non-Governmental Organizations/State Government Krishi Vigyan Kendras should henceforth be redesignated uniformly as Scientist/Assistant Professor (PB-3, ` 15600-39100 with GP ` 6000) to ensure much needed parity across teaching, research and extension positions.

6. SMSs who are in technical cadre at present in Krishi Vigyan Kendras under Indian Council of Agricultural Research Institute should be redeployed or redesignated as Scientists and the positions may be adjusted through cadre strength of the concerned Indian Council of Agricultural Research institute/overall Indian Council of Agricultural Research level.

7. The total staff strength for each Krishi Vigyan Kendra should be increased from 16 to 22, comprising one Chief Scientist, 10 Scientists, one Computer Programmer, one Farm Manager, one Lab Technician, one Technician (T-I- Field/Farm), one Assistant Administrative Officer, one Stenographer Grade III, one Lower Division Clerk-cum- Store Keeper, two Drivers and two Supporting Staff.

8. Since Krishi Vigyan Kendras are 100% funded by the Indian Council of Agricultural Research, the host organizations be accorded full freedom and assume full responsibility to recruit Krishi Vigyan Kendra staff without any restriction/ban. Krishi Vigyan Kendras should not be sanctioned or annual grants released unless the State Government agrees to recruit all sanctioned staff. Also the staff recruited in Krishi Vigyan Kendra must not be transferred for at least five years. The Memorandum of Understanding should also be clearly modified to this effect.

9. Pay structure, as sanctioned by Indian Council of Agricultural Research for the Krishi Vigyan Kendra staff, should be adopted by all host organizations without any variation whatsoever. Krishi Vigyan Kendra under Non-Governmental Organizations, which do not have approved promotion policy, must adopt Modified Assured Career Progression Scheme as implemented by the Indian Council of Agricultural Research and amended from time to time. Similarly, the posts that come under the definition of isolated posts in Krishi Vigyan Kendras (other than Indian Council of Agricultural Research and Non-Governmental Organization Krishi Vigyan Kendras) will also follow Modified Assured Career Progression Scheme.

10. Payment of retirement benefits in the form of Gratuity and Contributory Provident Fund for Krishi Vigyan Kendra staff must be made applicable by all host organizations. At the same time, the benefit of study leave to the staff under Non-Governmental Organization Krishi Vigyan Kendras be also extended as per Central Civil Service Leave Rules of 1972.

11. The Krishi Vigyan Kendra staff under Non-Governmental Organizations should be treated on par with

the Indian Council of Agricultural Research/State Agriculture Universities staff especially in respect of age limit, experience and other service requirements in order to overcome the existing restrictions in their lateral movement. This would help in strengthening and attracting talent to Non-Governmental Organization Krishi Vigyan Kendras, and provide equal opportunity to those working in Non-Governmental Organization Krishi Vigyan Kendras for career advancement.

CONCLUSION

Since the establishment of the KVK, Staff are facing many problems due to lack of uniform policy on KVK. To overcome this ambiguity implementation of high power committee recommendations is the only solution. Implementation of One KVK One Policy and Equal work & Equal pay will remove the disparity among the KVK staff of different host organizations.

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Trichoderma to Manage Soil Borne Diseases in Madhya Pradesh

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INTRODUCTION

Economically important agricultural, horticultural and ornamental crop plants are attacked by various pathogens resulting crop losses. Soil borne pathogenic fungi viz., *Pythium, Fusarium, Rhizoctonia* and *Phytopthora* attack most of the economically important crop plants (either through seed before germination or seedling after germination) resulting in heavy losses. The development of such a global system for sustainable food production is one of the greatest challenges faced by humans. Presently, the most widely used control measures for suppressing the pathogens is the use of fungicides. However, problem encountered, such as development of resistance by the pathogen to the fungicide, and requirement of repeated applications, added to the increase cost of chemical have given impetus to alternative measures for control of plant disease.

In recent years, biological control of plant pathogens has received increasing attention as a promising supplement or alternative to chemical control. Biological control of plant pathogens is an attractive proposition to decrease heavy dependence of modern agriculture on costly chemical fungicides, which not only cause environmental pollution but also lead to the development of resistant strains. The genus *Trichoderma* by virtue of its broad spectrum action against a number of plant diseases caused by fungi, bacteria and even nematodes has occupied the top position among the bio-protectants developed for plant disease management (Lorito *et al.*, 1999) These have long been recognized as biological agents to control plant diseases. Since the first application in 1930s, *Trichoderma* species became popular biological agents to protect crops against plant pathogens all over the world. Past research indicated that *Trichoderma* can parasitize fungal pathogens and produce antibiotics. Weindling (1932) described in detail the mycoparasitism of a fungal pathogen causing damping off disease (*Rhizoctonia solani*) by the hyphae of *Trichoderma*, including coiling around the hyphae, penetration, and subsequent dissolution of the host cytoplasm. He also described an antibiotic which was toxic to both *R. solani* and *Sclerotinia americana*, and named it gliotoxin.

The use of *Trichoderma* as a biological agent of plant diseases has long been known, however, these were introduced to Vietnam only in the last two decades (Tran, 1998). Research has been done on biological control potential of *Trichoderma* spp. against several pathogens attacking vegetables, fruits, field and industrial crops. *Trichoderma* species are ubiquitous soil and compost borne saprophytes that have received enormous scientific interest as biocontrol agents of plant diseases caused by destructive root and soil pathogens. *Trichoderma* species compete well for food and site, produce antibiotics and had an enzyme system capable of attacking a wide range of pathogens through mycoparasitism.

Trichoderma- a genus under Deuteromycotina is considered as a class of imperfect fungi, without known sexual stage. They are known to control soil borne fungal pathogens belonging to class ascomycete, deuteromycete, and basidiomycete and also certain air borne pathogens (Monte,2001).

General Characteristics

- On potato dextrose agar (PDA), Trichoderma colonies are initially white, but on cornmeal dextrose agar (CMD), they are transparent. Conidia usually form in a week as compact or loose tufts in hues of green, yellow, or less frequently white; mycelium is usually not visible on CMD. It's possible for the PDA to release yellow pigment.
- Conidiophores are tufted either loosely or compactly, frequently forming distinct concentric rings or being carried along the few aerial hyphae. Because of their high branching, they are challenging to quantify. The longest side branches that are farthest from

the tip of the conidiophores are produced by the main branches, which may or may not be paired. The longest secondary branches are those that are closest to the main axis, and they are frequently paired. With regard to the main axis, all primary and minor branches emerge at or close to 90°. Trichoderma conidiophores that typically have two branches take on a pyramidal shape.

- Conidia usually smooth and appearing dry, conidia can be contained in drops of clear, green, or yellow liquid in certain species, such as T. virens and T. flavofuscum. Most species have ellipsoidal conidia that are 3-5 × 2-4 µm.
- Phialides can be cylindrical or almost subglobose, but they usually have an expanded center. Phialides can be arranged in whorls, held at a 90° angle to one another, or in different penicillate (gliocladium-like) forms. Phialides can either be solitary or densely grouped along a broad main axis (e.g., T. polysporum, T. hamatum).Chlamydospores may be produced by all species, and they are typically unicellular sub globose and terminate short hyphae; they may also be formed within hyphal cells. Chlamydospores of some species are multicellular (e.g. *T. stromaticum*).

Trichoderma teleomorphs are species belonging to the ascomycete genus Hypocrea Fr. The development of fleshy, stromata in hues of light or dark brown, yellow, or orange is what distinguishes them. The perithecia are submerged entirely. Though bicellular, ascospores disarticulate at the septum very early in development.

Attributes of Trichoderma

- Insensitive to a number of chemicals
- Effective against a wide range of plant pathogenic fungi, bacteria and nematodes
- Highly rhizosphere competent
- No effect on non target population
- No effect on mankind
- Less possibility of development of resistance to pathogens
- Low cost and Eco-friendly
- Easily culturable and Fast multiplication

Method of application

1. **Seed treatment:** Apply 6 - 10 g of Trichoderma powder per Kg of seed before sowing.
2. **Nursery treatment:** Apply 10 - 25 g of Trichoderma powder per 100 m2 of nursery bed. Application of Trichoderma with neem cake or FYM increases the efficacy.
3. **Cutting and seedling root dip:** Mix 10g of Trichoderma powder along with 100g of well rotten FYM per liter of water and dip the cuttings and seedlings for 10 minutes before planting.
4. **Soil treatment:** Apply 5 Kg of Trichoderma powder per hector in 500 kg of farmyard manure and cover it for 7 -10 days with polythene. Sprinkle the heap with water intermittently. Turn the mixture in every 3-4 days interval and then broadcast in the field.
5. **Plant Treatment:** Drench the soil near stem region with 10g Trichoderma powder mixed in a liter of water

Benefits of Trichoderma application

1. **Disease Control**: Trichoderma is a powerful biocontrol agent that is widely used to treat diseases that are soil-born. It has been effective in combating harmful fungi from a variety of genera, including Phytopthara, Scelerotia, and Fusarium.
2. **Trichoderma strains:** solubilize micronutrients and phosphates, promoting plant growth. Applying Trichoderma strains to plants makes them more drought-tolerant by increasing the amount of deep roots they have.
3. **Biochemical Elicitors of Disease:** It is known that certain strains of Trichoderma cause plants to become resistant. It is currently known that Trichoderma produces three kinds of chemicals that cause resistance in plants. In plant cultivars, these substances cause the

formation of ethylene, hypersensitive reactions, and other defense-related reactions.

4. Transgenic Plants: By introducing the Trichoderma endochitinase gene into plants like tobacco and potato plants, the plants' resistance to fungal development has been boosted. Certain transgenic lines have a high level of tolerance to both soil-borne pathogens such Rhizectonia spp. and foliar pathogens including Alternaria alternata, A. solani, and Botrytis cirerea.

5. Bioremediation: Trichoderma strains are crucial to the bioremediation of pesticide- and herbicide-contaminated soil. They can break down a variety of pesticides, including carbonates, organophosphates, and organochlorines.

Major Limitations of Biological Control

- ✓ Short Shelf Life
- ✓ Lack of proper application technology
- ✓ Subject to environmental influence like high moisture, high pH etc.
- ✓ Chance of mutation and variations
- ✓ Too specific or slow acting
- ✓ Population dependent performance
- ✓ Marketing of poor quality products
- ✓ lack of faith and awareness among the farming community

Mode of action of Trichoderma

There are five different mechanisms by which Trichoderma controlled other microorganisms;

1. Competition

Trichoderma species are generally considered to be aggressive competitors and the ability of *Trichoderma* to compete is species dependent. The competition for nutrients, primarily carbon, nitrogen, and iron is one of the method of the biological control of soilborne plant pathogens (Elad et al., 1999). Competition through rhizosphere competence is a mechanism that has gained adherents in recent years. It is an important mechanism because a biocontrol agent cannot compete for space and nutrients if it is unable to grow in the rhizosphere (Ozbay and Newman, 2004).

2. Induced Resistance

Specific strains of fungi in the genus Trichoderma colonize and penetrate plant root tissues and initiate a series of morphological and biochemical changes in the plant, considered to be part of the plant defense response, which finally leads to induced systemic resistance (ISR) in the entire plant (Howell, 2003). The plant response was marked by an increase in peroxidase activity (often associated with the production of fungitoxic compounds), an increase in chitinase activity, and the deposition of callose-enriched wall appositions on the inner surface of cell walls.

3. Biofertilization and Stimulation of Plant Defense Mechanism

Trichoderma strains are known to associate with plant roots and root ecosystems. They are also plant symbiont and opportunistic avirulent organisms, able to colonize plant roots by mechanisms similar to those of mycorrhizal fungi producing compounds that stimulate growth and plant defense mechanisms. This mechanism includes plant root colonization and rhizosphere modification. Root colonization by Trichoderma strains mostly enhances root growth and development, crop productivity, resistance to abiotic stresses and the uptake of nutrients (Arora *et al,*1992). The activity of Trichoderma helped in Rhizosphere modification**s.** The pH of the microbial environment is one of the major factors affecting the activity of both Trichoderma and pathogenicity factors secreted by different microorganisms (Arst and Penalva,2003).

4. Antibiosis

Antibiosis may be simply a highly effective mechanism for suppressing pathogens in the rhizosphere. Antibiosis occurs during interactions involving low molecular weight diffusible compounds called antibiotics produced by Trichoderma strains that inhibit the growth of other microorganisms. *Trichoderma* spp. produces alkyl pyrones, isonitriles, polyketides, peptaibols, dikeyopiperazines,

sesquiterpenes, and steroids have been associated with biocontrol activity of some species (Howell,1998). Apart from these antibiotics, it produces volatile and non-volatile toxic metabolites viz; harzianic acid, alamethicins, tricholin, peptaibols, antibiotics, 6-penthyl-a-pyrone, massoilactone, viridin, gliovirin, glisoprenins, heptelidic acid that impede colonization by antagonized microorganisms (Vey et al., 2001).

5. **Mycoparasitism**

Mycoparasitism is considered an important mechanism of biological control and probably depends on the production of lytic enzymes including Beta-1, 3-gluconase, and proteases. Several chitinolytic enzymes have been reported in *T. harzianum* including endochitinases, exochitinases and 1, 4-Beta-N-acetyl-glucosaminidases which are induced during growth in liquid medium containing chitin as carbon source. Mycoparasitism is a complex process including several steps. The initial interaction shows that the hypha of the mycoparasites grows directly towards its host. When the mycoparasite reaches the host, its hypha coils it or attaches to it by forming a hook-like structure. Following these interactions hypha sometimes penetrates the host mycelium, apparently, by partially degrading its cell wall (Elad *et al.,* 1983).

6. Inactivation of the Pathogen's Enzymes

Trichoderma harzianum produces proteases that are capable of degrading the pathogens plant cell wall degrading enzymes, and thereby reducing the ability of the pathogen to infect the plant.

Precautions with Trichoderma Application:

- Don't use chemical fungicide after application of Trichoderma for 4-5 days.
- Don't use *Trichoderma* in dry soil. Moisture is a essential factor for its growth and survivability.
- Don't put the treated seeds in direct sun rays
- Don't keep the treated FYM for longer duration

Compatibility of Trichoderma with other biological agents and fungicides:

Trichoderma is compatible with Organic manures, biofertilizers like *Rhizobium, Azospirillum, Bacillus Subtilis* and *Phosphobacteria*. *Trichoderma* can be applied to seeds treated with metalaxyl or thiram but not mercurials. It can be mixed with chemical fungicides as tank mix.

De Cal (1994) reported that bio control agents that can tolerate a certain level of fungicides were mixed with agrochemicals, resulting in eradication of diseases. Wedajo (2015) found that *Trichoderma* species was 50% compatible with curzate (400 ppm) and Mancozeb (600 ppm) fungicides. Bagwan (2010) reported that thiram, copper oxychloride and Mancozeb at 0.2 % are compatible with *Trichoderma harzianum* and *Trichoderma viride* . It was also reported compatibility of *Trichoderma*species with Dithane, Bavistin and Ridomil at any level of selected concentration that is., 50 ppm, 100 ppm, 200 ppm, 300 ppm and highly insensitive to blue copper and captaf. Deepthi (2013) reported that the *Trichoderma* was more compatible with mancozeb followed by copper oxychloride.

Vijayaraghavan and Abraham (2004) observed that mancozeb was compatible with *Trichoderma* species. Vasundara *et al* (2015) reported that seed treatment of *Trichoderma viridae* would be high compatible with fungicide mancozeb at 3000 ppm concentration, followed by combination of mancozeb with imidacloprid 3000 + 2000 ppm, imidacloprid at 2000 ppm concentration respectively. Moderate compatibility were recorded in the treatments of Tebu-conazole (1000 ppm), Carbendazim (1000 ppm) + Imidacloprid (2000 ppm), Mancozeb (3000 ppm) + Chlorpyriphos (6000 ppm), carbendazim (1000 ppm) alone.

Experience and Success with the application of Trichoderma in Plant Disease Management:

To assess the economic feasibility, 185 on farm trails in Chickpea, lentil, Betlvine, Chilli and Ginger crops were conducted in light to medium soil during 2008-15 in Chhatapur and Sagar districts. Each trail was conducted in 0.2 ha area and same area adjacent to the demonstration plot was kept as farmer practice. During the on farm trails, *Trichoderma viride* have proved successful in large number of field as well as vegetable crops.

Diseases management in Betelvine Crop:

Twenty On farm research trails were conducted for validation and awareness among betelvine growers regarding disease management practice in Betelvine growing villages Garhimalhera and Maharajpur of Chhatarpur district. Soil application of *T.viride* @ 2.5 kg/ha with oilseed cake, the cuttings of betelvine treated with Streptocycline and then planted in rows. Soil application of *Trichoderma viride* before planting and drenching in rainy season @ 2 Kg/ha with oilseed cake reduced the incidence of sclerotial wilt and phytophthora foot and leaf rot disease by 18.9 to 8.1 and 16.8 to 3.1, respectively.

Table 1: Effect of disease management practices on soil borne disease of Betelvine.

Treatment	Disease incidence			Fresh leaf yield (q/ha)	B:C ratio
	Phyt ophthora Blight (%)	Sclerotial wilt (%)	Root rot (%)		
Soil application of *Trichoderma viride* @ 2.5 kg/ha with oilseed cake, the cuttings of betelvine treated with Streptocycline and then planted in rows. Soil drenching with Copper hydroxide 50 WP was do ne in the first week of July. General spraying wit h Dichlowas 76 S L was done in the month August and Mancozeb in the month of October to check the infection from anthracnose disease.	8.1	3.1	4.2	72.0	4.56
Farmers ' practic e (Cutting treatment with Copper fungicide and spray of any fungicide at disease appearance)	18.9	16.8	12.7	58.0	3.68

Rhizome rot diseases management in Ginger:

Ginger (*Zingiber officinale* Rose) is an herbaceous perennial, it occupying 4400 ha In Madhya Pradesh, with very low productivity 1.27 tonnes per ha. The reason of low productivity seems to be continuous use of degerated seed which is prone to various diseases like rhizome rot or soft rot. Rhizome rot is widely prevalent throughout the ginger producing area. It is mostly caused by different species of *Fusarium* and / or *Pythium*. The soil application of *Trichoderma viride* than rhizome treatment with same was tested at 45 farmer's field in Chhatarpur and Sagar districts.

Maximum germination was found in copper hydroxide treated plots (92%) which is at par with *Trichoderma viride* (91 %) in comparison to control (72%). The minimum rhizome rot incidence was observed in Copper hydroxide (6.2%) treated plots followed by *Trichoderma viride* (6.4%) in comparison to control (28.6%). The highest Ginger yield were 133 q/ha in Copper hydroxide which is at par with *Trichoderma viride* (126 q/ha) treated plots in comparison to control (61 q/ha).

Table 2 : Efficacy of various chemicals in the control rhizome rot disease

Treatment	Germination (%)	Rhi zome rot (%)	Rhizome yield (q/ha)
Trichoderma viride	91	6.4	126
Copper hydroxide	92	6.2	133
Farmers practice	72	28.6	61
C.D. (5%)	1.6	4.8	12.8

Management wilt disease in Chilli:

Maximum germination was found in copper hydroxide treated plots (92%) which is at par with *Trichoderma viride* (91 %) in comparison to control (72%). The minimum rhizome rot incidence was observed in Copper hydroxide (6.2%) treated plots followed by *Trichoderma viride* (6.4%) in comparison to control (28.6%). The highest Ginger yield were 133 q/ha in Copper hydroxide which is at par with *Trichoderma viride* (126 q/ha) treated plots in comparison to control (61 q/ha).

Title of O n Farm Testing	Insect/ disease incidence	Yield (q/ha)	Net return	B:C ratio
T1- Farmers practice (No Se edling Treatment)	10.9	74.7	70875	2.72
T2- Seedling Treatment by *Trichoderma viride* @10 g/lit of water	7.1	87.2	88910	3.12
T3- Seedling Treatment + Soil application of *Trichoderma viride* 2.5 kg/ha with FYM	2.9	101.0	108820	3.55

Management wilt disease in Gram and Lentil:

Thirty On Farm trails were conducted in 5 village of Chhatarpur districts. In the demonstration plot 2.5 kg *Trichoderma viride* inoculated in 250 kg FYM and mixed with the Soil before sowing. The seed of Gram treated with the Trichoderma @ 10 gm/kg seed and then sown. Results of field demonstration in gram showed that the wilt incidence reduced from 10.45 to 4.05 per cent. Due to reduced incidence of disease, the yield of gram increased from 925 to 1099.5 kg/ha (18.8 %) and B:C ratio 3.86 to 4.12 in comparison to farmers practice (Seed treatment with Mancozeb or Carbendazim).

. Twenty On Farm trails were conducted in lentil crop in 2 village of Chhatarpur and sagar districts. Soil application of *Trichoderma viride* @ 2.5 kg with 250 kg FYM and seed treatment with the same @ 10 gm/kg seed, reduced wilt incidence by 68.1 and 68.6 percent in comparison to farmers practice (Seed treatment with Mancozeb or Carbendazim).

Crops	Disease incidence (%)		grain yield (qtl/ha)		Increas e in Yield (%)	Additional cost of cultivatio n	Additional net return	B:C ratio	
	Demo	F P	Demo	FP				Demo	FP
Lentil	9.4	30.0	6.18	5.12	20.7	600	3710	3.37	3.08
Gram	7.2	22.6	11.4	8.30	37.3	950	8350	4.0	3.27

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Unraveling the Science of Natural Farming: Microbiological Perspective and KVK Experiences

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INTRODUCTION

Indian Agriculture has progressed a lot from the pre-independence era. We have come out from the phase of food scarcity to food sufficiency. Population of our country has increased from about 34 crores (in 1947) to today's (2023) 1,428,627,663, a 0.81% increase from 2022 and it is projected to reach 150 crore by 2030 and 166 crore by 2050. Competing with this population explosion Agricultural Scientists of NARS has been successful to increase food grain production to meet the increasing domestic requirement of food. Agricultural production has increased from 50.82 million tonnes in 1950 to 329.67 million tonnes in 2023. Green Revolution has contributed to a great extent to achieve the food security of this huge population which is about 17.76 % of total world population. However, all these successes are based on input intensive agricultural technologies. Chemical fertilizers and chemical pesticides have played a big role in this journey for supply of plant nutrients and control of insect pests, diseases and weeds which, of late, has an adverse impact on environment and soil health. On the contrary, Masanobu Fukuoka of Japan in his lifetime promoted and Mr. Subhas Palekar Ji of our country has been promoting low input Zero Budget Natural Farming (ZBNF) and they have claimed that food production through these natural farming practices will not be hampered rather both soil health and environmental health will be restored and improved. There is a paradigm shift in Indian Agriculture from chemical intensive agriculture to natural farming with locally available ingredients with the farmers. Government of India has taken an initiative through ICAR in general and KVKs in particular for implementation of a Project on 'Outscaling of Natural Farming through KVKs' of which Sasya Shyamala Krishi Vigyan Kendra, RKMVERI is also associated. Besides, Network Project on Natural Farming is also being implemented in our University where we are trying to unravel the science of natural farming.

Organic farming vs. natural farming:

Organic farming is being practised by many farmers in India for long. Government of Sikkim has declared adoption of organic farming in 2003. Economic Survey 2022-'23 mentions that India has 4.43 million organic farmers, the highest in the world. Now natural farming is progressing. In Andhra Pradesh, 5,23,000 farmers have converted 13 % of productive agricultural land to ZBNF. Potential challenge to scale up ZBNF is its capacity to supply nutrients to plants which is very low. On the other hand, under current trends 60% of India's population (which is >10% of global population) will experience severe food deficiency by 2050. Either free living N-fixers in soil or symbiotic N-fixers in legumes provide major portion of N to the crops. But even with maximum potential N-fixation, only 51-80 percent of applied N as fertilizer is expected to be supplied to the crops.

Common perception of the microbial world is pathogenicity, infections, diseases etc. while plant growth promoting microbes like bacteria and fungi play an important role in mobilizing plant nutrients in soil. In plants microbiome, there are microbes in every sphere of the plants – phyllospheres, endosphere and rhizosphere and their role in biological control of pathogens, plant growth promotion and ameliorating abiotic stress is well documented. Network complexity gradually decreased from from organic greenhouse to conventional greenhouse experiments. Green nodes are significantly more abundant in organically managed plots while red nodes are significantly more abundant in conventionally managed plots.

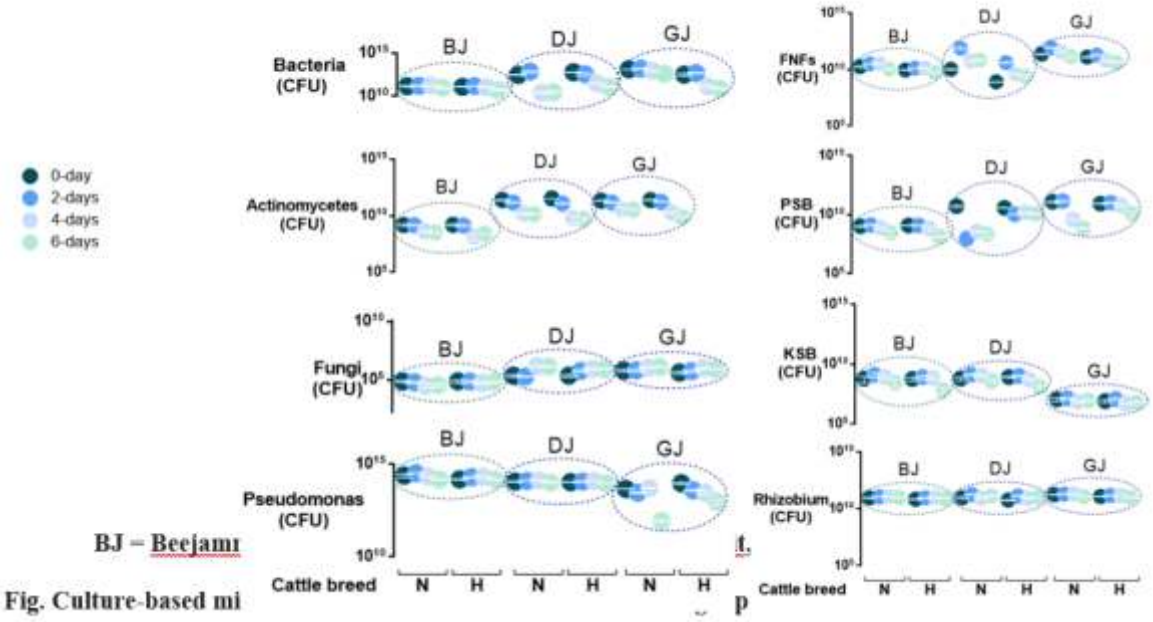
Characterization of ingredients of natural farming inputs:

Four pillars of Natural farming are – Jeevamrit, Beejamrit, Mulching and Whapasa. Of these inputs, Jeevamrit is the only input in natural farming which is used for gradual promotion of nutrient supplying capacity of soil. Main ingredients of Jeevamrit and Beejamrit are cow dung and cow urine. Now the question is, “Does the difference in breeds impact the natural farming formulations? We conducted several experiments on studying physico-chemical, bio-chemical and microbiological

properties of the key ingredients like cow dung and cow urine of native breed and cross bred cows (Holstein). It was found that in general, cow dung and cow urine of native breeds were superior in case of organic C, available N, P and K, total soluble protein, free fatty acids, total indole acetic acid, gibberellins, flavonoids and phenolics content. But so far as microbiological counts are concerned, it was found to be higher in the cow dung of native breeds while cow urine of crossbred cows showed higher microbial count for total bacteria, fungi, actinomycetes, FNFs, phosphate solubilising bacteria potassium mobilizing bacteria, Rhizobium and Pseudomonas. So, for preparation of natural farming inputs, cow dung of native breeds and cow urine of crossbred cows may be used in combination.

Characterization of natural farming inputs:

After characterization of ingredients, physic-chemical, biochemical and microbiological characterization of the natural farming ingredients like Beejamrit, Ghanjivamrit and Dravjeevamrit were also done. Incubation study was done at 0, 2, 4 and 6 days for the three inputs prepared from native and Holstein breed. Organic carbon, free fatty acids, total soluble protein, plant available nutrients, indole, gibberalic acid, phenolics, flavonoids and CFU counts of agriculturally important microorganisms were studied. Plant available nutrient content was found to be very low in all the ingredients prepared both from native and crossbred cows. Two to three days' incubation was found to be optimum for preparation of all the natural farming inputs after which content of all the parameters (physic-chemical, biochemical and microbiological) under study decreased and inputs prepared from native breeds were found to be superior in all respects.



BJ – Beejamı t.

Fig. Culture-based mi p

KVK experiences:

KVKs are implementing the project on "Outscaling of natural farming through KVKs" throughout the country. There is no prescribed protocol. We are learning through experiences during implementing the project. Sasya Shyamala KVK is also implementing the project in the district of South 24 Parganas, West Bengal from 2022-'23. We conducted programmes for creating awareness among the farmers, training and demonstrations on natural farming in KVK farm and farmers'fields in different crops like greengram, cucumber, cauliflower, cabbage, knol khol, radish, tomato, broccoli, chilli, coriander etc. It was found that yield was satisfactory in case of greengram while other nutrient exhaustive and medium duration crops did not perform satisfactorily. Mean population of pod borer in case of greengram was also higher in natural farming and organic farming plots in comparison to the chemical farming plots.

Table. ***Crop Performance under ZBNF in different demonstration:***

Crop	Variety	Cost of Cultivation in Demo Plot (Rs./ha.)	Yield in Demo Plot (qtl/ha.)	Cost of Cultivation in Non-Demo (Rs./ha.)	Yield in Non-Demo (qtl/ha.)	Feedback of Farmer
Greengram	PDM 139	22500	9.24	25800	8.59	Yield is satisfactory, Application of Jeevamrit and Agniastra is helpful to boost the plant growth and to check the insect
Cucumber	Seven Star	32000	21	34300	22.7	Jeevamrit application in soil and spray is helpful for plant growth, but initially the weed population is high thus requirement of weeding is more. Time consuming compared to chemical spray.
Broccoli	Green magic	28600	13.2	45900	21	Yield is not satisfactory, curd size is less, delayed curd formation and early maturity
Chilli	Deb 1310	32900	9.4	41400	28	Plant growth is very less, yield is not good, Application of Agniastra & Dasaparni performed well in managing insect pest.

Om Shanti Jeevan Jyoti Education Society Murwara Katni Madhya Pradesh had done so many works in remote villages of Kutch Gujarat State, as to free educates to children, Distribution of Corona virus kits to Villagers as well as Industrial Workers, also distributed food packets as well as provide guide lines & optimum production technology to Formers of Katni District Madhya Pradesh state.

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