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SUSTAINABLE AGRICULTURE

VOLUME I

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PREFACE

We are delighted to publish our book entitled ***"Sustainable Agricultural Volume I".*** *This book is the compilation of esteemed articles of acknowledged experts in the fields of basic and applied agricultural science.*

The Indian as well as world population is ever increasing. Hence, it is imperative to boost up agriculture production. This problem can be turned into opportunity by developing skilled manpower to utilize the available resources for food security. Agricultural research can meet this challenge. New technologies have to be evolved and taken from lab to land for sustained yield. The present book on agriculture is to serve as a source of information covering maximum aspects, which can help understand the topics with eagerness to study further research. We developed this digital book with the goal of helping people achieve that feeling of accomplishment.

The articles in the book have been contributed by eminent scientists, academicians. Our special thanks and appreciation goes to experts and research workers whose contributions have enriched this book. We thank our publisher Bhumi Publishing, India for taking pains in bringing out the book.

Finally, we will always remain a debtor to all our well-wishers for their blessings, without which this book would not have come into existence.

Editors

CONTENT

GROWING OPPORTUNITIES: EXPLORING ENTREPRENEURSHIP IN RURAL INDIA THROUGH AGRITOURISM

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Abstract:

Tourism has become the largest industry in the world. The overall contribution of travel and tourism to the global GDP amounted to 5.81 trillion U.S. dollars (Statista Research Department, 2023). The value of the agri-tourism market was USD 69.24 billion in 2019 and is projected to reach USD 117.37 billion by 2027. Agritourism has its roots in the late 19th century in Europe when city inhabitants looking for a vacation from the city were drawn to farm stays. There are various motivations to start agritourism as a business. A successful agritourism venture needs thoughtful planning and its implementation. Some famous agritourism sites in India are Etikoppaka Village, Vishakhapatnam District, Andhra Pradesh specialized in woodcraft, Coorg District of Karnataka famous for coffee plantation etc. Entrepreneurship plays a crucial role in the development of agritourism, which is the practice of attracting visitors to rural areas to experience the farming and agricultural way of life. Case study of Samir Ranjan Bordoloi a 44-year Agripreneur from Jorhat, Assam operating an integrated approach of organic farming, model villages, and agritourism on his farm Basanti Organic Tea farm at Gandhiagaon village of Panitola.

Keywords: Agritourism, Entrepreneurship, Business model, Innovation, Sustainability.

Introduction:

"We wander for distraction, but we travel for fulfillment." - Hilaire Belloc

India is a country with a variety of cultural traditions and geographical features that offers a distinctive fusion of traditional and contemporary methods of agriculture and tourism. Tourism has become the largest industry in the world. The overall contribution of travel and tourism to the global GDP amounted to 5.81 trillion U.S. dollars. (Statista Research Department, 2023). The value of the agri-tourism market was USD 69.24 billion in 2019 and is projected to reach USD 117.37 billion by 2027. Registering a CAGR of 7.42%, the market will exhibit steady growth during the forecast period (2020-2027). In India, the combination of agricultural and tourism-related activities is known as agritourism, and it is seen as a promising area for business growth. Agritourism offers farmers a special chance to diversify their sources of revenue and show off their farming methods to tourists. The industry also gives visitors a genuine taste of rural life, including farming, harvesting, cooking, and intercultural exchanges. Encouraging entrepreneurship in the agritourism industry should not only benefit the local community but also aid in the preservation of rural culture. Agritourism has flourished in India as a result of the rising desire for environmentally friendly and immersive travel, opening up new opportunities for entrepreneurship development. The chapter includes the potential of agritourism as an entrepreneurial opportunity in India, including its challenges, opportunities, and policy implications. The potential of agritourism as a business opportunity in India, including its challenges, opportunities, and policy implications.

Agritourism: Genesis

Although agritourism is a relatively new idea, its origins can be found in long-standing agricultural and rural practices. Agritourism has its roots in the late 19th century in Europe when city inhabitants looking for a vacation from the city were drawn to farm stays. These early types of agritourism entailed staying on a farm and helping out on the farm with tasks like harvesting fruit and milking cows. In the early 20th century, this kind of agritourism was also common in the United States. Back in the 1800s, the University of Tennessee in its Extension Publication had considered it as agritainment. The origin of the term agri-tourism is credited to Italy in the 1970s. Agritourism started to develop into a more commercialized business in the middle of the 20th century as farms and rural regions started to provide tourists with additional amenities and activities. Several causes, such as the rising popularity of organic farming and sustainable agriculture, the expansion of local food movements, and the demand for unusual travel experiences, have contributed to the growth of agritourism. In India, this concept was initiated by a tourism industry professional Pandurang Taware in 2005. Agri-tourism Development Corporation (ATDC) was started on 16th May 2004 in Malegaon near Baramati in Maharashtra.

Motivations of operating Agritourism Business

Fig. 1: Motivation of operationg agritourism business

Model of agritourism entrepreneurship development

A successful agritourism venture needs thoughtful planning and implementation. Here is stepwise process how an agritourism business can be developed-

Identifying goals
↓
Conduct market research
↓
Develop business plan
↓
Assessment of resources
↓
Create marketing plan
↓
Implement business plan
↓
Offer exceptional customer experiences
↓
Evaluate and improve

Fig. 2: Model of agritourism entrepreneurship development

Table 1: Agritourism sites and their specialization

States	Name of Village	Specialization
Andhra Pradesh	Etikoppaka Village, Vishakhapatanam District.	Wood Craft
Arunachal Pradesh	Deke Village, West Siang District	Ethnic tribal culture
Bihar	Nepura Village, Nalanda District	Tussar Silk weaving
Himachal Pradesh	Nagar, Kullu District	Topi and Shawl Weaving
Jammu & Kashmir	Agar Jitto Village, Udhampur District	Handicraft
Karnataka	Coorg District	Coffee Plantation
Kerala	Kalady Village, Ernakulam District	Spice plantation

Entrepreneurship- a catalyst for Agritourism in Rural Development

Entrepreneurship can play a crucial role in the development of agritourism, which is the practice of attracting visitors to rural areas to experience the farming and agricultural way of life. By creating and managing innovative agritourism ventures, entrepreneurs can stimulate economic growth in rural communities, create new jobs, and promote local agriculture. Here are some ways in which entrepreneurship can act as a catalyst for agritourism development:

1. Identifying new opportunities: Entrepreneurs are often skilled at identifying new opportunities and niches in the market. They can use this ability to develop unique agritourism experiences that appeal to visitors. For example, an entrepreneur may create a farm-to-table restaurant that serves locally grown produce or develop a farm-stay program where visitors can stay on a working farm and participate in daily activities

2. Adding value to agricultural products: Entrepreneurs can add value to agricultural products by developing new products or processes that make them more appealing to consumers. For example, an entrepreneur might create a line of artisanal jams, jellies, and sauces using locally grown fruits and vegetables.

3. Diversifying income streams: Agritourism can provide farmers with an additional source of income, which can be particularly important during times of economic uncertainty. Entrepreneurs can help farmers develop new agritourism ventures that complement their existing operations and generate additional income. For example, a farmer might create a pick-your-own pumpkin patch or start a corn maze to attract visitors during the fall season.

4. Promoting local culture: Agritourism can help to promote and preserve local culture by showcasing traditional farming practices, crafts, and foods. Entrepreneurs can work with local farmers and artisans to create unique agritourism experiences that highlight the region's cultural heritage. For example, an entrepreneur might organize a festival that celebrates local music, dance, and cuisine.

5. Supporting sustainable agriculture: Agritourism can also promote sustainable agriculture practices by educating visitors about the importance of preserving natural resources and supporting local agriculture. Entrepreneurs can develop agritourism experiences that incorporate environmental education and sustainable farming practices. For example, an entrepreneur might offer guided tours of an organic farm or provide workshops on sustainable agriculture practices.

Overall, entrepreneurship can be a powerful catalyst for the development of agritourism. By creating new and innovative agritourism ventures, entrepreneurs can help to promote economic growth, preserve local culture, and support sustainable agriculture practices in rural communities.

Case study:

Samir Ranjan Bordoloi a 44-year Agripreneur from Jorhat, Assam operating an integrated approach of organic farming, model villages, and agritourism on his farm Basanti Organic Tea farm at Gandhiagaon village of Panitola. Ten farm tourism destinations have been created as part of the initiative, which is assisting roughly 125 farmers who are involved. Ten young people are employed directly, while many more are indirectly involved in the project. The business is supported by a large number of domestic and international tourists who come to take advantage of the organic farms and the warm welcome of the locals. YATRA is a tour package that allows visitors to experience living in an organic tea garden, making hand-made green tea, picking tea leaves, living in bamboo huts, sailing in bamboo boats, staying in a bamboo village, helping farmers plough, making compost, and vermicompost, and tasting the regional cuisine and culture. Today the annual turnover of his farm is 1 crore. He faces many constraints but through innovation, they overcome the constraints.

Conclusion:

In conclusion, agritourism can provide a unique opportunity for rural entrepreneurs to create successful and sustainable businesses. A key factor to success in this field is developing a strong business model that takes into account the specific needs and interests of both visitors and farmers. Additionally, rural entrepreneurship plays a crucial role in the success of agritourism ventures. Successful rural entrepreneurs can identify new and innovative ways to create value for their customers and generate revenue for their businesses. This requires a combination of creativity, strategic thinking and willingness to take risks. Additionally, entrepreneurs must consider factors such as zoning laws, safety regulations, and environmental concerns when selecting a site for their agritourism business. Overall, rural entrepreneurship and agritourism present promising opportunities for individuals who are interested in creating sustainable and successful businesses in the agricultural sector. By developing strong business models, leveraging their entrepreneurial skills, selecting the right site, and studying successful case examples, entrepreneurs can increase their chances of success in this exciting and growing field.

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AUTOMATIC IDENTIFICATION AND QUANTIFICATION OF FOLIAR DISEASE SEVERITY IN SOYBEAN PLANTS USING COLOUR SENSING AND IMAGE PROCESSING

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Abstract:

The image retrieval method is used to solve the problem of detecting soybean foliar disease. We investigate the suitability of image retrieval algorithms for categorizing soybean plant diseases. To address this issue, we provide two feature descriptors, HIST and WDH, as well as investigate numerous other colour and texture-based feature descriptors, including BIC, CCV, CDH, LBP, SSLBP, LAP, and SEH. Using background removal, researchers describe an efficient method for soybean disease retrieval and classification. This study aids in the identification of infected lesion patterns, which is completely automated and does not require human interaction at any level. Several novel parameters, including the Disease Severity Index (DSI), Infection-Per-Region (IPR), and Disease-Level-Parameter (DLP), for evaluating disease severity and level-classification, have also been developed.

Introduction:

Soybean is grown in many nations and is one of the world's most important commercial crops. The primary countries involved in soybean production are the United States, Brazil, Argentina, China, and India, which contribute 38, 29, 22, 6, and 5% of total global soya production, respectively. Hartman et al. [1], because of the extremely similar symptoms of the various types of diseases, soybean plant foliar detection is a challenging challenge that necessitated the employment of complex image processing algorithms to address. The major components utilized to categorize soybean diseases are background subtraction, infected area identification, disease characterisation, and disease categorization. Feature extraction is the foundation upon which every categorization approach is built, and the success of any method is strongly dependent on how features are described. We investigate two feature extraction approaches, colour histogram features and wavelet decomposed colour histogram features, and applies them to the classification of soybean plant diseases. We also employed several other cutting-edge colour and texture-based feature descriptors to evaluate its performance in the current circumstance because the optimal feature for this stated challenge has yet to be determined. The query image is assigned to the disease with the most images in the list of obtained images. According to the literature, various researchers have used digital image processing technologies and pattern recognition techniques for agriculture applications such as weed management, foliar infection identification, and vegetable and fruit grading. Sankaran [2] investigated several agricultural electronics and information technology methods. Sensing systems for infection detection and cataloguing are based on intricate interactions between sensor and plant, making field estimation extremely difficult. The authors demonstrated the application of electronics and information technology in several crops, but not in soya beans. Cui et al. [3] employed a multispectral image sensing and image processing technique to detect soybean rust. They employed a CCD camera and a portable Spectro-radiometer to detect rust severity and found the lowest spectrum band reflectance in badly diseased soya plant leaves. [2] Also provided a few metrics for evaluating the rusting effect in soya plant leaves, which include the infected area ratio (RIA), lesion colour index (LCI), and rust severity index (RSI). Their research focused solely on rust, and the method proposed was not automatic. To address the method's shortcomings, an automatic thresholding system for distinguishing between infected and healthy pixels in soya bean leaves was created. A fully automatic disease identification and level estimate system based on colour picture sensing and processing has been suggested. Several novel parameters, including the Disease Severity Index (DSI), Infection Per Region (IPR), and Disease-Level-Parameter (DLP), have also been developed for quantifying disease severity and level classification. Those named Shrivastava et al. [4] suggested technique for cataloguing four soya plant foliar diseases is based on visual colour sensing, statistical texture and normalized-DCT based hybrid descriptors, and Linear Discriminant Analysis (LDA). Dubey and Jalal [5] proposed a colour, shape, and texture-based image processing technique for detecting apple disease. Dubey and Jalal [5] presented a system for classifying fruits and vegetables from photographs in their two articles.

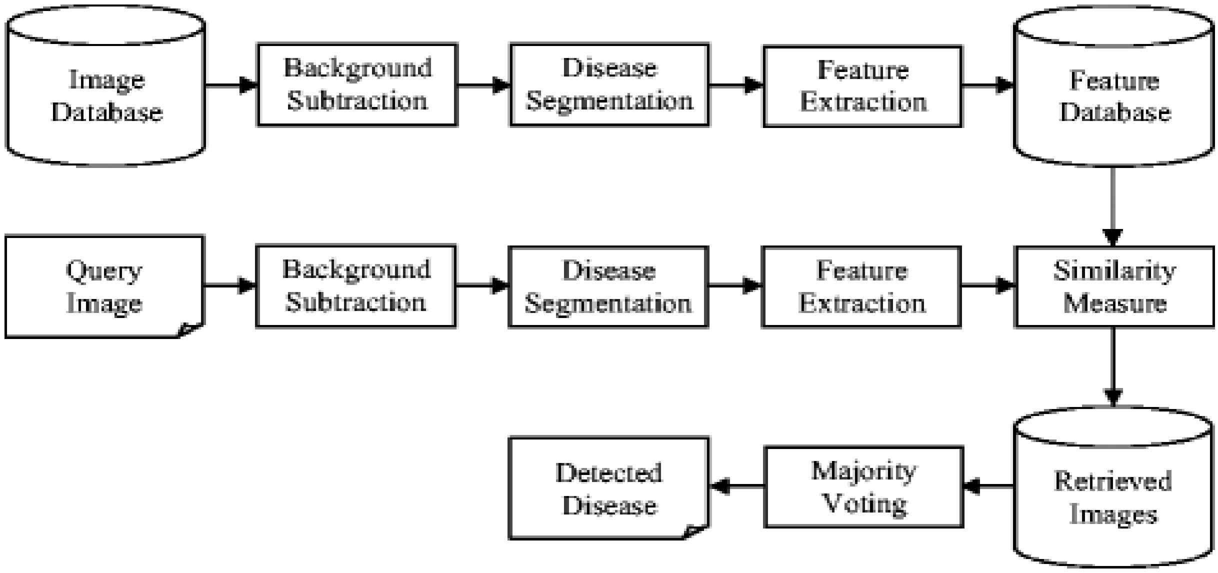

Fig. 1: Flow diagram of the soybean plant foliar detection [6]

Colour Models

Choosing colour model

The soybean photos gathered were composite colour photographs made up of discrete red, green, and blue components. Each of those component images used an 8-bit grey scale to indicate the purity of the colour on a scale of 0 to 255 from black to white. In a prior study, infected areas were distinguished from healthy leaf sections using colour differentiation, with the expectation that the leaf colour would alter after disease infection.

Centroids of leaf colour distribution

Although the fast image processing method could quickly set a reasonable threshold value to separate diseased parts from the healthy section of a leaflet, it was still difficult for real-time field application. An research was done to find a realistic approach for identifying rust severity without image segmentation in order to solve this challenge.

Procedure and methodology

A multispectral CCD camera was utilized to acquire leaflet images of varying levels of rust infection. The camera has three CCD channels, blue (B), green (G), and red (R), and an image resolution of 1392 H 1040 V at 8 bits per pixel. The B, G, and R channels were centred at 475, 540, and 625 nm, respectively, with bandwidths of 50, 50, and 60 nm. The lens had a focal length of 14 mm. Sample photos were captured using a digital frame grabber installed on a desktop PC computer. This device was capable of capturing 7.5 photos per second. To reduce image processing burden and avoid unneeded complexity, leaflets with varying amounts of rust infestation were manually cropped in Photoshop 7.0. A hue value-based segmentation threshold was used to separate the infected and healthy portions of those picture samples. Before converting the leaflet image from RGB to HSI format, the background was adjusted to blue to differentiate the leaflets from the background in hue imaging. Following the conversion, a three median filter was employed to improve visual quality and eliminate random noise. Different infection levels were coloured green, grey green, tan, dark or reddish brown.

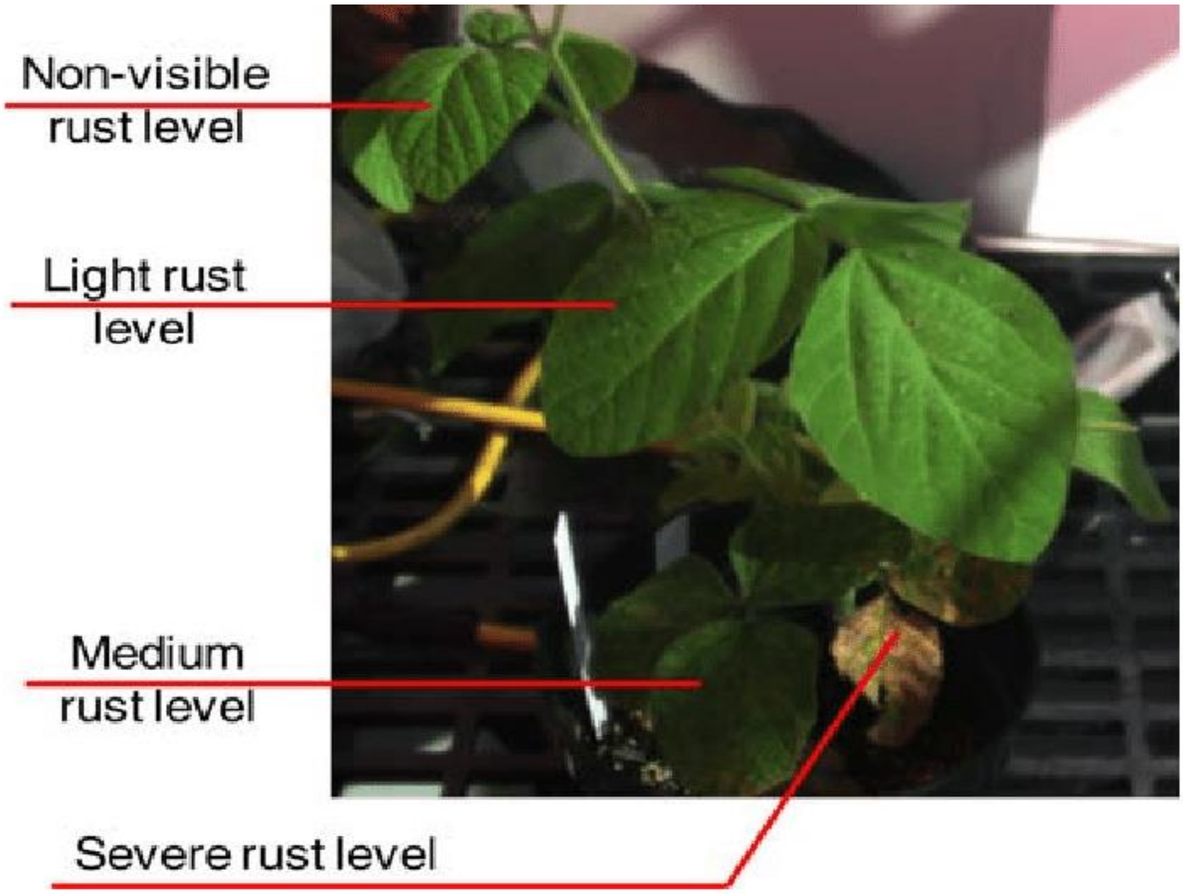

Fig. 2: Showing rust disease of soybean [7]

Multispectral image analysis

The first stage of image analysis was to manually remove leaflets from the backdrop by setting background pixels' (R, G, B) values to (0, 0, 255). After that, the leaflet image was transformed from RGB to HSI format for further processing. The generated colour photographs were treated with a three median filter to improve visual quality and eliminate random noise. Based on hue value variations, the contaminated pixels were eventually separated from the healthy portion of the leaflet hue image. The key to completing the segmentation successfully was determining an appropriate threshold value.

Detection using image retrieval

Image retrieval is a technology that searches a large database for the best matching photos to a given query image that are visually and semantically more similar. Image retrieval is used to handle a variety of problems, including colour and texture categorization, medical diagnostics, biomedical image retrieval, and so on. We use image retrieval to solve the challenge of detecting foliar growth on soybean plants.

Image classification

Disease segmentation, and feature extraction procedures are performed for each image in the training and test databases, similarly to the image retrieval approach given in earlier sections. In the retrieval method, we used each image in the database as the Multimed Tools Appl query image, whereas in the classification method, only some images from each category will be used to test the method's efficiency, and the remaining images from each category will be used to train the classifier (i.e., the entire database is divided into two parts, one with training images and the other with test images).Three supervised classifiers, SVM, KNN, and PNN, utilizing the feature vectors of training images after feature extraction. Finally, these trained classifiers are used to classify test photos into one of the trained categories of soybean plant diseases based on feature vectors generated using the same descriptor that was used to construct feature vectors for the training images. Different classifiers utilize different training procedures, but they always execute optimization operations to differentiate the classes. It should be noted that the KNN and PNN classifiers may train and classify images from more than two categories; however the SVM classifier can only be utilized with two classes [8]. The average accuracies for each feature descriptor using SVM, KNN and PNN classifiers respectively. The y-axis shows the average accuracy in percentage and x-axis represents the number of images per disease for training. We have performed each experiment 10 times with different training images and finally taken the average to produce the final accuracy (i.e. 10-fold validation is performed in the experiments). We have observed across the results that better accuracy is gained using the BIC descriptor for SVM and KNN classifiers. The accuracies using CCV and CDH are generally better than HIST and WDH for SVM and KNN classifiers whereas in the case of PNN classifier the accuracies using HIST and WDH are highest among all even better than BIC using which highest accuracies are obtained in SVM and KNN cases. The BIC feature descriptor having performance good compare than other feature descriptor for both classification and retrieval. KNN classifier is better class separability with BIC descriptor for classification. The first method is based the retrieval concept whereas second one is based on the classification concept. Both the approaches are supervised in nature [9].

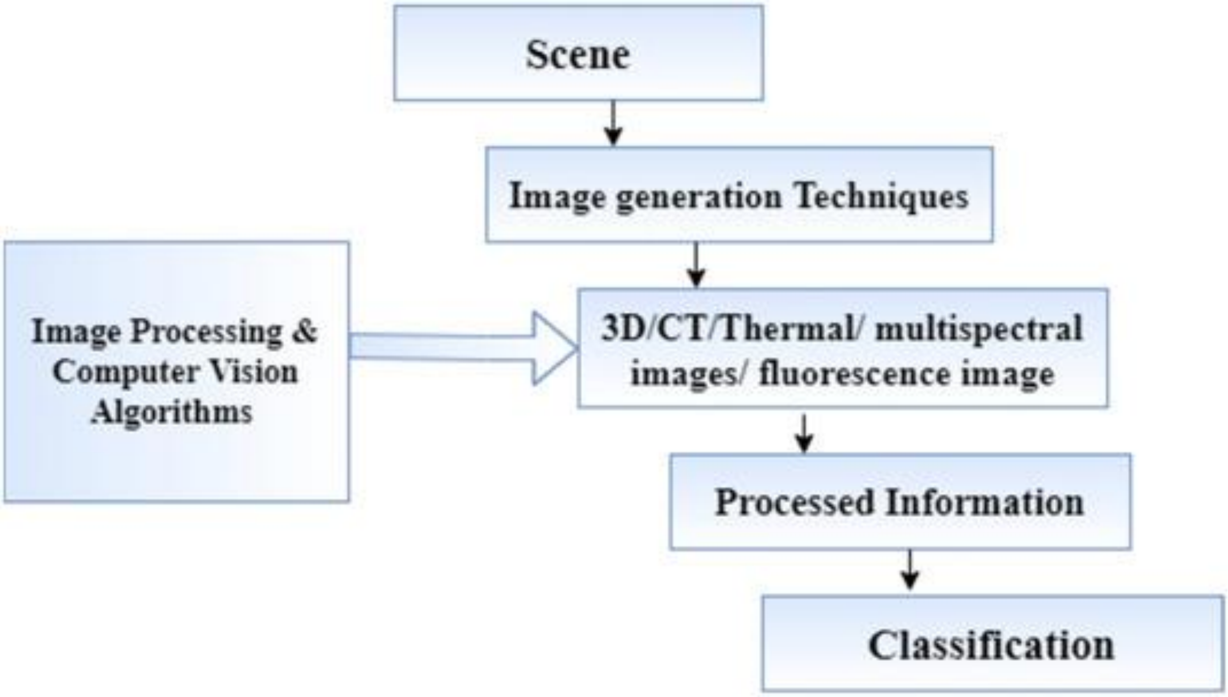

Fig. 3: Image processing method [10]

Conclusion:

The proposed method used image retrieval to solve the problem of foliar detection in soybean plants. We also introduced two feature descriptors, HIST and WDH, as well as investigated numerous other colour and texture-based feature descriptors, including BIC, CCV, CDH, LBP, SSLBP, LAP, and SEH. The retrieval-based approaches are used to test all of the feature descriptors. The system obtains the top matching images from the database for a query image using some similarity measure applied to its feature descriptors in the retrieval process. The BIC feature descriptor performs better than the other examined feature descriptors for illness recognition approaches such as retrieval. When compared to the other descriptors, the BIC descriptor performs better in terms of ARP, ARR, and ARA. The two descriptors HIST and WDH, which are produced directly from the histograms of each colour of infected area, perform nearly identically, since the ARP, ARR, and ARA values for both are approximately equal. The BIC descriptor improves the performance of the L1, Chisquare, and D1 similarity measures, whereas the WDH descriptor improves the performance of the L1, Euclidean, and Cosine similarity measures. In this case, we can say that the L1 distance-based similarity metric is more suited for detecting foliar changes on soybean plants. CDH is more resistant to retrieval with picture blur, and LAP descriptor is also resistant to image blurring since it can retrieve all instances of query photos while blurred. In classification-based approaches, the system first trains a classifier using the feature descriptions of the training images, and then uses the trained classifier and the feature description of the test image to categorize the test images. SVM, KNN, and PNN classifiers were examined. For the classification-based recognition technique, the KNN and SVM classifiers outperform the BIC descriptor in terms of class separability, whilst the PNN classifier outperforms the HIST and WDH.

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INSECTICIDAL ACTIVITY OF RHIZOSPHERIC BACTERIA AND THEIR EFFECTS ON PLANT GROWTH

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Abstract:

The use of natural pesticides is an alternative and eco-friendly method of pest management in agricultural fields. A variety of crop plants generate Indole 3 acetic acid (IAA) through plant growth-promoting rhizobacteria (PGPRs). In the present study, rhizobacteria were isolated from the rhizosphere of Holarrhena pubescens, their insecticidal activity was evaluated, and IAA was produced by cultivating different types and concentrations of C sources and N sources and the ability of superior strains to stimulate growth in some crop plants in sterile soil. Response surface methodology was used to select the best IAA-producing bacterial isolates. IAA production was enhanced by manipulating sugar type, sugar concentration, and strains. On the basis of different plant growth-promoting attributes, four out of 20 isolates were selected as efficient PGPRs. The isolates MHA-01, MHA-07, MHA-09, and MHA-11 showed superior IAA production at pH 8 (91.7 mg ml—1) and 37°C (81.7 mg ml—1). The highest level of IAA production was obtained with dextrose (1.25%). The MHA-01 strain has increased seed germination rates by 33.78% and the vigour index by 90.14% when compared to control plants after 10 days. After 30 days, MHA- 01 treatment increased the fresh and dry weights of shoots (9.5 ± 0.47g, 6.3 ± 0.31g) and roots (6 ± 0.3 g, 2.9 ± 0.15g) of treated plants compared to untreated plants. *Zea mays* exhibited the highest chlorophyll ((chl-a = 0.23554µg/ml and chl-b = 0.34842µg/ml) and carotenoid content (0.00872µg/ml) when inoculated with the MH-11 strain in comparison with *Vigna radiata*, *Pisum sativum* and *Cicer arietinum*. In the present study, rhizobacteria that produce secondary metabolized have insecticidal potentiality against mealy bug, IAA found to be effective in enhancing plant growth were exploited. In addition to controlling their production, response surfaces offer an excellent tool for optimizing.

Keywords: Rhizobacteria, insecticidal activity, Growth promotion, Indole-3-acetic acid, carbon sources, Optimization, Response surface methodology,

Introduction:

Agricultural crops have always been plagued by numerous pests such as fungi, weeds, and insects, causing a dramatic drop in the yield of the plants (Nawaz *et al.*, 2016). The use of chemicals is highly effective for the control of these pests, because not only do they affect a wide range of hosts, but they are also detrimental on the environment and the sustainability of farming systems. Therefore, synthetic pesticide use has declined by 2% per year in commercial agriculture as a result of regulatory restrictions, while biopesticide use has increased by 10% as an alternative agrochemical (Damalas and Koutroubas, 2018). Biopesticides are derived from animals, plants and other natural materials such as fungi, bacteria, algae, viruses, nematodes and protozoa. Microbial biopesticides are one of the most widely known types of biopesticide, and they command 5% of the global pesticide market, with microbial biopesticide taking first place (Pathma *et al.*, 2021). Although biopesticides are promising, their widespread adoption is hampered by a lack of available products to meet farmer needs, the high cost of refined products, and their slow action levels (Verma *et al.,* 2021). Howeve, these drawbacks must be weighed against a tolerable level of toxicity, if any, that biopesticides manifest. In addition, they are biodegradable, specific in action (harmless to non-target organisms), and provide an alternative method of dealing with pest resistance issues caused by synthetic pesticides (Mishra *et al.,* 2020). As science waits to address the drawbacks of this approach, raw extracts of pesticidal plants can be used in the meantime, especially by local farmers and countries in developing regions. Sustainability through biopesticide-driven agriculture is socially acceptable, stimulates economic productivity, and encourages environmental responsibility.

Sustainable agriculture meets the increased demand for food in today's agricultural sector by using sustainable farming practices (Fasusi & Babalola, 2021). The use of conventional agriculture methods is significant in meeting the food needs of an increasing population, but it has also led to an increasing reliance on fertilizers (Santos *et al.,* 2012). In recent decades, fertilizers have become increasingly important for farmers as a reliable crop protection method, helping them achieve economic stability (Mącik *et al.,* 2020). There have been a number of factors that have negatively affected farmers' crop yields worldwide, including infertility of soil, heavy metal contamination, infestation of plants with pathogenic microorganisms (Gouda *et al.,* 2018), development of pathogen resistance, and environmental impact from non-targeted agricultural practices (Sharma *et al.,* 2019). A way to address this problem is to reduce land degradation and use plant-beneficial rhizobacteria as bioinoculants that require a good understanding of a sustainable agricultural vision where crops need to be resistant to disease, salt and drought, and must be able to with stand heavy metal stress (Vejan *et al.,* 2016). Organic fertilizers containing bio-based materials are gaining popularity because they offer an alternative to agrochemicals and are more innovative in how they are applied to crops (Raja, 2013). Microorganisms that reside in the roots help control plant growth and protect the plant against pests by producing defense enzymes (Barea, 2015). Rhizobacteria provide plants with benefits through their ability to fix atmospheric nitrogen, dissolve inorganic phosphates, and produce siderophores and IAA (Bharti & Barnawal., 2019). The need for rhizobacteria, which can promote plant growth and control pathogenic microorganism attacks, is one of the possible solutions, and they can also greatly improve crop yield and overcome challenges caused by agrochemicals (Armada *et al.,* 2014). Plant growth-promoting rhizobacteria (PGPR) are the most promising microbial species found in soil. As a result, PGPR may be used to improve plant health and accelerate plant growth without polluting the environment (Calvo *et al.,* 2014). Among the beneficial microbiomes in the rhizosphere, there are PGP rhizobacteria, nitrogen-fixing symbionts, endophytes, mycorrhizal fungi, disease-controlling microorganisms, protozoa, and mycoparasitic fungi (Koskey *et al.,* 2021). Inoculants of plant-beneficial Rhizobacteria are preparations that contain cells from various strains of bacteria that can be applied to soil or plants to boost their metabolic processes and prevent them from being harmed by microbial pathogens and pests. In the last few decades, a variety of PGPR species has been studied and some have been commercialized, including *Pseudomonas, Bacillus, Enterobacter, Klebsiella, Azobacter, Variovorax, Azosprillum,* and *Serratia* (Kumari *et al.*, 2018). As plants synthesize plant hormones for growth promotion, including auxins for weed suppression (Azizoglu, 2019), gibberellins, ethylene, abscisic acid, jasmonic acid, cytokinins, salicylic acid and strigolactones for diseases suppression (Goswami and Deka, 2020; Saad *et al.,* 2020), indirect mechanisms come into play to suppress fungal, bacterial, nematode, and viral path. Microbes that positively impact plant growth have a special preference for plants, which directly impacts the microbe communities rhizospheric (Barriuso *et al.*, 2008). A number of growth-related plant parameters, including seed germination rate, vigour index, shoot fresh weight, root fresh weight, shoot biomass, root biomass, plant canopy size, and fruit number were influenced by rhizobacteria producing Indole Acetic Acid. Since, different bacteria, fungi and algae are capable of producing physiologically active amounts of IAA which has been found to be very important for plant growth and development. Microbes released many secondary metabolized such as amino acids, sugars and organic acids which helps the plants in various physiological activities. The rhizospheric bacteria produced IAA huge amount due to the supply of substrates required for this secondary metabolite production (Zhao *et al.*, 2010). The plant growth promoting activity reported by many researchers in *Zea maize, Vigna radiata*, *Cicer arietinum*, and *Pisum sativum* (Dasgupta *et al.*, 2015; Osman *et al.,* 2018; Kumari *et al.,* 2018; Khambani *et al.,* 2019). Improvement in crop yield and to attain success in sustainable agricultural systems use of plant growth promoting rhizobacteria is a promising alternative to chemical fertilizers, pesticides, fungicides etc (Kalayu, 2019).

This study was conducted to evaluate the insecticidal activity of isolated rhizobacteria that produce IAA and to optimize factors contributing to a high concentration of IAA using response surface methodology. Furthermore, the present study also examined some differences in growth parameters between crops of *Zea maize, Vigna radiata, Cicer arietinum,* and *Pisum sativum* using MHA 01, MHA 07, MHA 09 and MHA 11.

Materials and Methods:

1. Source and used of chemicals

The chemicals used in this experiment are Luria-Bertani broth, Nutrient Broth, Yeast extract and crude IAA was purchased from HiMedia. tryptophan, $FeCl_3$, $H2SO_4$, Salkowski reagent (2% 0.5 M $FeCl_3$ in 35% perchloric acid), 5% Sodium hypochloride (NaoCl), Dextrose, Maltose, Sucrose, Starch, Mannose, Mannitol DMSO (dimethyl sulphoxide), n-Hexane, Diethyl ether, Dichloromethane, and Ethyl acetate solvent and Silica gel was purchased from Merk, India. All the chemicals and media supplied from the laboratory of Gour Banga University.

2. Isolation of rhizospheric bacteria from soil

The soil samples were collected from Sreegopal Banerjee College's Medicinal plants garden in Bagati, Mogra, Hooghly. The root with intact plant was dug out carefully with 15 cm soil slab and the roots clumps soil which tightly bound were carefully stored in sterile polyethylene and used for isolation of PGPRs. The bacterial isolation from the soil was done by standard tenfold serial dilution method (Ribbons *et al.*, 2006). The excess moisture was removed through soil air dried technique. 1gm of soil was suspended in 10 ml autoclaved distilled water and 1 ml of soil solution from each tube was passed on to the next tube and subsequently a dilution range of 10^{-1} to 10^{-10} was prepared. Nutrient Agar media (NA) used to prepare fresh plates and 10 µl of soil solution was spread on sterile nutrient agar plates and incubated at 37^0C for 24 hrs. Morphologically distinguishable colonies were picked and streaked on another fresh nutrient agar plates from the several bacterial colonies that were grown on NA plates. Pure cultures colonies were obtained by re-streaking method. The production of IAA was determined according to Gordon and Weber., 1951. The bacterium was inoculated into Luria-Bertani broth medium amended with 0.1 mM tryptophan, and the cultures were incubated at 30°C for 24 hrs on a rotary shaker and centrifuged at 10,000 g for 15 minutes. Cell free supernatant was assessed for IAA production by the Pellet-Chollet method (Dobbelaere *et al.*, 1999). The reaction mixture included 1 ml of reagent (consisting of 12 g $FeCl_3$ per litre in 7.9M $H2SO_4$) and 1 ml of sample supernatant. The solution was mixed well, allowed to stand at room temperature for 30 minutes, and observed for color change. IAA production was optimized by choosing the maximum number of isolates producing IAA. These isolates were grouped according to their collection sites and analyzed for various plant growth-promoting activities. In sterile conditions, nutrient agar slants were stored with purified cultures at 4^0C.

3. Collection of mealy bugs

A camel hair brush was used to collect specimens of adult female mealybugs from mango groves located on the campus of the University of Gour Banga and transported to the Department of Botany's laboratory. We maintained the two generations at 26°C and 75 ± 5% relative humidity on fresh pumpkin fruits for about two weeks in the laboratory (Majeed *et al.*, 2018). A toxicological bioassay was conducted on healthy and active 2^{nd} instar nymphs and adult females that were obtained from a field collection of 2^{nd} generation mealy bugs.

4. Detection of IAA production

The IAA production was detected by the method of Brick *et al.*, 1991 with some modification. The freshly grown cultures was inoculated in 30 ml nutrient broth and kept at 37^0C for 36 hrs at 120 rpm in an incubator shaker. Fermentation cultures were centrifuged at 8,000 rpm for 10 min. at room temperature. Then 2 ml Salkowski reagent (2% 0.5 M $FeCl_3$ in 35% perchloric acid) added in 1 ml Cell Free Supernatant (CFS) in a test tube. Further, two drops of orthophosphoric acid added to it and kept in dark for color formation. The optical density was recorded at 530 nm after 2 hrs. IAA concentrations were determined using the standard plot of IAA.

5. Assays of Standard IAA

Crude IAA was purchased from HiMedia and different concentrations (20, 50, 100, 150, 200, 250 and 300 µg ml^{-1}) were prepared in distilled water. Salkowski reagent was added for color formation in different dilution of IAA (1:2) followed by the addition of two drops of orthophosphoric acid and kept in dark. The optical density measurements were made at 530 nm and standard curve was plotted.

6. Production optimization of IAA

The culture medium was inoculated with 24 hrs grown cultures (O.D = 0.5) of isolates MHA-01, MHA-07, MHA-09, and MHA-11 for IAA production. The experiment was based on four different parameters viz. Temperature, pH, and carbon source and nitrogen sources were taken for the study. The basic IAA production medium consisted of the peptone 10 g l^{-1} yeast extracts 6 g l^{-1} and NaCl 5 g l^{-1}. All cultures were incubated at 37^0C at 120 rpm for 36 hrs for observation. pH is one of the most important physicochemical parameters for IAA production. The pH range of 5–11 was examined for its effect on IAA production by different isolates. The IAA production depend on the temperature which is also an important parameter for the growth of bacteria affected by low or high temperature and IAA production is dependent upon the correct growth of microorganism. The IAA production was tested at 25, 30, 35, 37, 40 and 45^0C at 120 rpm. Six different sugars viz. Dextrose, maltose, sucrose, starch, mannose and mannitol at different concentrations of 0.5%, 0.75%, 1.0%, 1.25%, 1.50% and 1.75% were tested. Different nitrogen sources viz. beef extract, soybean meal, malt extract, and potassium nitrate at varying concentrations of 0.50%, 0.75%, 1%, 1.25%,1.50% and 1.75% were used for the study. The amount of IAA production was quantified through the standard plot.

Isolates		Carbon source		
Strain	Code	Sugar	Code	Concentration
MHA-01	01	Sucrose	1	0.5
MHA-07	07	Starch	2	0.75
MHA-09	09	Maltose	3	1
MHA-11	11	Dextrose	4	1.25
		Mannitol	5	1.5
		Mannose	6	1.75

7. *In vitro* and *In vivo* effect of selected isolates in crop plants

Seeds of four crop plants viz. *Zea maize*, *Vigna radiata*, *Cicer arietinum*, and *Pisum sativum* were purchased from jayashree beej ghar, Malda market. Fresh bacterial cells were collected by centrifugation at 8000 rpm for 5 min at 4^0C from large volume of broth culture of shake flask and pellet was washed twice with sterile distilled water, and suspended in 10 ml sterile distilled water and adjust O.D. value 07 approximately 10^4–10^6 colony forming units (C.F.U.) per seed, vortex and used for seed treatment. Approximately 15-20 seeds of all crops were surface sterilized with 5% sodium hypochloride (NaoCl, Merk, India) for 1 min and washed three times in sterile distilled water. The bacterial suspension and dry seeds were mixed gently by the stirred for 5 min. Bacterized seeds were spread on a Petridish and air dried overnight at room temperature. The number of bacterial cells per seed was determined via serial dilutions and was set to approximately approximately 10^4–10^6 colony forming units (C.F.U.) per seed at O.D. value 07. To assess the effect of the strains MHA-01, MHA-07, MHA-09 and MHA-11 on germination and seedling vigour, 15 seeds inoculated with bacterial strain were incubated in two

9 cm Petridishes on two layers of moistened filter paper (Whatman No. 1). As a control treatment, seeds treated with distilled water instead of bacterial suspensions were also established. Maintain sufficient moisture for germination, the Petri dishes were moisture in every alternate day, with sterile distilled water and incubated at 28^0C ± 2^0C in a light incubator. The germination percentage was recorded every 24 hrs for 10 days. Root and shoot length were measured after 10 days (the experiment was repeated thrice). The germination rate and vigour index were calculated using following formula (Chowdhury *et al.*, 2020).

Germination rate (%) = (number of seeds germinated/ total number of seeds) × 100

Vigour index = % germination × total plant length

After 10 days seedling was transfer in soil pot containing double autoclave soil and allow to grown up to 30 days. Then plants were carefully uprooted and the shoots and roots were separated and dried in an oven at 50^0C for 48 hrs to calculate the dried root and shoot biomass.

8. Photosynthetic pigments analysis

To analysis of photosynthetic pigments, 100 mg tissue from the terminal opened tender leaf of the bacterial treated and control plants were separately cut into small pieces and mixed with 7 ml of DMSO (dimethyl sulphoxide) in test tubes at 65^0C for 3 h. After crushing the samples, DMSO was poured onto make up the volume up to 10 ml and the absorbance of the clear extract was measured using UV-vis Spectrophotometer (UV-Vis1800, Shimadzu, Japan) at 645 and 663 nm marking blank as pure DMSO (Sharma *et al.*, 2003). Extraction and estimation of Photosynthetic pigments from leaves of maize plants were ground with DMSO. Estimation of the chlorophylls and carotenoid were followed the method of Lichtenthaler, 1987. Photosynthetic pigments viz. total chlorophyll, chlorophyll a, chlorophyll b and carotenoids were expressed as mg/g of fresh leaf tissue. The absorbance for chlorophyll-a, chlorophyll-b and carotenoid was recorded at 663, 645, and 470 nm, respectively.

9. Extraction of crude extract from cell free supernatant

The active strain MHA-01, MHA-07, MHA-09 and MHA-11 were inoculated in 100 ml sterile Nutrient Broth containing 250 ml Erlenmeyer flask and incubated at 37^0C in B.O.D incubator (Labtek, India) for 24 hrs using previously described method. After 10 days fermentation, broth was centrifuge at 8000 rpm for 10 min at 4^0C and collected the cell free supernatant (CFS) in a 50 ml centrifuge tube. Different solvents with increasing polarity viz. n-Hexane, Diethyl ether, Dichloromethane, and Ethyl acetate were used (1:1, v/v) for extraction of antifungal compounds from cell-free supernatant. The solvent supernatant mixture was agitated gently for 10 min in separating funnel and stand by 3-5 days for completely separated solvent phase from cell free supernatant. The solvent phase containing antifungal compounds was collected from each used solvent and concentrated by rotary vacuum evaporators (RotaVap, R-150, Superfit, Mumbai, India) and assayed for their antifungal activity by well agar diffusion method (chowdhury et al; 2020). After repeated solvent fractionation purification, concentrated Dichloromethane crude extract was passed through a silica gel column using MERCK silica gel (100-200 mesh) as the stationary phase and n-Hexane ethyl acetate (1:1) as the mobile phase and then dried using rotary evaporator.

10. Toxicity bioassay of bacterial crude extract

The toxicity of pesticides was assessed by bioassay for 2nd instar nymphs and adult females of laboratory-reared mealy bugs (Majeed *et al.*, 2018). The bacteria extracts were extracted using Dichloromethane solvent. The effectiveness of five different bacterial extract concentrations, i.e. 0.0, 15.0, 30.0, 45.0, 60.0 and 75.0 %, against 2nd instar mealy bugs was investigated in four replicates for each. A total of four replications of each crude extract were conducted against adult female mealy bugs at concentrations of 0.0, 15.0, 30.0, 45.0, 60.0 and 75.0 %, A completely randomized design (CRD) was used in this study. The crude extracts were serially diluted using distilled water. Nymphs were subjected to bioassays using the leaf dip method, and female adult insects were subjected to bioassays using freshly cut citrus twigs. After dipping leaf discs and twigs in treatment solutions for 30 seconds, they were air dried on towel paper at room temperature (22^0C) for 15 minutes, before being transferred onto moist filter paper discs in sterilized glass petridishes (diameter: 9 cm). Leaf-discs and twigs were dipped in treatment solutions for 30 seconds and were air dried at room temperature (22^0C) on towel paper for 15 min before their transfer on moist filter paper discs in sterilized glass petridishes (diameter = 9 cm). A camel-hair brush was used to release fifteen mealy bug nymphs or five adult females on the treated mango leaf discs (and/or twigs).

11. Statistical analysis

The experiments performed in the present study were done in triplicates and all the experiments repeated twice using totally randomized design. Exploratory data analysis was done. Normality of the data was checked by Shapiro-Wilk. One-Way ANOVA was used for analysis of variance in the data. RSM model was created for detecting main effects and interaction effects of predictor variables (Strains, Sugar type, sugar concentration) on IAA production. Linear regression models were created between sugar type and sugar concentration to understand the IAA production process. All the analysis was done, and plots were made in R 3.6.3 software (www.r-project.org) and the analyses were run in the software environment R Studio 1.2.5042 (http://www.rstudio.com).

Results:

1. Screening of IAA producing bacteria

The rhizobacterial strains were screened for IAA production and showed that all the strains were able to produced significant amount of IAA in tryptophan-supplemented medium, whereas strains MHA-01, MHA-07, MHA-09 and MHA-11 were potent to IAA production in the medium devoid of tryptophan (Table 1).

Table 1: Indole acetic acid production by cultures isolated from the rhizospheric soil of Kurchi (*Holarrhena pubescens*)

Strains	Tryptophan dependent IAA Production (µg/ml)	Tryptophan independent IAA Production (µg/ml)
MHA 01	607.8	350.02
MHA 02	35.2	0
MHA 03	26.4	0
MHA 04	96.8	5.8

MHA 05	29.7	0
MHA 06	152.9	12.02
MHA 07	590.02	340.9
MHA 08	78.9	0
MHA 09	458.8	255.8
MHA 10	26.7	0
MHA 11	563.8	324.8
MHA 12	134.7	9.02
MHA 13	78.7	0
MHA 14	36.4	0
MHA 15	48.9	0
MHA 16	104.8	13.8
MHA 17	110.7	16.9
MHA 18	78.9	0
MHA 19	70.8	0
MHA 20	68.9	0

2. Effect of Temperature and initial pH for IAA production

The isolated strain MHA-01 was able to produce good amount of IAA throughout the pH range tested and the highest amount of IAA (85.7 µg ml^{-1}) produced at pH 8 (Figure-1). The strain MHA-07 increased the IAA production from 5 - 8 pH rang, decreased from 9-11 pH ranges and it showed maximum production (77.71 µg ml^{-1}) at pH 8. The stain MAH- 09 produced 67.16 µg ml^{-1} IAA at pH 8 and 32 µg ml^{-1} IAA at pH 11 and strain MAH-11 produced 72.12 µg ml^{-1} IAA at pH 8 and 42 µg ml^{-1} IAA at pH 11.

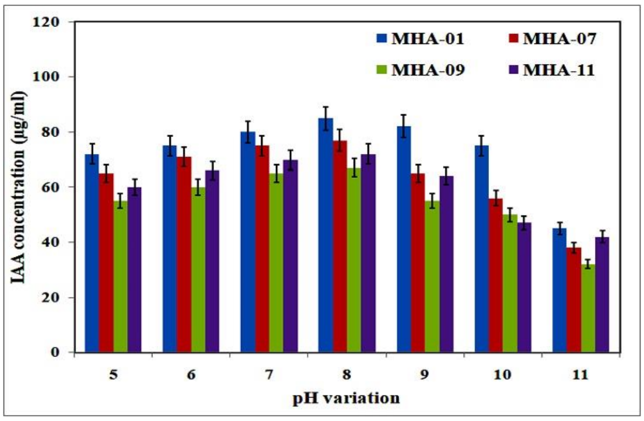

Fig. 1: Effect of pH on IAA production by PGPR.

The effect of temperature was studied in the range 20–45^{0}C whereby maximum yield was observed at 37 ^{0}C by all isolated strains (Figure. 2). The strain MHA-01 produced maximum 80.24 µg ml^{-1} followed by 77.16 µg ml^{-1}, 70.36 µg ml^{-1}, 72.12 µg ml^{-1} IAA by MHA-01, MHA-07, MHA-09 and MHA-11, respectively.

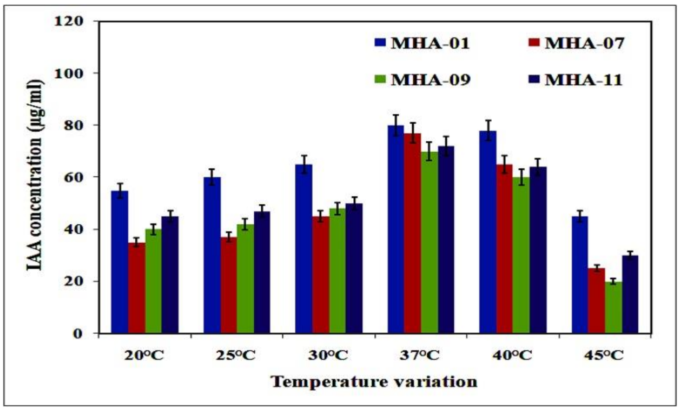

Fig. 2: Effect of temperature on IAA production by PGPR

3. Effect of Carbon source for IAA production

The most important carbon source was Dextrose producing 100µg /ml IAA at 1.25% and 93 µgml^{-1} at 1% concentration by the strain MHA-01. The strain MHA-07, MHA-09 and MHA-11 produced maximum 89 µgml^{-1}, 70 µgml^{-1} and 80 µgml^{-1} IAA, respectively. The production of IAA enhanced by the addition of sucrose as a carbon source in NB media. The highest IAA production showed in 1.25% sucrose concentration. The MHA-01 strain produce 98 µg/ml IAA followed by 87 µg/ml, 70 µg/ml and 75 µg/ml IAA by the strains MHA-07, MHA-09, and MHA-11, respectively. Starch was one of the important carbon sources for IAA production. It produced highest 80 µg/ml IAA by the strain MHA- 01 by the addition of 1% starch in NB media. The others strains viz. MHA- 07, MHA-09 and MHA-11produced highest 75 µg/ml, 55 µg/ml and 60 µg/ml of IAA in addition of 1% concentration of starch. The production of IAA significantly increased by the amended of 0.75% maltose sugar. MHA-01 produced maximum (79 µg/ml) amount of IAA followed by MHA-07 (75 µg/ml), MHA-09 (65 µg/ml), and MHA 11(70 µg/ml), respectively. In the presence of mannose sugar, the highest IAA producing activity found in 1% concentration by the isolated strain MHA-01 which was 67 µg/ml. The other strains MHA-07, MHA- 09 and MHA-11 produce highest 56 µg/ml, 43 µg/ml, and 39 µg/ml IAA, respectively. Similarly in the presence of mannitol sugar, all strains synthesized highest IAA in 1% concentration which were 65 µg/ml, 50 µg/ml, 45 µg/ml and 55 µg/ml by the strains MHA-01, MHA-07, MHA-09 and MHA-11, respectively (Figure 3: a, b).according to one way ANOVA analysis, there a no significance difference between strains in different sugars and between sugars in different strains (Figure - 4 a, b).

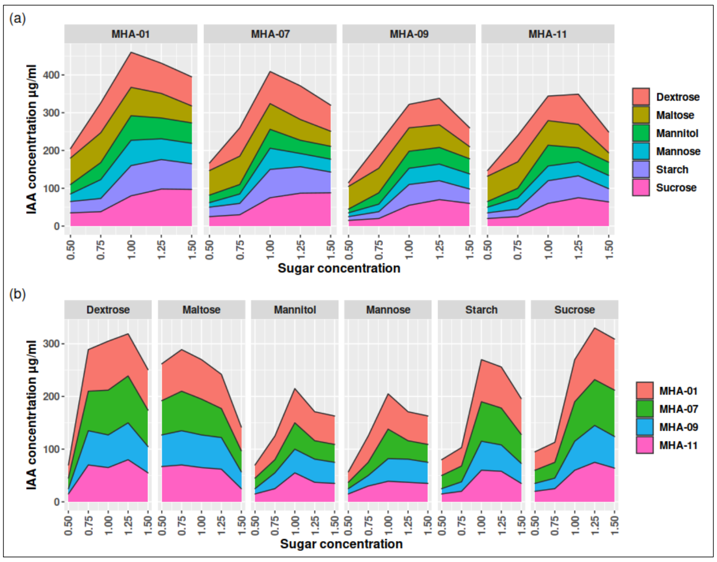

Fig. 3: Comparison of IAA production by permutation combination of sugar type, sugar concentration and strain (a, b).

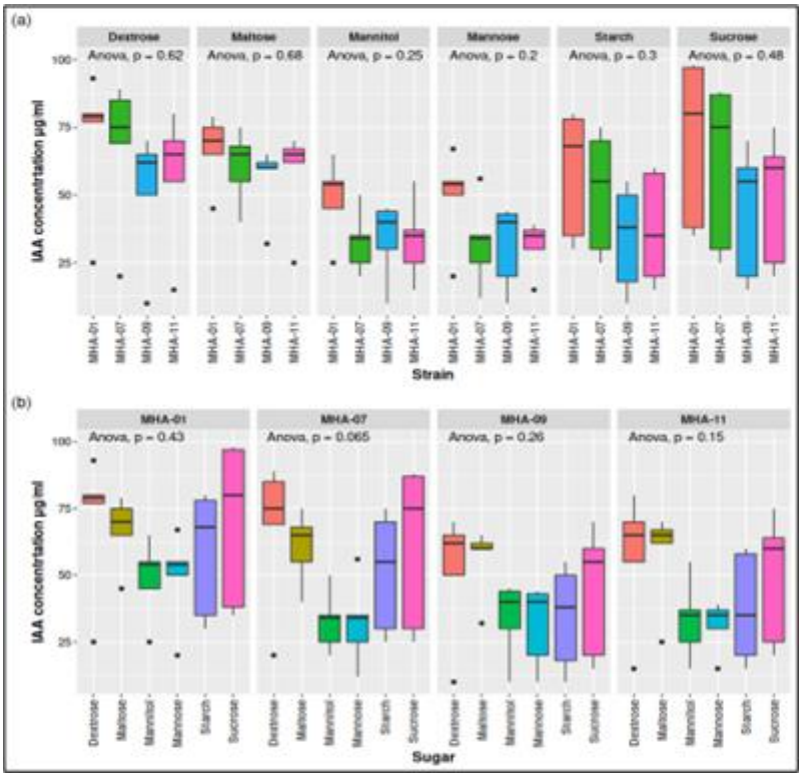

Fig. 4: Analysis of variance in IAA production between strains in different sugars (a) and between sugars in different strains (b).

4. Effect of Nitrogen source for IAA production

The used of malt extract in NB media showed that the significant amount of IAA production which was shown in Figure 5A. The strain MHA-01 produced highest 95 µg/ml IAA followed by 79 µg/ml, 60 µg/ml, 91 µg/ml, by the strains MHA-07, MHA-09, MHA-11, respectively. The used of Beef extract showed the maximum IAA production in 1.25%

concentration by the all strains as shown in Figure 5B. The strain MHA-01 showed highest 80 µg/ml IAA followed by 75 µg/ml, 55 µg/ml and 77 µg/ml by the strains MHA-07, MHA-09, MHA-11, respectively. The application of Soyabean meal enhanced the maximum IAA production 80 µg/ml and 75 µg/ml by the strains MHA-01 and MHA-07 in 1% concentration. The strains MHA-09 and MHA-11 produced 60 µg/ml and 79 µg/ml IAA in 1.25% concentration as shown in Figure 5C. The used of Glycine significantly increased the production of IAA in 1% concentration which was shown in Figure 5D. The highest IAA production showed by the strain MHA-01 in terms of 60.25 mg/ml followed by the 34.12 mg/ml and 51 mg/ml by the strain MHA-07 and MHA-11, respectively. The strain MHA-09 utilized the glycine 1.25% for the better production of IAA. Similarly in case of Ammonium nitrate, all the strain used and increased IAA production up to 1% concentration which was shown in Figure 5E . The strain MHA-01 produced 65 µg/ml IAA followed by 35 µg/ml, 30 µg/ml and 56 µg/ml by the strains MHA-07, MHA-09 and MHA-11, respectively. The strain MHA-01, MHA-07 and MHA-11 utilized the potassium nitrate up to 1% concentration in ratio of IAA production in terms of 45 µg/ml, 15 µg/ml and 35 µg/ml as shown in Figure 5F. The strain MHA-09 produced 17 µg/ml IAA in 1.25% potassium nitrate concentration and decreases the IAA production.

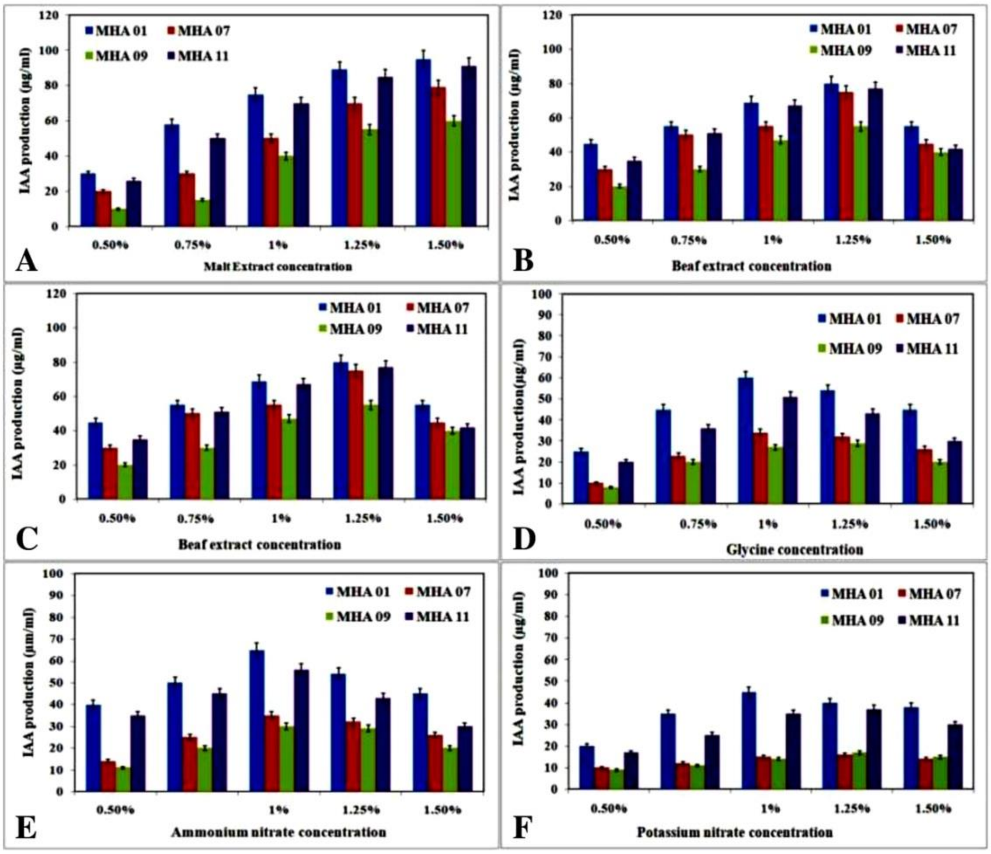

Fig. 5: Graph showing effect of various nitrogen sources for IAA production;(A) Malt extract concentration;(B) Beef extract concentration;(C) Soybean meal concentration; (D) Glycine concentration; (E) Ammonium nitrate concentration; (F) Potassium nitrate concentration.

5. Seed germination rate assessment of bacterized seeds and vigour index

Assessment of rate of germination of bacterized seeds, vigour index of treated seedling after 10 days and plants growth parameters of *Zea maize*, *Vigna radiata*, *Cicer arietinum*, and *Pisum sativum* plants were compared with control which was shown in Figure-6. The seed germination rate of *Zea maize* plant treated with strain MHA-01 had increased by 33.78% compared with the control whereas the vigor index was increased by 90.14% whereas the seed germination rate 25.57%, 28.37%, 21.62% and vigour index 81.08%, 81.75%, 79.72% treated with the strains MHA-07, MHA-09, and MHA-11 respectively. The seed germination rate of *Vigna radiata* plant treated with strain MHA-01 had increased by 38.01% compared with the control whereas the vigor index was increased by 82.67% whereas the seed germination rate 29.57%, 35.21%, 28.16% and vigour index 73.29%, 73.94%, 75.35% treated with the strains MHA-07, MHA-09, and MHA-11 respectively. The seed germination rate of *Pisum sativum* plant treated with strain MHA-01 had increased by 42.02% compared with the control whereas the vigor index was increased by 112.90% whereas the seed germination rate 37.68%, 36.23%, 22.53% and vigour index 111.29%, 113.70%, 116.93% treated with the strains MHA-07, MHA-09, and MHA-11 respectively. The seed germination rate of *Cicer arietinum* plant treated with strain MHA-01 had increased by 37.06% compared with the control whereas the vigor index was increased by 79.86% whereas the seed germination rate 23.61%, 25.77%, 27.77% and vigour index 71.38%, 69.44%, 68.03% treated with the strains MHA-07, MHA-09, and MHA-11 respectively. The results suggest that rhizobacterial treatment could improve the germination and vigour of *Zea maize*, *Vigna radiata*, *Cicer arietinum*, and *Pisum sativum* seeds.

6. Assessment of plant growth promotion of some crop plants

Assessment of plant growth parameters viz. shoot fresh weight, root fresh weight, shoot biomass and root biomass of *Zea maize*, *Vigna radiata*, *Pisum sativum,* and *Cicer arietinum* plants were compared with control which was shown in Figure-6. The application of MHA-01 increased shoot fresh and dry weight (9.5 ± 0.47g, 6.3 ± 0.31g) and root fresh and dry weight (6 ± 0.3 g, 2.9 ± 0.15g) of maize plants compared to untreated maize plant at 30 days followed by strains MHA-07, MHA-09 and MHA-11. The shoot fresh weight 7.5± 0.37g, 8 ± 0.4g, 9 ± 0.45g and root fresh weight 3 ± 0.15g, 5.6 ± 0.28g, 4.9 ± 0.24g increased with the application of strains MHA-07, MHA-09 and MHA-11, respectively. The application of bacterial strain MHA-01 significantly increased highest shoot dry weight 6.3 ± 0.31g root dry weight 4.9 ±0.24g among the bacterial isolates. Similarly the highest plant growth promotion observed in case of *Vigna radiata* by means of shoot fresh weight 7.5 ± 0.38g, shoot biomass 5.4 ± 0.27g and root fresh weight 4 ± 0.2g, root biomass 4.1± 0.20g with the application of MHA-01 strain. Isolates MHA-09 and MHA-011 showed better response on treating the seeds of *Pisum sativum* with production of 9.9 ± 0.49 g and 8.1 ± 0.4g and of shoot fresh weight and 5.9 ± 0.29g and 5.3 ± 0.26g dried root biomass compared to control plant. In case of *Cicer arietinum* the highest shoot fresh weight was shown 7± 0.35g and 7.4 ± 0.37g and shoot biomass and root biomass was 5 ± 0.25g and 4.6 ± 0.23g by isolate MHA-01 and MHA-09 among the bacterial strains.

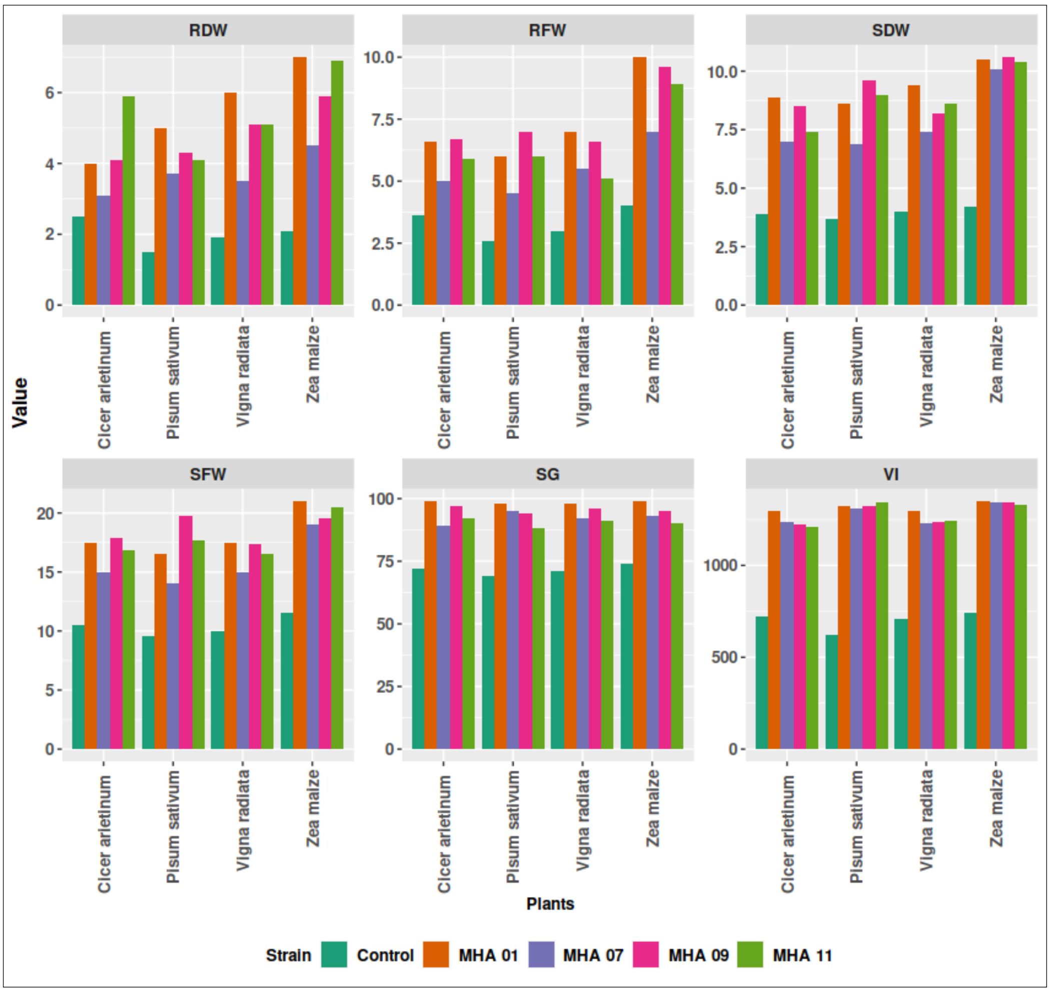

Fig. 6: Assessment of seed germination, vigour index, plant growth parameters and comparison between strains. RDW = Root dry weight, RFW = Root fresh weight, SFW = Shoot fresh weight, SDW = Shoot dry weight, SG = Seed germination, VI = Vigour index.

7. Photosynthetic Pigments analysis

The results of photosynthetic pigments estimation by application of MH-01, MH-07, MH-09 and MH-11 rhizobacterial strains in *Zea maize*, *Vigna radiata*, *Pisum sativum*, and *Cicer arietinum* pots showed in figure-7. Among the pots crops, *Zea maize* pot showed that highest chlorophyll (chl-a = 0.23554µg/ml and chl-b = 0.34842µg/ml) and carotenoid content (0.00872µg/ml) observed by the inoculation of MH-11 strain followed by the MH-01, MH-07, MH-09. Similarly in case of *Vigna radiata*, *Pisum sativum*, and *Cicer arietinum*, MH-11 significantly performed the highest photosynthetic pigments production than the other three strains.

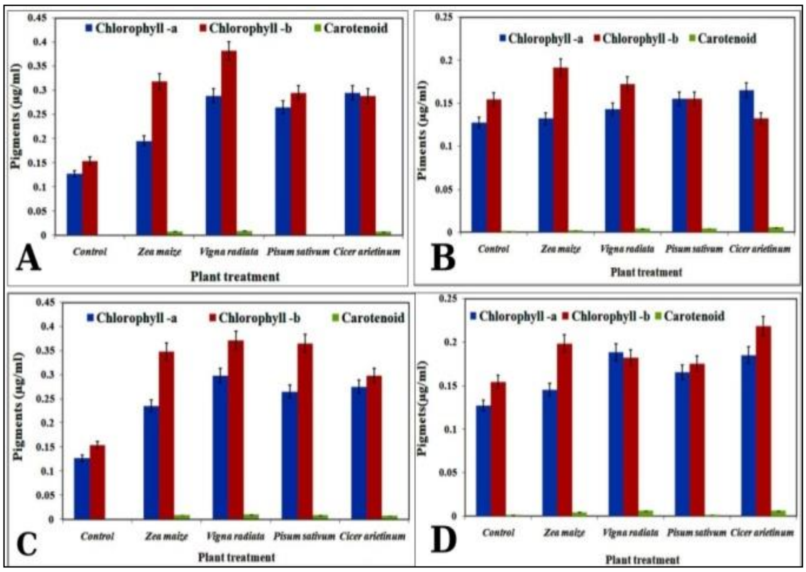

Fig. 7: Photosynthetic pigments analysis of crop plants treated by PGPR stains; (A) MHA-01 ; (B) MHA-07;(C) MHA-09; and (D) MHA-11

9. Toxicity assay against mealybugs

The toxicity assay showed that the crude extracts of MHA-01, MHA-07, MHA-09, and MHA-11 were biopesticidal and killed the mealybug at different concentrations. The percentage of dead increases as concentration increases, as shown in figure-8.

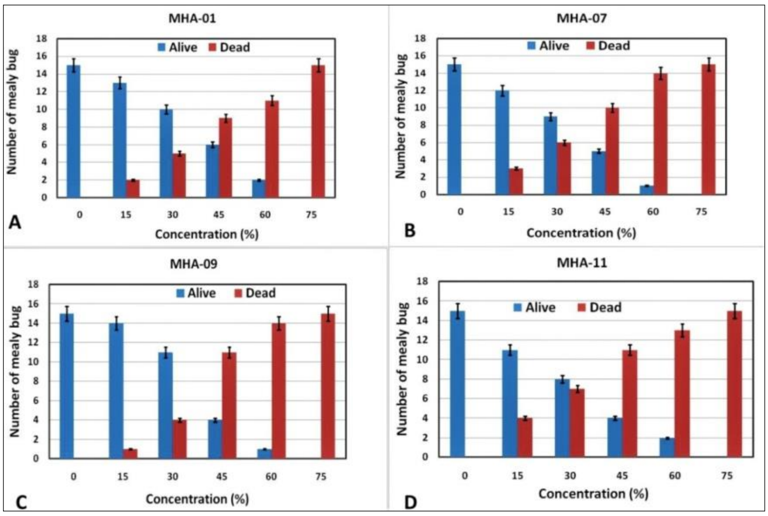

Fig. 8: Toxicity assay of bacterial crude extract against mango mealy bugs in different concentration. Here (A) indicated the effect of MHA-01strain; (B) effect of MHA-07 strain; (C) effect of MHA-09 strain and (D) effect of MHA-11strain.

Discussion:

Bacterial pesticides are the cheapest and most common type of insecticide that has been used in agriculture for many years. Compared with traditional pesticides, biopesticides are a better alternative that is environmentally friendly, target-specific, readily biodegradable, and safer. The most commercially exploited Gram-negative bacteria are *Clostridium bifermentans*, *Pseudomonas aureofaciens*, and *Pseudomonas alcaligenes*. There are certain strains of *Pseudomonas* bacteria that colonize plant roots and are pathogenic to insects; these strains could be used to formulate bioinsecticides against root-feeding insects for the protection of crop plants

(Kupferschmied *et al.,* 2013). Insecticides are made from bacteria, such as *B. popilliaes, B. sphaericus, B. thuringiensis,* and *B. popilliaes* (Bp), but *B. popilliae* in particular is an obligate pathogen of scarab larvae, causing 'milky disease,' and is highly specific.

The isolated bacteria screening for plant growth promoting rhizobacterial (PGPRs) properties and among them four were selected and used for optimization of IAA production. The most potent four IAA producing isolates produce IAA in the presence of tryptophan and absence of tryptophan in NB media (Table-1). The isolated strains produce of IAA only in the presence of L-tryptophan indicates that the tested strains utilize L-tryptophan as a precursor for IAA production during their growth in the medium. Maximum IAA production was obtained with isolate MHA 01. The plants growth can be affected by soil pH in the plant rhizispheric soil because of metal ions could reach toxic levels in the soil at Lower pH limits (Mohit B., 2013). The physiological and metabolic process of plant depends on soil pH and metal cations, therefore, impact of pH range of 5–11 was only checked for IAA production (Figure - 2). Bharucha *et al.,* 2013 showed that the maximum IAA production at pH 7.5 by *Pseudomonas putida* UB-1 and whereas Shanti *et al.,* 2007 suggested that production varied between pH 6.4 and 7.8 by *Rhizobium* sp. isolated from root nodules of *Vigna mungo* L. Sachdev *et al.,* 2009 showed that the maximum production observed at pH 6 - 8 and optimum at pH 7.2 by *klebsiella pneumonia* isolated from wheat rhizosphere. Similar result was shown in other studies (Sudha *et al.,* 2012) where 37 °C was the best temperature for IAA production for *Rhizobium* and *Bacillus* spp. The production of IAA optimized by the used of several carbon sources that are also used in production of others secondary metabolites. Six different types of sugars (Sucrose, Starch, Maltose, Mannitol, Mannose, and Dextrose) were used in this study to check their effect on IAA production (Figure- 3 a. b). The used of various carbon sources showed that monosaccharide's were better sources than disaccharides and polysaccharides. In this content, dextrose was found as the best sugar source for IAA production. The individual carbon sources affect the IAA production which was studies on bacteria by Shanti *et al.,* 2007 and Sridevi *et al.,* 2008. The production IAA optimized by the used of several carbon sources that are also used in production of others secondary metabolites. Six different types of sugars (Sucrose, Starch, Maltose, Mannitol, Mannose, and Dextrose) were used in this study to check their effect on IAA production (Figure. 3A–F). The used of various carbon source showed that monosaccharide's were better sources than disaccharides and polysaccharides. In this content, dextrose was found as the best sugar source for IAA production. The individual carbon sources affect the IAA production which was studies on bacteria by Shanti *et al.,* 2007 and Sridevi *et al.,* 2008. The effect of different concentrations of sugar sources in basal media was different due to variable utilization of sugars by bacteria during their growth. *Acetobacter diazotrophicus* and *Pseudomonas fluorescence* produced IAA 48 mg ml^{-1} by the addition of ammonium chloride as nitrogen sources (Jeyanthi et al., 2013). According to Balaji, 2012, *Pseudomonas* species produced IAA 210 mg ml^{-1} after addition of yeast extract and 18.08 mg l^{-1} after addition of soyabean meal as the best nitrogen sources. According to recent study by Nutarata *et al.,* 2017 showed that the application of *Enterobacter* sp. DMKU-RP206 improve IAA production 13.4-fold which was higher amount of IAA than previously reported for the genus *Enterobacter*.

The statistically analysis of variance in IAA production between strains in different sugars (a) and between sugars in different strains (b) (Figure-4). From the RSM model, main effects or the First Order effect of sugar type (p=0.0038947) and sugar concentration (p=2.966e-12) found significant but strain not found significant (p=0.3516260). Interaction effects between Strain: Sugar-type (p=0.6210806) and Strain: Sugar-concentration (p=0.3513582) not found significant but interaction between sugar-type: Sugar-concentration (p=0.0381735) found significant. The model found moderately good and significant (R-squared= 0.5768, Adjusted R-squared = 0.5422, DF= 110, p < 2.2e-16, alpha = 0.05). According to the surface plot Starch (Sugar-type 2), with concentration of 1.25 is most suitable for high amount of IAA production (figure-.8)

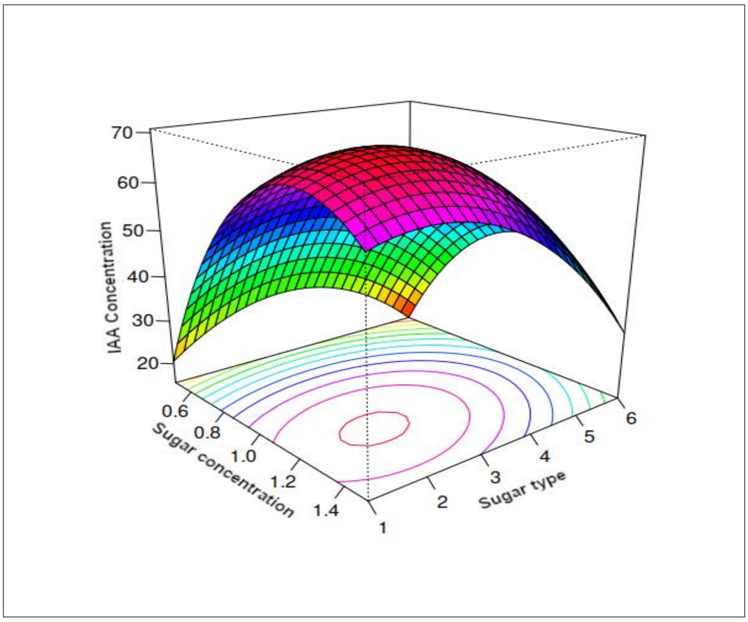

Fig. 8: Response surface plot showing interaction effect of sugar type and sugar concentration on IAA production. Sugar types are in coded value (1= Sucrose, 2= Starch, 3= Maltose, 4= Dextrose, 5= Mannitol, 6= Mannose)

From the violin plot there seems clear difference in IAA production due to different sugar types, due to different strain types (Figure-9A). There is overall significant difference in IAA production between all the strains (p=0.0093), but no significant difference found between MHA-01:MHA-07, MHA-07:MHA-09, MHA-07:MHA-11, MHA-09:MHA-11, although significant difference found between strains MHA-01:MHA-09, MHA-01:MHA-11 (Figure-9B). Overall significant difference (p=8.8e-05) in IAA production in different sugar types was found (Figure-9C). Overall significant difference (p=1.3e-08) in IAA production in different sugar concentration was found (Figure -9D).

Correlation between IAA production and sugar concentration was found positive and significant in Dextrose (R=0.57, p=0.0093), Manitol (R=0.57, p=0.008), Mannose (R=0.59, p=0.006), Starch (R=0.62, p=0.0034), Sucrose (R=0.84, p=3.2e-06) but in Maltose the correlation was found negative and significant (R=-0.73, p=0.00028) [Figure- 10].

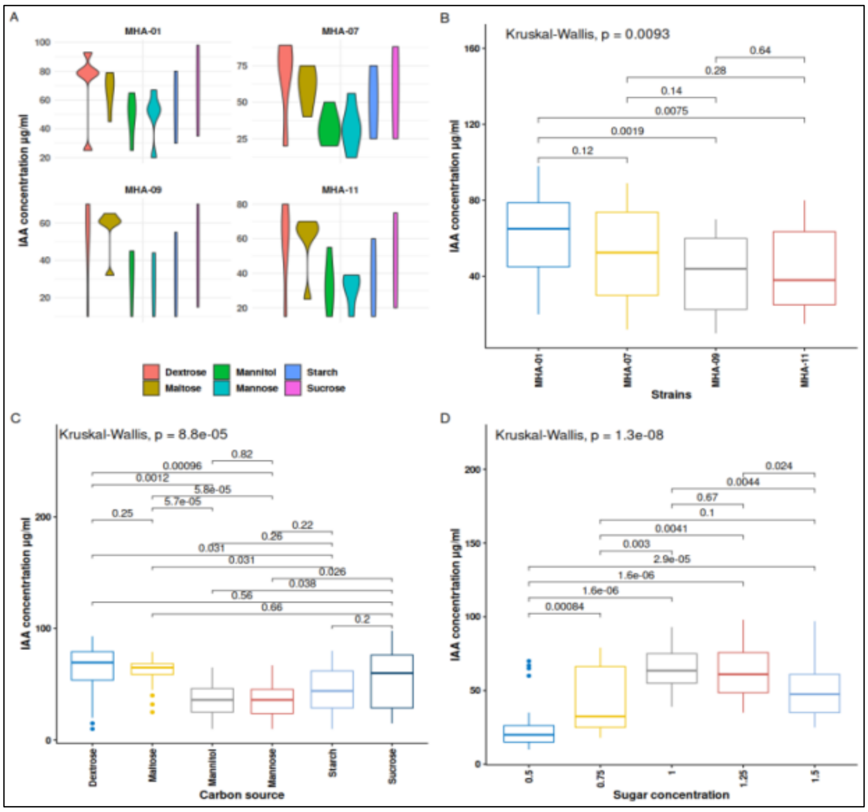

Fig. 9: Violin plot (A) shows overall data distribution of IAA production in four strains. Box plot showing differences in IAA production between four strains (B), between six sugars (C) and between sugar concentrations (D).

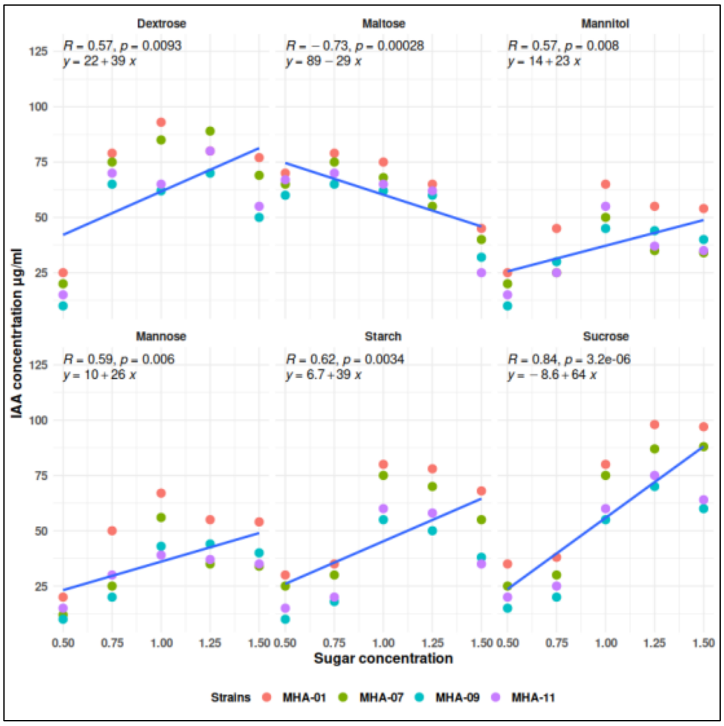

Fig. 10: Linear regression models showing correlation between IAA production and sugar concentration in different strains.

The seeds of *Zea maize, Vigna radiata*, *Pisum sativum,* and *Cicer arietinum* treated with strains MHA 01, MHA 07, MHA 09 and MHA 11 significantly increased the percentage of seed germination by 33.78%, 38.01% , 42.02%, and 37.06% compared with the control, while the vigour index was increased by 90.14%, 82.67%, 112.90%, and 79.86%, respectively. The application of MHA 01 increased shoot fresh weight 82.60% in case of *Zea maize*, 75% in case of *Vigna radiata*, 71.87% in case of *Pisum sativum* and 66.66% in case of *Cicer arietinum* above control (Figure-5). Similarly root fresh weight increased 150% in case of *Zea maize* 133.33% in case of *Vigna radiate,*130.76% in case of *Pisum sativum* and 83.33% in case of *Cicer arietinum* above control. The application of MHA 11 in case *Zea maize, Vigna radiata*, *Pisum sativum,* and *Cicer arietinum* showed the moderate percentage of growth increase shoot fresh weight 73.91%, 65%, 84.37%, and 60% and root fresh weight 122.5%, 70%, 130.7% and 63.88%, shoot biomass 147.61%, 115%, 143.24% and 89.74% and root biomass 228.57%, 168.42%, 173.33 and 136% higher than the control. Similarly the application of strains MHA 07 and MHA 09 in case of *Zea maize, Vigna radiata*, *Pisum sativum,* and *Cicer arietinum* showed that shoot fresh weight, root fresh weight, shoot biomass and root biomass significantly increased than the control plants (Figure-5). The application of *Burkholderia and Herbasprillum* in Maize (*Zea mays* L.), sugarcane grass, shorgum increased the growth and production by synthesis of indole-3-acetic acid (IAA) (Da Silva *et al.*, 2016; Dos Santos et al. 2017, Chowdhury *et al.,* 2020). The growth and yield of many important crops, including maize, banana, and Bt cotton increased by the application of PGPR (Pastambh *et al.,* 2016). *Pseudomonas aeruginosa* PS24, an antagonistic bacteria showed the multiple plant growth promoting attributes such as phosphate solubilization activity, indole acetic acid (IAA), siderophore, and HCN production (Uzair *et al.,* 2018).The enteric bacteria *Salmonella* showed the production of IAA, colonizing plant tissues and help in interaction with plants and animals providing new incentives to gain insight into the function of this plant hormone in a larger biological context (Cox *et al.*, 2018).The screening of beneficial microorganisms from different plants rhizosphere based on IAA producing properties which is considered as effective tool rhizobacterial isolates on plant growth (Wahyudi *et al.*, 2011). The involvement of rhizobacterial isolates for enhancing the plant growth by synthesizing IAA which was confirmed previous studies. Root elongation of *Sesbania aculeate* and *Brassica campestris* was found to occur by inoculation with *Azotobacter* spp. and *Pseudomonas* spp., and by *Bacillus* spp (Ghosh *et al.*, 2003), in *Vigna radiata* by *Pseudomonas putida* (Pattern *et al.*, 2002), and in *Pennisetum americanum* by *Azospirillum brasilense* (Tien *et al.*, 1979). Effect of IAA producing isolate was also observed in *Solanum lycopersicum,* where it significantly increased the shoot and root biomass and chlorophyll (a and b) contents as compared to control plants. The root-associated strains of *Pseudomonas* can reduce plant diseases by directly fighting pathogens as well as by indirectly activating plant defenses. Several studies have documented the benefits of induced systemic resistance (ISR) caused by root-colonizing *Pseudomonas* in monocotyledonous and dicotyledonous plants against pests caused by fungal, oomycete, bacterial, and viral pathogens, as well as herbivorous insects (van de Mortel *et al.*, 2012; Zamioudis and Pieterse, 2012; Balmer *et al.*, 2013).

Application of MHA-11 significantly enhanced total chlorophyll and carotenoid content of leaves in *Zea maize* by 52.63% and 82.75% over untreated control plants followed by 60.29%, 56.45% and 51.78% of *Vigna radiata*, *Pisum sativum,* and *Cicer arietinum* respectively. Similarly application of MHA-01, MHA-07, and MHA-09 in *Vigna radiata, Pisum sativum,* and *Cicer arietinum* pot increased the total chlorophyll and carotenoid content in treated plant over the control.Chlorophyll biosynthesis has been considered as an indicator of net physiologically available iron to the plant. Higher absorption of iron is correlated with higher contents of chlorophyll a, chlorophyll b and total chlorophyll (Katyal and Sharma, 1980, Chowdhury, 2021). The increase in chlorophyll content could be due to the utilization of microbial siderophore by the plants. The best way to control insecticide-resistant pest species is to screen out alternate options that cause the least off-target effects. In the modern era of bio-intensive agriculture, bacterial-derived chemicals have emerged as more environmentally friendly and safer alternatives to synthetic pesticides (Castillo-Sánchez *et al.,* 2010). An insecticidal effect of four different bacterial extracts on mango mealybug nymphs and adults was determined in this study using two bioassays. There was no effect of mealybug on the control treatments. In contrast, adult female mealybugs were more susceptible to bacterial extract than second-instar nymphs, most likely due to their more intricate body integument (Waxy layer of mealy powder covered with intricate body integument) (Mani and Shivaraju, 2016).

Conclusion:

There is an increasing need for bacterial pesticides to replace toxic and hazardous synthetic chemicals, thus providing effective biorational options against mealybugs and other homopterous pests, and so they should be incorporated into future pest management programs. In this study, we employed a RSM approach to optimize the production of IAA by MHA- 01, MHA -07, MHA-07 and MHA-11 with the goal of exploring formulations best suited for commercial agriculture. IAA production was enhanced by optimizing the culture conditions using a statistical design method and a suitable medium for improved IAA production was developed. The maximum yield of IAA was obtained at pH 8 (85.7 µg ml^{-1}) and at temperature 37°C (80.24 µg ml^{-1}) by isolate MHA 01. Dextrose (1%) was found to be the best carbon source for isolate MHA 01 with 93 µg ml^{-1} IAA production and malt extract was the good nitrogen source for IAA production showed maximum production by MHA-01 95 µg/ml at 1.5% concentration. strains MHA- 01, MHA-07, MHA- 09 and MHA 11 significantly increased the percentage of seed germination by 33.78%, 38.01% , 42.02%, and 37.06% compared with the control, while the vigour index was increased by 90.14%, 82.67%, 112.90%, and 79.86%. The application of strains MHA- 01, MHA -07, MHA-07 and MHA-11 in case of *Zea maize, Vigna radiata, Pisum sativum,* and *Cicer arietinum* showed that shoot fresh weight, root fresh weight, shoot biomass and root biomass significantly increased than the control plants. Therefore, further research is needed to confirm that rhizobacteria have the potential to contribute to plant development, plant defense, and plant productivity in order to ensure sustainable agriculture.

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Compliance with ethical standards:

The authors declare that they have no conflict of interest. This article does not contain any studies involving animals or human participants performed by any of the author.

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DEVELOPMENT OF WIND SPEED INDICATOR FOR THE AGRICULTURAL SECTOR

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Abstract:

For many nations, agriculture serves as the foundation of their economies, and it makes a considerable contribution to the economic growth of developing nations. Additionally, it directs developed nations' economic prosperity. Agriculture is coping with new, major difficulties. According to the FAO, in order to feed the world's rapidly expanding population and urbanisation, food output must increase by 70% globally. Modern crop management techniques are still insufficient to meet the world's unrelenting demand for food. Exponential population expansion, climate change, and poor agricultural practises are the main causes of this problem.

With the advent of the Internet of Things (IoT) concept, agricultural practises are no longer as archaic as they once were. Over the years, humankind has grown from humble beginnings. The current revolution in agriculture, which must satisfy the demands of an expanding global population, cut production costs, and adjust to climate change, has been greatly aided by technology. Several factors must be taken into account in the field of agriculture in order to improve crop quality, particularly when it comes to the growth of crops while taking into account climatic factors like wind direction, humidity, amount of rainfall, temperature, and pressure. An IoT-enabled wind speed indicator has been created and put through testing in this study.

Introduction:

In many fields, including meteorology, climatology, air quality assessment, agriculture, architecture, energy generation, performance analysis of outdoor sports, and many others, the study of wind data is essential. Of course, if some fields are not properly taken into consideration, the wind could pose a problem. The agricultural industry is one such field. Grof *et al.* (2019) assert that using cutting-edge technology like the Internet of Things (IoT), it is critical to boost the productivity of agricultural and farming activities in order to raise yields and cost-effectiveness. IoT is a vital part of the future Internet and consists of a combination of global data and web-connected objects or things. By reducing human involvement, IoT focuses on automating operations. According to Chowhan *et al.* (2018), IoT automates operations by employing sensors to gather data, controllers to process that data, and actuators to complete those processes.

Effects of climatic parameters on agriculture

1. Wind

The topography, elevation, proximity to the coast, flat plains, flora, and other variables all affect the wind velocity at a given location. Crop growth is influenced by wind both biologically and mechanically (directly and indirectly). The tissues of agricultural plants become mechanically lacerated and bruised by the wind. Crop plants such as wheat, maize, sugarcane, rice, etc. lodge due to violent winds. High wind speeds in bare deserts constantly erode the soil, which makes it impossible for plants to flourish. According to Wakhale *et al.* (2014)., the wind has a significant impact on the amount of humidity in the air.

The season of blossoming is when crops are severely damaged by hot, dry winds. Poor seed germination results from plants' internal water balance being out of equilibrium. The evaporation of fluids from the stigmas is a further form of flower injury.

2. Temperature

Temperature has a different impact on different plant species' growth and development. Each plant has a minimum, maximum, and ideal temperature range that it needs to grow. The growth of plants can be impacted by extreme heat or cold. While excessive heat can significantly lower grain production, frost can result in sterility and abortion of grains that have already formed. Cell division, photosynthesis, transpiration, and yield all slow down if the temperature falls slightly below the ideal temperature.

If the temperature drops very low, the water within the intercellular spaces of plants, such as potatoes, tea, etc., freezes into ice crystals. Plants may become dehydrated as a result. On occasion, a layer of ice or snow might form on the soil surface as a result of a change in temperature. This layer prevents new oxygen from penetrating the soil, which suffocates plant roots.

According to Bellasio (2014), heat stress can affect the growth stages of both annual and perennial crops. Moisture is lost from the crop and the soil when the temperature is high. In the excessive heat, the majority of the plants are wilting.

This may even result in a scenario where the leaves finally dry out, turn yellow, and die. Tomatoes, cucumbers, pumpkins, and other warm-climate plants stop producing and drop their flowers, whilst cabbage, broccoli, and spinach start bolting. The environment's growing need for water vapour is another significant effect of rising temperatures. Due to this need, plants must transpire more water through their leaves, which raises the temperature of the leaves and inhibits photosynthesis.

3. Pressure

Given that it has a direct impact on the rates of photosynthesis and respiration, the total pressure is crucial for plant growth. Under lower total pressure, photosynthesis and transpiration rates both accelerate.

4. Humidity

Problems like foliar and root infections, sluggish drying of the growing medium, plant stress, loss of quality, loss of yields, etc. are all directly attributed to humid air. As a result, more pesticides are required to control disease, and plants typically have weak, stretched growth, which makes them less appealing. Plant growth is frequently hampered by low humidity because crops take significantly longer to reach a size that is suitable for sale. Additionally, growth is challenging, lower leaves frequently fall off, and overall quality is subpar. Regardless of the humidity level, crop quality loss lowers crop selling prices and raises production expenses, both of which lower profitability.

5. Rainfall

The way rain falls is important because it determines whether the soil has enough moisture to support plant growth during the growing season. Rainfall that is evenly distributed encourages brisk plant development. Crops may be scorched by inadequate distribution as a result of prolonged exposure to sunshine, especially in sandy soils where water retention is very low.

Crops require water throughout the growing season, so it's important to have access to enough when using rainfall as a source of irrigation. However, if there is a dry spell lasting a week or two, it could be harmful to seedlings because they lack established root systems that could help them access water deeper in the soil. If no water is supplied to these crop fields, it may lead to crop failure and the wilting of seedlings. Furthermore, leafy vegetables like lettuce, cabbages, and spinach could prematurely flower and turn bitter.

On the other hand, improper rainfall distribution can cause tomatoes and other fruit and vegetable plants to flower and set fruit before they have had enough time to develop vegetatively. When rainfall is not distributed evenly, cereal crops like maize, sorghum, and pearl millet may also be compelled to blossom and set tassels earlier than is necessary for vegetative growth.

Methodology:

Creating the CAD model

The CAD model of the 15ft wooden pole is created before actually designing the pole. SOLID EDGE V20 is the software used for modeling purposes. The diameter of the pole is taken as 4cm. A rectangular box is constructed at the top of the pole to place the anemometer. Windsock is placed on one side of the pole. Figure 1 shows the CAD model of the prototype.

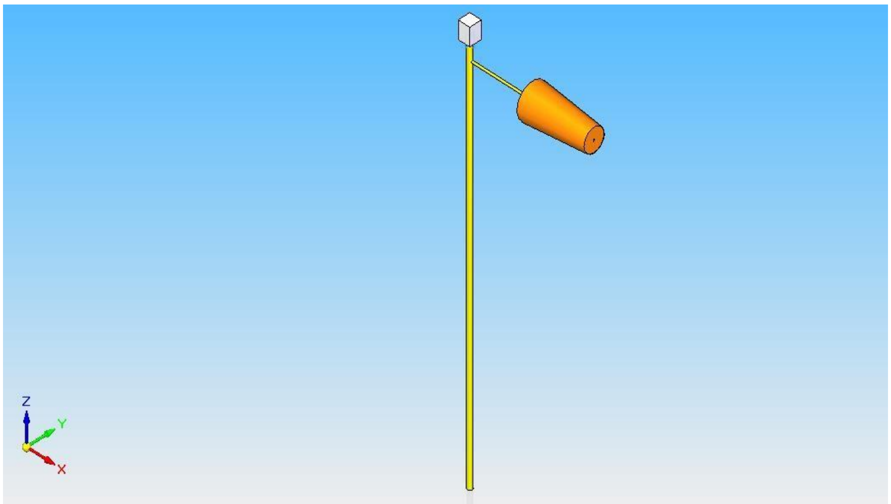

Fig. 1: A 3D CAD model of the pole

Constructing a 4-cup anemometer

A low-cost Anemometer is constructed from scratch. An infrared sensor is attached which follows a certain process by which the velocity of wind is calculated. The developed anemometer is shown in Figure 2. The Raspberry PI 3B+ is programmed using Python language and embedded in the developed system along with rain sensors, pressure sensors, temperature and humidity sensors.

Fig. 2: A 4-cup anemometer

Installation of the pole

The 15 feet pole is divided into two parts: 10ft is a wooden pole and 5ft is a metal pole. The diameter of a wooden pole is 4cm while that of a metal pole is 2cm. Both the poles are assembled to form a 15ft pole to which all the IoT sensors including the anemometer and the windsock is attached and installed at an appropriate location. The final prototype is shown in Figure 3.

Fig. 3:The final prototype

Results and Discussion:

From Raspberry PI 3B+ the data is fed in the Excel sheet and the wind rose graph is plotted accordingly. Various parameters such as date, time, wind speed, and wind direction are obtained. The values obtained from the microcontroller are shown in Table 1

Table 1: Data obtained from Raspberry Pi 3B+

Sl. No.	**Date**	**Time**	**Wind Speed (M/S)**	**Wind Direction**
1	02-05-2022	10:00 AM	2.5	North
2	02-05-2022	10:00 AM	0.7	North East
3	02-05-2022	10:00 AM	5.5	South East
4	02-05-2022	1:00 PM	3.5	East
5	02-05-2022	1:00 PM	1.1	South West
6	02-05-2022	4:00 PM	5.9	South East
7	02-05-2022	4:00 PM	2.4	West

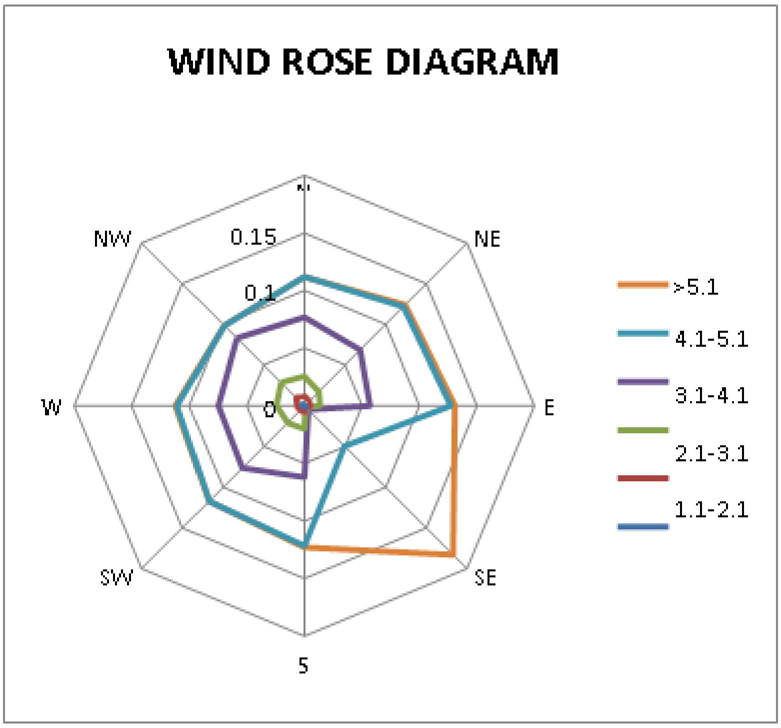

Fig. 4: Graphical representation of Wind rose diagram based on the data

Figure 4 provides a clear picture of the maximum wind speed at a particular location. The color bars of the wind rose to refer to the speed of the wind in meters per second (m/s). Varma *et al.* (2013) concluded that the directions of the wind rose with the longest spokes showing the wind direction with the greatest frequency. The graph depicts that the wind speed was maximum in South East direction at a chosen location having a velocity greater than 5.1 m/s Temperature, Humidity, Pressure, and amount of rainfall are the different climatic parameters obtained from Arduino through C++ language. The data is updated in the Excel worksheet every 10 seconds. Table 2 depicts the climatic parameter readings obtained from Arduino.

Table 2: Climatic parameter readings obtained from Arduino of sample 1

Sl. No.	Created at	Temperature	Humidity	Pressure	Rain
1	2022-04-16 15:29:00	26.7	67	929.34	70
2	2022-04-16 15:29:19	26.7	67	929.29	70
3	2022-04-16 15:29:36	26.7	67	929.3	70
4	2022-04-16 15:29:53	26.7	67	929.35	70
5	2022-04-16 15:30:09	26.7	68	929.28	70
6	2022-04-16 15:30:26	26.7	68	929.3	70
7	2022-04-16 15:30:42	26.7	68	929.29	71

Below are the results obtained in the form of graph for easy understanding by the farmers. The graph contains time in the X-axis and various climatic parameters in the Y-axis. Figure 5 shows the temperature v/s time graph of sample 1.

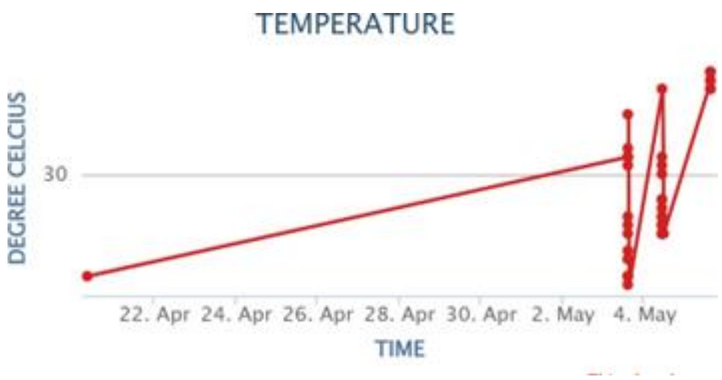

Fig. 5: Temperature graph of sample 1

Humidity in terms of percentage is shown in Figure 6 The X-axis denotes time and the Y-axis denotes humidity.

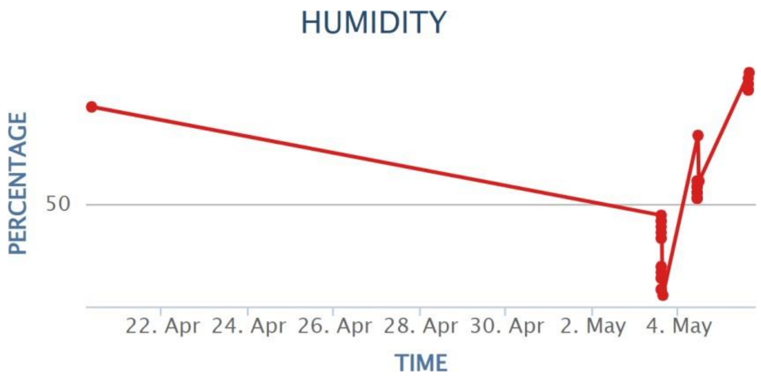

Fig. 6: Humidity graph of sample 1

The plot depicts a variation of the amount of rainfall with time for a particular day in Figure 7. Here the rainfall is measured in terms of percentage.

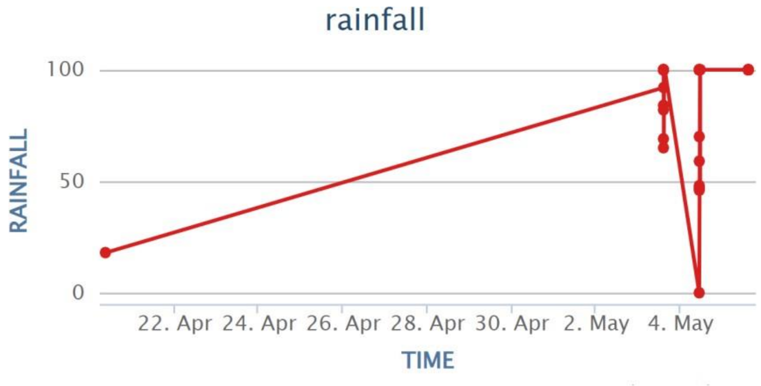

Fig. 7 : Rainfall graph of sample 1

Conclusion:

Based on the above-mentioned system setup, the wind velocity and wind direction along with the different levels of temperature, pressure, humidity, and rainfall were sensed and the data was updated in the Excel sheet every 10 seconds. The results were obtained in the form of a graph for feasibility. In the absence of human beings in the agriculture field, this system provides continuous field monitoring and provides the required data. The microcontroller sends the sensed data to the respective channel periodically through a communication protocol. These data are plotted concerning time and can be used for future analysis. Agricultural field status can be monitored remotely in terms of the graph in the ThingSpeak web service. Applications can be created related to farming which are deployed in the cloud and can be used by farmers or researchers.

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METHODS OF CROP IMPROVEMENT: AN OVERVIEW

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Introduction:

The main object of the plant breeding is to produce the new crop varieties superior in all aspects as compared to the existing types. This object is achieved by different methods of crop improvement as fallows. 1. Introduction and Acclimatization 2. Selection 3. Hybridization 4. Mutational breeding 5. Polyploidy 6. Biotechnoligical methods and 7. Breeding for disease resistance. Out of these Introduction and Acclimatization, Selection methods and Hybridization methods are considered for studies. Centres of origin and domestication of crop plants, plant genetic resources; Acclimatization; Selection methods: For self pollinated, cross pollinated and vegetatively propagated plants; Hybridization: For self, cross and vegetatively propagated plants – Procedure, advantages andlimitations.

Centres of Origin:

It is evident from the study of geographical distribution of plants that the species of plants are not uniformely distributed throughout the world. The part of earth between 20^0 S and 37^0 N including South East Asia, China, Indonesia, India, Malaya, Archipelago, South West Asia, Tropical Africa, Avicenia, Central America, South America and Mexico abounds in different kinds of vegetation and the species show maximum diversity of forms in these regions. The regions or areas having species with maximum diversity of forms were termed the Primary centres of oringin of cultivated crops by N. I. Vavilov in 1936. According to the concept of centres of origin of cultivated plant species put forth by Vavilov, the then Directror of Institute of Plant Industries, Leningrad, the cultivated crops of the world originated in these primary centres of origin.

In other words, the places where the crop species show maximum diversity of forms, genetic variability and heritability and the primitive ancestral species are in abundance are referred to as primarycentres of origin. In the central region of the primary centres of origin occur dominant genes and in peripheral part, there occur recessive genes. These places display continuous variability in a particular crop species. In these primary centre of origin plants occurs in wild state. Later, when the crop species move to different places primarily due to activities of man hybridization and mutation occur in wild forms and the useful variations or changed wild forms are selected and protected by man. The wild forms contain dominant genes and their cultivated forms possess recessive genes.

Besides the primary centres of origin, there are some regions where some crop species show considerable diversity, although they did not originate there and only recessive genes are prevalent there. These regions are referred to as secondary centres of origin of those species. The secondary centres of origin of crop plants are not inhabited by closely related wild species. For example, Oat (*Avena sativa*) shows maximum variability in Spain and several species occur over there, yet all related species do not occur there. Therefore, Spain cannot be primary centre of origin but it is the secondary centre of origin of Oats. J. R. Harlen in 1948 planted an expenditure to Turkey for the exploration of plants and in the course of journey he found tremendous plant diversity in some small patches of land to which he named microcentres. From such microcenters some precious plants may be obtained and utilized in experimental studies relating to biosystematics and origin of cultivated species.

N. I. Vavilov recognized the following centres of origin of cultivated species and grouped them into Old World Centers of Origin and New World Centres of Origin.

Old World Centres of Origin:

The old-world centres of origin include the following centres.

1. The China Centres of Origin:

The center is considered to be the oldest and the largest independent centre of origin of cultivated crops in the world. It includes mountainous parts of Central and Western China and neighboring tracts. Jowar (*Sorghum* species), Soyabean (*Glycine max*), Opium poppy (*Papaver somniferum*), Tea (*Camelia sinensis*), Radish (*Raphanus sativus*), Brinjal (*Solanum melanjana*), *Cucumis* species, Buckwheat (*Fagopyrum esculentum*) etc., are considered to have originated in the China center of Origin. This center is also considered to be the place of origin of apple, Palms (*Prunus divaricata*), Peach (*Prunus persica*), Orange (*Citrus nobilis*), Apricot (Prunus armenia) etc. This is the secondary centre of origin of sesame (*Sesamum indica*), Turnip (*Brassica rapa*), Rajma (*Phaseolus vulgaris*), Cowpea (*Vigna anguiculata*), bean and Maize (Zea mays).

2. The Hindustan Center of Origin:

The Hindustan centre of origin has been divided in the following two centers of origin by Vavilov in 1935.

2-A. Indo-Burma Centre of Origin:

Excepting Punjab and North Western parts, whole of India and Burma are included in this centre. It is considered to be the centre of origin of Rice (*Oryza sativa*), Sugarcane (*Saccharum officinarum*), Pigeonpea-Tur (*Cajanus cajan*), Chick-pea (*Cicer arietinum*), Mung (*Vigna radiata*), Cowpea (*Vigna anguiculata*), Jowar (*Sorghum vulgare*), Bean (*Dolichus lablab*), Lettuce (*Lactuca indica*), *Cucumis sativus*, Oat (*Avena sativa*), Yams (certain species of *Dioscorea*) etc. All tropical fruits such as Guava (*Psidumguayava*), Jamun (*Eugenia jambolana*), Mango (*Mangifera indica*) are considered to have originated in this centre. Deshi cotton (*Gossypium arboreum*), Jute (*Crorchorus*sp.), *Subaniaaegyptica,* Indigo (*Indigofera* sp.), Black pepper (Piper nigrum), Arecanut, some citrus species, Coconut (*Cocos nucifera*), Cardemom etc., also originated in this centre of origin.

2-B. The Siam-Malaya-Java Centre of Origin:

It includes Malaya, Java, Sumatra, Philippines and Indichina etc. Several important plants like Turmeric (*Curcuma domestica*), Ginger, Black pepper, Hemp (*Canabis sativa*), Cardemomum, Banana (*Musa parasidiaca*), Some species of Citrus and several fruits are thought to have originated in this center of origin.

3. The Central Asia Centre of Origin:

It is also known as Afghanistan centre of Origin. This centre includes Northwest India (Punjab and Kashmir), Afghanistan, Russia, Northwest Frontier Province, Tadjikistan, Uzbekistan and adjoining areas. Important crops like Russian wheat (*Triticum aestivum*), Club wheat (*Triticum compactum*), Sunn hemp (*Crotalaria juncea*), Ccarrot, Pea (Pisum sativum), Mung, Radish (*Raphanus sativum*), Onion (*Allium cepa*), Garlic (Allium sativum), Spinach (*Spinacea oleracea*), Broad bean (*Vicia faba*), Brassicas, Linseed and some other fruits like apple (*Pyrus malus*), Almond (*Pyrus amygdalus*), Grapes (*Vitis vinifera*), Pistacia nut (*Pistacia vera*), Apricot (*Prunus americana*), Pear (*Pyrus communis*) are supposed to have originated in this centre. It is the secondary centre of origin of rye (Secale cereale).

4. Near East or Persian Centre or Asia Minor Centre of Origin:

This centre includes Asia minor, whole of Transcaucasien Iran, highland of Turkamanistan etc. Nine species of *Triticum* including *T. monococcum, T. durum, T. turgidum, Rye,* Alfalfa (*Medicago sativa*), Persian clover (*Trifolium resupinatum*), Carrot (*Dacus carota*), Cabbage (*Brassica oleracea*), Avena species, *Lactuca sativa* and fruits like Pomegranate (*Punica granatum*), Pear, Almond, Chestnut (Casteneasps.), Water melon and Cucumis melo are supported to have originated in this centre. This is the secondary centre of origin of Coriander (*Coriandrum sativum*), Black mustard), Rape (Brassica campesteris), Leaf mustard (B. japonica) and Turnip (B. rapa).

5. Mediterranean Centre of Origin:

This centre is considered to be the place of origin of some cultivated species of wheat such as Durum wheat (*Triticum durum*), Emmer wheat (*T. dicoccum*), Oat (species of *Avena*), Barley (*Hordeum vulgare*), Lentil (*Len culinaris*), several species of lathyrus, Pea (*Pisum sativum*), Chick pea, Broad bean (*Vigna faba*), Clover (*Trifolium* species), Vetch (*Vicia sativa*), Mustard (several species of *Brassica*), Onion, Garlic, Beet (*Beta vulgaris*), *Asparagus officinales*, Lavender and Pepermint (Mentha species).

6. Abyssinian Centre:

Some important crop such as Barley, Emmer wheat, Lentil (Len culinaris), Linseed (*Linumusitatissimum*), Bajra (*Pennisetum americanum*), Jowar (*Sorghum vulgare* or *bicolor*), Chickpea, Sem (Dolichus lablab), Pea, Safflower (Carthamus tinctorius), Sesame, Castor (*Riccinus communis*), Okra (*Abelmoscus esculentus*) and Coffee (*Coffea arabica*) are considered to be originated in this centre of origin. It is the secondary centre of broad bean.

New World Centres of Origin

Expeditions in new world were made in 1932 and the following centers of origin were recognized.

7. The South Mexican and Central American Centre of Origin:

It is also known as the Mexican Centre of origin. It includes South Mexico and Central America. Maize (*Zeamays*), Rajma (*Phaseolus vulgaris*), Lima bean (*Phaseolus lunatus*), Sweet potato (*Ipomoea batatas*), Tobacco (*Nicotiana tabacum*), *Gossypium hirsutum, G. purpureascens*, Chillies (*Capsicum annum*), Pumpkins (*Cucurbita melanosperma*), Melons (*Cucumis melo*), Papaya (*Carica papaya*), Arrow-root (*Marantaarundinacea*) and some other crops originated from this centre of origin.

8. The South American Centre of Origin:

It includes high mountaneous regions of Peru, Bolivia, Columbia, Part of Chile and Brazil, whole of Paraguay and Ecuador. Many cultivated species of Potatoes, Maize, Lima bean, Peanut (*Arachis hypogea*), Tomatoes, Egyptian cotton (Gossypium brabadense) and Quinine (*Chinchona calysaya*), Casava (*Manihot Atilissima*), Rubber (*Hevea*sps.) originated in this centre.

Recently one more centre namely USA Centre of Origin has been introduced in which two crops sunflower (*Helianthus annus*) and Jerusalem artichoke (*Helianthus tuberosus*) are believed to have originated.

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ENTOMOPHAGY: ADVANTAGES AND POTENTIAL HAZARDS FOR SUSTAINABLE AGRICULTURE

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Abstract:

Entomophagy refers to the intake of insects in raw or processed form. Insects from diverse taxa are fed globally as they are considered traditionally delicious and nutritionally abundant. Insects can be eaten as whole or processed. Entomologists and nutritionists across the globe have viewed insects as the storehouse of essential and vital nutrients. Thus large scale farming of nutritive insects and consequent processing and consumption by humans can help us meet our goals of zero hunger, no poverty, and nutritional well being. It is also considered as a strategy to mitigate climate change and promote sustainable agriculture. Despite being a vigilant option to eradicate global hunger, it is believed to possess serious microbiological health risks. Inefficiency of the value chain system in farming and processing of insect driven foods and lack of suitable regulations requires immediate attention to boost up consumer confidence on these value-added products.

Keywords: Entomophagy, Food, Insects, Nutrients

Introduction:

Since the advent of the ancient human civilisations, human ancestors have learnt to satisfy their dietary demands by consuming insects. Aristotle, the father of Biology, presented the first scientific evidence of Entomophagy. Nearly, 2 billion people in various parts of the world consume insects (Tao and Li, 2018). The use of insects for food is more prevalent in tropical and sub-tropical countries by the economically weaker sections of the society (Tao and Li, 2018) apart from China and Mexico in the temperate world. Also, in the current era, demand for insect based foods has also scaled up in the developed countries of the world owing to its nutritional richness. Yet, there are major food safety concerns that need to be addressed before the insect based foodstuffs are commercialised.

The world population is aggressively shooting up and it is estimated to cross the 9 billion mark by 2050 (Van Huis *et al.*, 2013). On the other hand, the major concern the globe is witnessing at the present moment is climate change. Added together, the above mentioned issues demand an increase in food production by 60%. These concerns undoubtedly calls for development of alternative and innovative ways ensuring that quality and safe food is available to all strata of the society. One additional advantage of entomophagy is rearing and usage of insects on organic wastes will reduce the emissions of greenhouse gases thus mitigating Global warming (Van Huis *et al.*, 2013). Edible insect industry also demands limited land acreage and portray a high reproduction rate and high conversion efficiency (Klunder *et al.*, 2012). Added to that, yellow mealworms and black soldier fly can convert up to 45% and 55% respectively of their dietary protein to edible body mass (Van Huis *et al.*, 2017) as compared to chicken where only 33% of the dietary protein is converted to edible body mass. There are broadly three ways by which insects can be accepted i.e. wild harvests, semi-domesticated and agriculture.

Edible insect industry also offers socio-economic benefits to the rural poor by generating huge scale employment opportunities, empowering the women and enhancement of the livelihood eradicating poverty, hidden hunger and mal-nutrition (Roos and Van Huis, 2017). Developed countries like Holland and Belgium and developing countries like Kenya and Thailand are the pioneers in promoting Entomophagy. Future willingness to consume insects and Perception of insects in diet is represented in Figure 1 and Figure 2 respectively (Tao and Li, 2020). The map of disgust, acceptor and traditional countries for entomophagy is shown in Figure 3 (Toti *et al.*, 2020)

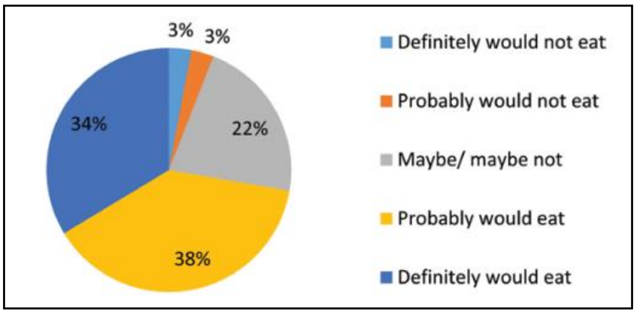


Fig. 1: Future willingness to consume insects (Tao and Li, 2018)

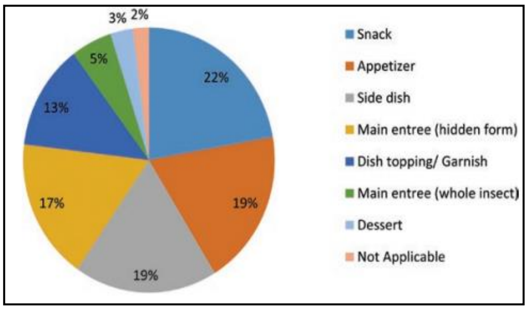


Fig. 2: Perception of insects in diet (Tao and Li, 2018)

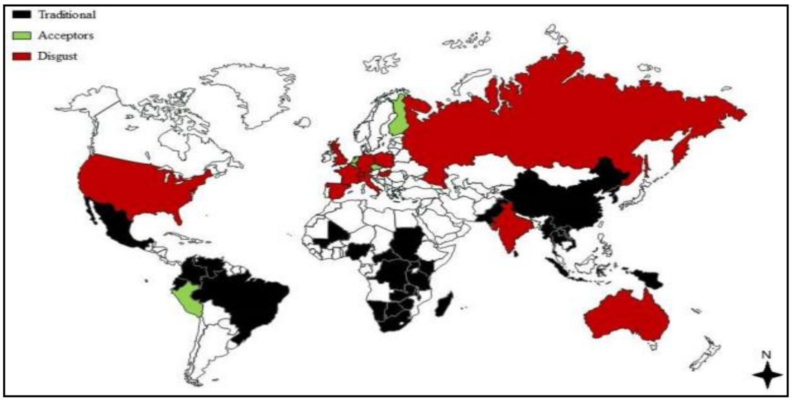


Fig.3: Map of disgust, acceptor and traditional countries for entomophagy (Toti *et al.*, 2020)

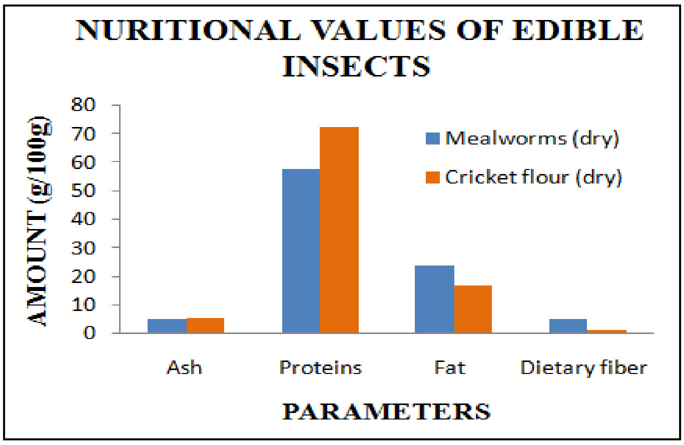
Benefits of entomophagy

Edible insects as sources of vital nutrients in the human diet

Malnutrition, Hidden hunger, under nutrition, micronutrient deficiency, obesity, impaired metabolism, protein deficiencies are some of the major challenges that threaten human health considerably. Therefore, diversification of diets for incorporation of various unexplored food sources as edible insects needs to be globally accepted (Sun-Waterhouse *et al.*, 2016). Nearly, 2000 species of insects were explored and used to mitigate nutritional deficiencies. The most commonly eaten insect types include beetles (31%); ants, wasps and bees (14%); dragonflies (3%); locusts, crickets and grasshoppers (13%); caterpillars (18%); scale insects, leafhoppers, cicadas and plant hoppers (10%); termites (3%) and flies (2%) (Van Huis *et al.*, 2013). Insect species most suitable for mixed feed production are black soldier fly larvae (*Hermetia illucens*), silkworms (*Anaphe panda*, *Bombyx mori*), worms (*Tenebrio molitor*, *Alphitobius diaperinus*), locusts (*Locusta migratoria*), crickets (*Gryllodes sigillatus*, *Gryllus bimaculatus*, *Acheta domesticus*), the cockroaches (*Blaptica dubia*, *Nauphoeta cinerea*) termites (*Kalotermes flavicollis*) and wax moths (*Galleria mellonella*) etc. (Bosch *et al.*, 2014)

Mostly commonly farmed and accepted edible insect types are the mealworms (*Tenebrio molitor*) and crickets like (*Acheta domesticus*) in Europe (Francis *et al.*, 2019). Added to this, the insects are eaten in raw or processed form as toasted, steamed, chutney, boiled, baked, fried or roasted, washed etc. (Grabowski *et al.*, 2016). Publication of insect cook books must be encouraged for delicious insect recipes. Homogenising the insects to produce bread, pasta, patties etc. is a usual practice in European countries. Milling, processing to granular or pasted forms, grinding is used to develop insect derived products that have higher consumer preference. These products can also be added to the regular wheat or rice flour to further improve the nutritional value. Majority of the insects fed upon are terrestrial (88%) and a few are aquatic (12%).

The nutritional profile depends on various factors like the stage of the insect, type of insect, rearing and processing method of the insect (Kulma *et al.*, 2019). The major nutrient obtained from edible insects is protein, that ranges from 35-71% (Figure 4) depending on insect type, the highest being the termites from Isoptera (Rumpold *et al.*, 2013). The energy profiles of mealworms (dry) and cricket (dry) is shown in Figure 5.



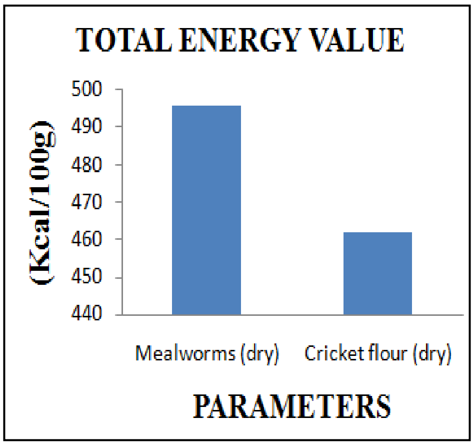


Fig. 4: Nutritional profile of Insects **Fig. 5: Total energy value of insects**

("Edible Insects: Benefits and Potential Risk for Consumers and the Food Industry," 2021)

The Bombay locust, house cricket, and mulberry silkworm all had high protein contents, with between 27 and 54g/100g of consumable part, according to a more recent investigation conducted in Thailand (Kohler *et al.*, 2019). Fresh weight protein content for crickets and mealworms ranges from 19 to 22 g/100 g (Van Huis *et al.*, 2013) that is at par with the conventional animal protein sources. Thus it is concluded that insect derived proteins have higher biological value and digestibility with an amino acid score of 46-96%. A comparative view of the amino acid content (g / 100g) in the cricket and mealworm dry flour is present in Figure 6. With recent findings linking animal-derived sources of protein like processed meats to the rise of non-communicable diseases like cancer, more interest in cultivating and eating edible insects is anticipated.

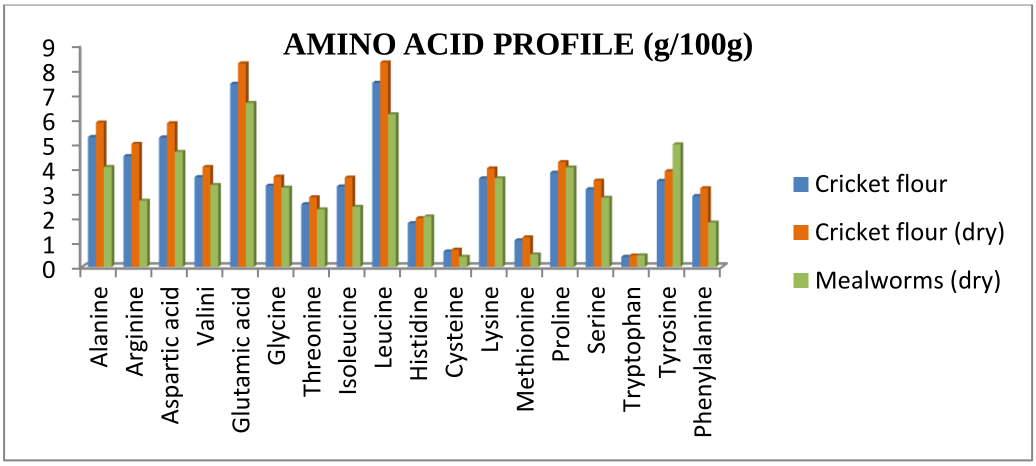


Fig. 6: Amino acid profile of insects ("Edible Insects: Benefits and Potential Risk for Consumers and the Food Industry," 2021)

Fats contribute to a large proportion of edible insect biomass. The fat content ranges from 13-33% across various insect groups (Rumpold *et al.*, 2013). The edible insect flours are rich in polyunsaturated fatty acids. Thus, they help to reduce cholesterol levels declining the incidence of coronary heart diseases. Insect-based products contain plant sterols and are healthier (Sabolova *et al.*, 2016). The concentration of polyunsaturated and monounsaturated fatty acids in mealworms and cricket flour is represented in Figure 7.

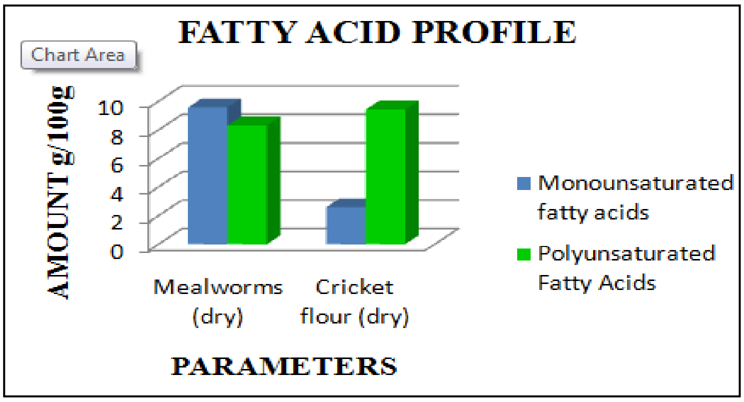


Fig. 7: Fatty acid profile of Insect ("Edible Insects: Benefits and Potential Risk for Consumers and the Food Industry," 2021)

Insects are chief sources of essential minerals. Insects have higher amounts of phosphorous and magnesium (orthopterans). Insects are also generally regarded as good sources of manganese, iron, copper, zinc and calcium. The mineralogical profile of mealworms and crickets are represented in Figure 8.

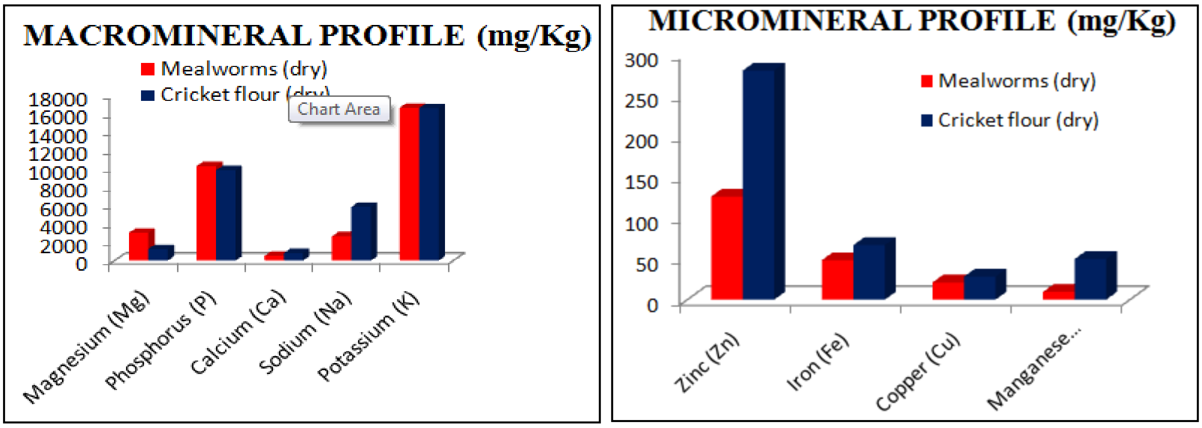


Fig. 8: Mineralogical profile of Insects ("Edible Insects: Benefits and Potential Risk for Consumers and the Food Industry," 2021)

This is used to mitigate zinc deficiency and iron deficiency that stands out at 17% and 25% respectively. The insects have low amount of sodium making it a suitable dietary option for sodium sensitive people. Insects are claimed to be novel sources of vitamins as pantothenic acid, riboflavin, etc. crickets and locusts are rich sources of folic acid. The vitamin constitution of insects can be enhanced by feed manipulation (Pennino *et al.*, 1991).

Environmental implications of entomophagy

The population growth is exploding. The land resources are scarce. This in turn results in over-exploitation of natural resources and leads to environmental degradation. Thus, issues as climate change, environmental degradation, and Green house effects heavily threaten agricultural productivity and food security. Conventional protein sources like livestock and fish based products demand higher environmental costs. Additionally, the excrements contain potentially harmful microorganisms and heavy metals that contaminates environment (Thorne *et al.*, 2007). They are also responsible for release of ammonia (18%) and other green house gases that threaten environmental quality. Contrary to this, edible insect rearing industry has many benefits like using the organic waste matter generated, low green house ammonia emissions, higher feed conversion efficiency (crickets are twice as poultry in conversion of feed to meat), value addition of the waste material, have less water requirement as compared to traditional livestock rearing, reduction of pesticide usage and pesticide residues in food. Entomophagy has been shown to be an effective strategy for controlling crop insect pests, such as locust in Thailand (Dobermann *et al.,* 2017). The global warming potential of various insect and animal based foods is represented in Figure 9

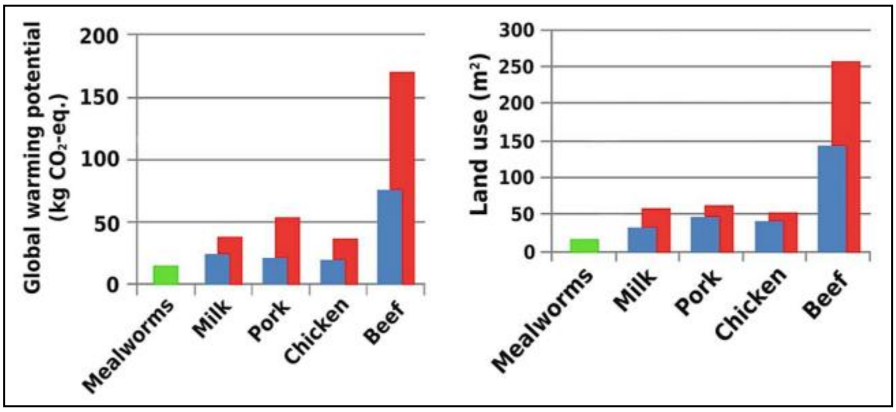


Fig. 9: Global warming potential of insect and animal driven foods (Stull and Patz, 2019)

Large scale insect rearing forms a source of livelihood

Wild insects are a crucial source of income to numerous rural populations in underdeveloped nations since they are abundant and need little or no technical expertise to harvest and prepare for consumption or sale. When food is sparse in areas where the practice of entomophagy is prevalent, edible insects is the major source of income hedging against unanticipated seasonal food shortages (Dufour, 1987). The low entry criteria for engaging in insect gathering, preparation, and commerce are believed to have spurred the prominent positions played by women and children in the edible insect industry in poor nations. Insect farming may create jobs and business possibilities. Due to increased demand for insects as food, there has lately been a transition from wild gathering to widespread domestication of insects such as crickets, which give substantial revenue to farmers. In Thailand, for example, insect cultivation, especially cricket rearing, is a proven subsistence approach that has been established to dramatically enhance the basic amenities of the nation's rural dwellers as an alternative source of income while also improving human and social assets. Fostering the adoption of insects into human meals may include encouraging people to start cultivating them with the objective to increase availability and lessen the possibility of endangerment caused by excessive utilization from continual natural harvesting in the wild. This, along with the increased legitimacy of insects as food, can only ensure that their demand will continue to rise.

Improvement in the human gut microbiota

Insects are abundant in chitin that makes them a valuable source of fibre in human diets. Chitin is a carbohydrate polymer obtained from the insect exoskeleton that has a pre-biotic potential and helps to nurture the gastrointestinal health of humans. Infectious microorganisms such as *Salmonella typhimurium* have been shown to be inhibited in the human gut by chitin and its analogs, while promoting the proliferation and flourishing of beneficial intestinal bacterial species such as *Bifidobacteria* and *Lactobacillus*. It is proposed that the addition of cricket chitin promoted the expansion of *Bifidobacterium animalis* by 5.7 times, and chitin enhanced the growth of *Lactobacillus rhamnosus* and inhibited the growth of *Escherichia coli*.

Risks associated with entomophagy

Consumer acceptability of insect based diets

The attitude of consumers to adopt insects as foods is not encouraging. In accordance to a current German study, the greatest barriers are neophobia and sense of disgust. Indeed, Europeans often identify edible insect intake with poor nations, yet the cultivation and consumption of culinary insects is accepted in several countries such as Austria, Holland, France and Belgium (Verbeke, 2015). According to studies conducted in several European nations, only a small percentage of individuals (6.3% females and 12.8% men) are inclined to replace meat with insects (Verbeke, 2015). It additionally says that employing insect-based products as food ingredients rather than selling complete edible insects would provide an enhanced chance to promote entomophagy in German markets (Orsi *et al.,* 2019).

In recent times, eating preferences in emerging economies have been noted to change more onto westernized diets, and with numerous individuals relocating and residing in urban areas, there has been a decline in the intake of traditional foods, including edible insects. Insufficient acceptance of entomophagy by the West, as well as negative depiction of the custom by certain publications in advanced as well as developing nations, has prompted reluctant adoption of insect intake, which could result in deficiencies in nutrition, especially among communities that rely on them for nourishment and sustenance. Convenience, environmental interest, and food neophobia represent a few of the elements that influence consumer intake of edible insects. An Italian study found an adverse connection between neophobia and customer desire to conduct entomophagy. Unexpectedly, the researchers also discovered that women were less inclined than males to ingest edible insects, a result that warrants more examination to see if sexuality truly performs an integral part in entomophagy.

It has been demonstrated that when palatable insects are offered in different food forms, such as cookie files, energy snacks, sandwiches, and sandwich spreads, consumers become more inclined to ingest them. (Megido *et al.,* 2013). Changes in adverse opinions (thus increasing consumer willingness to eat insects) about entomophagy have been reported from Italy and Denmark as a consequence of educating customers regarding the nutritional advantages of ingesting insects, and the identical strategy should be reproduced in other countries or societies in order to accomplish the comparable objective.

Health risks and hazards associated with entomophagy

Considerations about the security of food in relation to edible insects must be taken seriously, especially with regard to countries in the West, with the objective to advocate for and encourage their usage in human diets. The dangers associated with breeding and using insects in the production of food, involving their usage as nutritional supplements, are little understood. Except for the nutritive advantages of insects that are eatable, they may also carry exogenous and endogenous hazards to the well-being of humans, just like livestock and plant-based diets. Possible hazards to food security arising from edible insects are often divided into three broad groups: chemical, biological, and allergens (Murefu *et al.,* 2019). This essentially implies that in order to strengthen the nutritional aspect of edible insects, specific variables such as insect stage, species, sex, and in particular the proper selection of high-quality hazard free feed substrates must be evaluated and regulated, which is only feasible under controlled circumstances rather than untamed harvesting.

Pesticide residues in insect based diets

It was witnessed that customers who primarily relied on wild-gathered edible insects are especially susceptible to insecticide contamination of their food since pesticide-contaminated insects were marketed in Thailand, threatening entomophagists. On Kuwai, conceivably hazardous locust remnants laced with chlorinated and organophosphorus insecticides have been discovered on merchandise following agricultural spraying to eradicate the pest. In the present research, chlorinated and organophosphorus pesticide concentrations in insect examinations were elevated at 49.2 g/kg and 740.6 g/kg, respectively.

Mycotoxin contamination

Mycotoxins are fungal secondary metabolites generated from many phytopathogenic fungi as *Aspergillus*, *Penicillium* and *Fusarium*. Mycotoxins found and assessed in edible insects could have been the result of the invasion of feed substrate by the three mold taxa listed above, alongside their synthesis in the insects' stomach, as stated by FAO. This study illustrates that insects provide a food security risk, owing to the chronic and acute impact that these poisons can have on the health of humans as well as animals.

Of the various mycotoxins identified and/or assessed in edible insects, aflatoxins may be particularly dangerous to the well-being of humans. These contaminants are common in tropical nations, which have a connection with higher consumption of insects. Aflatoxins are known carcinogens that have also been related to impaired human growth (Liu *et al.,* 2012). A recently published study on aflatoxin contamination of dried insects and fish in Zambia found that levels were above the nation's legal limit of 10 g/kg for several edible insects (moth *Gynanisa maja*, and termite *Macrotermes falciger*). This obviously reveals that edible insects might contribute to the formation of aflatoxicoses if appropriate protocols are not followed with regard to their value-chain administration, particularly when ingested as packaged food items.

Antinutritional value edible insects

Antinutrients are naturally occurring compounds in foods that prevent nutrients from being consumed, digested, absorbed, and used. They are more prevalent and concentrated in diets composed of plants than in animal-derived meals. Antinutrients of various sorts were identified and measured in edible insect species. Phytates, saponins, tannins and alkaloids have been discovered in long-horned beetle, meal bugs, grasshoppers and termites.

In Nigeria, a thermally resistant thiaminase enzyme found naturally in African silkworm pupa has been linked to seasonal ataxic syndrome (Nishimune *et al.,* 2000) which is a clinical syndrome of acute cerebellar ataxia caused by the consumption of toasted *Anaphe venata* larval stages, a substitute form of protein eaten in western Nigeria."

Allergens associated with entomophagy

Certain proteins found in edible insects, such as arginine kinase, are regarded as allergenic substances (Murefu *et al.,* 2019). Typical allergens associated with edible insects besides aginine kinase include -amylase and tropomyosine. Research conducted in Belgium discovered that skin prick tests made with grilled *A. domesticus* insect samples sensitized 19% of people. There have been a few instances of negative impacts on customers from eating insects; nevertheless, recent research suggests that 18% of fatal responses to foodstuffs in China were caused by eating insects, and 7.6% of insect consumers in Laos had allergic reactions (Barennes *et al.,* 2015). Silkworm pupa is perhaps the most often ingested insect kind in China, and it is anticipated that a minimum of 1,000 consumers develop allergic responses. At this point, the sole insect-derived food additive that has been entailed in causing an allergic response is carmine derived from female cochineal insects (*Dactylopius coccus*).

Heavy metal contamination in insect based diets

Non-essential contaminants such as cadmium, mercury, arsenic and lead have been discovered and proven to form accumulations in insects, the degree of which depends on the metal element and development stage and species of insect. Cadmium and arsenic constitute the two heavy metals of most relevance because they concentrate in black soldier fly and yellow mealworm larvae, respectively, both of which are the two primary insect kinds of significant interest for use as feed, especially in Western nations.

Pathogenic organisms

Several pathogenic bacteria genera, including *Escherichia*, *Staphylococcus*, and *Bacillus*, have been shown to cause illness in both humans and invertebrates (including insects) presenting health risks to insects consumers. Research found potentially human harmful bacteria in Thai edible insects, including *Vibrio, Staphylococcus, Clostridium, Streptococcus,* and *Bacillus*. A more recent study that characterized microorganisms in raw edible grasshopper (*Ruspolia differens*) acquired from the wild in Uganda likewise suggested that edible insects might include possibly hazardous bacterium types. The researchers confirmed the presence of *Campylobacter, Staphylococcus, Neisseria, Pseudomonas, Bacillus*, and *Clostridium* genera in this case. As manufacturing prevention strategies are implemented, wild-harvested edible insects, especially the ones ingested uncooked, present more of a threat for people than cultivated insects.

Bioavailability and digestibility of edible insects

A number of variables have been discovered and identified as influencing nutritional digestibility and bioavailability of insect driven foods in human meals. These parameters, which include edible insect kind, processing technique, antinutritional components, and chitin levels, require more research. According to some studies, boiling and oven cooking procedures greatly boost protein digestibility in mealworms. Domestic cooking procedures, according to the authors of a recent study, lowered the protein bioavailability and mineral bioaccessibility of wild-caught mature edible insects (*Eulepida mashona* and *Henicus whellani*). This may be attributed to dietary protein and mineral association with the remainder of the edible insect diet matrix.

Regulation relating to edible insect farming

There are no restrictions governing the cultivation, processing, and sale of edible insects in developing nations where entomophagy is often practiced (Dobermann *et al.,* 2017), resulting in no hurdles to their use. The situation diverges in Western nations, wherein the majority are in the procedure of formulating, evaluating, and/or enforcing rules. EFSA mandated that all insect-based meals intended for consumption by human beings be categorized as novel foods. Novel foods are ones that haven't been consumed before by humans in the continent/region in consideration. Edible insects include entire insects, portions of whole edible insects, and components produced from them such as breakfasts/flours, in addition to substances apart from ones obtained from whole edible insects or their parts such as insect extracts.

Conclusion:

Edible insects offer greater nutrient density than animal-based diets and are more appealing to poor because of their rapid development rate, high food conversion efficiency, and lower requirements for resources. Edible insects may be considered as safe foods in nations or societies where entomophagy is prevalent, but this doesn't seem to be applicable in most industrialized countries, where majority of consumers are suspicious of their security and consequently unwilling to incorporate them in their diets. The scientific research on edible insects and food safety is few. Additional investigation is thus required to understand the risks associated with their consumption in order to protect the well-being of consumers.

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ISOLATION AND IDENTIFICATION OF SOIL MYCOFLORA IN AGRICULTURE FIELDS OF SADAK ARJUNI OF GONDIA DISTRICT (MS)

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Abstract:

Soil samples were collected from different locations of Sadak Arjuni of Gondia District during the months of February 2017 to January 2018 in three intervals. The samples collected in two zones viz. rhizoplane and rhizosphere. The collected samples were inoculated in Potato Dextrose Agar (PDA) and Czapek Dox Agar (CDA) medium supplemented by antibiotics such as penicillin and Streptomycin by using Serial dilution method and soil plate method. A total of 230 colonies were isolated. About 19 species belonging to 7 genera of fungi were isolated and identified while 21 strains were unidentified. Identification and characterization of the soil mycoflora were made with the help of authentic manuals of soil fungi. Maximum number of fungal colonies belonged to Ascomycotina and Deuteromycotina (191) and few to zygomycotina (18). Among the isolates *Aspergillus flavus, A. fumigatus, A. nidulans, A. niger*, *A. terreus, Fusarium oxysporum, Penicillium chrysogenum, Rhizopus stolonifer* and *Trichoderma viridae* were predominant. The percentile contribution of the mycoflora was graphically and statistically analyzed.

Keywords: Microfungi, Culture Media, Isolation, Fungal Diversity.

Introduction:

Soils are complex structures that play many important functions in supporting plant growth and development. One of the key components of soil that influences plant growth is the soil microflora, which consists of various microorganisms such as bacteria, fungi, and protozoa (Chiang and Soudi, 1994). Soil microflora plays a essential role in evaluation of soil conditions and in stimulating plant growth (Kiran *et al.*,1999). Microorganisms are helpful in increasing the soil fertility and plant development as they are included in several biochemical transformation and mineralization activities in soils. Method of cultivation and crop management practices found to have greater influence on the activity of soil microflora (Mc.Gill *et al.*, 1980). Continuous use of chemical fertilizers over a long period affecting soil microflora and there by indirectly affect biological properties of soil leading to soil degradation (Manickam *et al.*, 1972).

There is a massive microbial flora present in the earth and they are found in all types of soils (Mukerji *et al.*, 2006). These microbes may interact with the plants resulting sometimes in useful effect and other times in harmful consequences. Fungi are an important component of the soil microflora and are present in the form of mycelium, rhizomorphs or as spores. They play important role in soils and plant nutrition. Saprophytic fungi are able to live on dead and decaying organic matter. They secrete a varied number of enzymes that attacks effectively any organic material and converting it into simple soluble forms, which are readily available to higher plants. Due the degradative activities fungi play important role in recycling organic waste in environment. Unfortunately their degradative ability also results in the undesirable growth of fungi that destroy useful materials (Aina *et al.,* 2011). Fungi grow on diverse habitats in nature and are cosmopolitan in distribution requiring several specific elements for growth and reproduction. In laboratory, these are isolated on specific culture medium for cultivation, preservation, microscopical examinations and biochemical and physiological characterization (Aina *et al.*, 2011).

The species richness of a fungal community and relative abundance of individual species have been considered as measures of functional activities of the group in the particular habitat (Kjoller and Struwe, 1982). Fungi, bacteria and actinomycetes colonize diverse habitats and substrates and play substantial role in plant health and productivity besides producing diseases. The role of fungi in the soil is an extremely complex one and is fundamental to the soil ecosystem.

Rhizosphere

The rhizosphere is the narrow region of soil that surrounds and is influenced by the roots of plants. It is a dynamic and complex environment where plant roots interact with a wide range of microorganisms, including bacteria, fungi, and other soil organisms. These interactions are important for the health and growth of the plant, as well as for the overall health of the soil ecosystem.

In the rhizosphere, plants release organic compounds and other nutrients that support the growth and activity of soil microorganisms. In turn, these microorganisms can help to solubilize and mineralize nutrients that are essential for plant growth, such as nitrogen and phosphorus. Additionally, some soil microorganisms can form mutualistic relationships with plant roots, providing them with protection from pathogens or helping to fix atmospheric nitrogen.

Rhizoplane

The rhizoplane is the region around the root epidermis and outer cortex where soil particles, bacterial and fungal hyphae adhere. The functional definition is that after the roots have been shaken rapidly in water the remaining microorganisms and soil particles left are considered as belonging to the region of rhizoplane.

There are more numbers of microbes present in the rhizoplane than in the rhizosphere. The diversity of the fungal population is determined by counting the number of colony forming units (CFUs). By spreading the extracted soil microorganisms across agar and counting the number of independent clusters of microorganisms the CFUs were determined. Micro-organisms are abundant where the reliability of the root is compromised. Hence rhizoplane microorganisms tend to be found on older ones rather than younger roots.

Study site and location:

Sadak Arjuni of Gondia district (MS) located at 21.10°N 80.15°E. It has an average elevation of 256 metres (843 feet). It is located near the Maharashtra Chhattisgarh border on Mumbai-Kolkata National Highway 6. The temperature ranges from 15 - 42^0C. Red Sandy soils and Laterite soils are the major soil types existing.

The climates is characterized by a hot summer, well distributed rainfall during the south-west monsoon season and generally dry weather during the rest of the year. Farmers take up first crop of Paddy with monsoon rainfall and a second of Wheat, Gram, Linseed, Sunflower and many more crops with irrigation in Rabbi Season.

Materials and Methods:

Nutrient medium used:

Potato Dextrose Agar (PDA) and Czapek Dox Agar (CDA) medium used for isolation of fungi. The pH of the medium was maintained at 5.5 being optimal for the growth and sporulation in a majority of fungi.

Collection of soil samples:

The soil samples were collected from six different crop fields from six different locations of Sadak Arjuni. The samples were collected between the months of February 2017 to January 2018 in three intervals. Majority of fungi are microscopic and show huge variation in different sites of collection and at different depths. Therefore soils were collected from a depth of 15cm and are kept in sterilized Ziploc polyethylene bags. Each sample bag was labeled properly by indicating the site of collection, time, date and place of collection. The collected soil samples along with locations showed in Table:1.

Isolation of fungi from the soil samples:

The soil microfungi were isolated by two methods, Soil Dilution and Soil Plate method on Potato Dextrose Agar and Czapek's Dox Agar media.

Soil dilution plate method (Waksman,1922):

1gm of soil sample was suspended in 10ml of double distilled water to make microbial suspensions (10^{-1} to 10^{-5}). Dilution of 10^{-3}, 10^{-4} and 10^{-5} were used to isolate fungi. 1 ml of microbial suspension of each concentration were added to sterile Petri dishes (triplicate of each dilution) containing 15 ml of sterile Potato Dextrose Agar or Czapek,s Dox Agar medium. One percent streptomycin solution was added to the medium before pouring into petriplates for preventing bacterial growth and incubated at 28±2ºC in dark. The plates were observed everyday up to 4-7 days. Fungi were easily isolated because they formed surface colonies that were well dispersed (Fig: 1), particularly at higher dilutions.

Soil plate method (Warcup, 1950):

Almost 0.005g of soil was dispersed on the bottom of a sterile petri dish and molten cooled (40-45°C) agar medium (PDA) and (CZA) was added, which was then rotated gently to scatter the soil particles in the medium. The Petri dishes were then incubated at 28 ± 2^0C in dark for 4-5 days. One isolate of each fungal genus from each soil sample were selected at random for further subculturing and experiments. The subcultures were maintained on Potato Dextrose Agar.

Inoculating techniques:

The working benches in the laboratory were thoroughly sterilized by swapped with 70% alcohol, and also a burning blue flame was allowed to sterilize the surrounding air before the inoculation proper. The conical flasks were corked tightly with cotton wool and the Petri dishes were fully autoclaved (Aina *et al.,* 2011).

Identification of the soil fungi:

Generally identification of the fungal species is based on morphological characteristics of the colony and microscopic examinations (Diba *et al.,* 2007). The colony growth which includes length and width of the colony, the presence or absence of aerial mycelium, the color, wrinkles furrows and any other pigment production were the macro morphological characters evaluated. Although molecular methods continue to improve and become more rapidly available, microscopy and culture remain commonly used and essential tools for identification of fungal species (Diba *et al.*, 2007). The fungi were identified with the help of standard procedure and relevant literature (Gilman, 2001; Nagamani *et al.*, 2006).

Staining technique for fungi:

Inoculating needles were flamed over the burning Bunsen burner. Then using the needle, a small portion of the growth on the culture plate was transferred into the drop of lacto phenol in cotton blue on the slide. The specimen was teased carefully using inoculating wire loops to avoid squashing and over-crowding of the mycelium (Aina *et al.*, 2011). The specimen is observed under the microscope for microscopic identification (Fig: 3).

Statistical analysis:

Population density expressed in terms of Colony Forming Unit (CFU) per gram of soil with dilution factors. The CFU and Percent Contribution of each isolate was calculated by –

$$\text{CFU/gm of Soil} = \frac{\text{Average number of fungal colonies}}{\text{Dry weight of sample}} \times \text{Dilution Factor}$$

$$\text{\% Contribution} = \frac{\text{Total number of CFU of an individual Species}}{\text{Total number of CFU of all Species}} \times 100$$

Results and Discussion:

Soil microorganisms act as vital determinants of plant community variety and productivity (Wardle *et al.*, 2004). The environmental factors such as the soil pH, moisture, temperature, organic carbon and nitrogen play an important role in the distribution of mycoflora (Gaddeyya *et al.*, 2012). These are the main factors affecting the fungal population and diversity. The soil mycoflora in six different rice fields viz., Sadak Arjuni, Wadegaon, Kohmara, Sawangi, Saundad and Tidka were observed. Soil Dilution Plate and Soil Plate methods were used for the isolation of fungi during the present investigation.

During a period of 12 months the total number of fungal colonies isolated on Petri plates containing PDA medium were 229. As stated earlier Soil dilution plate and Soil plate method were employed for the isolation of fungi during the present investigation. A greater number of species and colonies were isolated on soil plates than on dilution plates and further the total number of species isolated decreased with increased dilutions of the samples. The purification of the culture (Fig: 2) was done either by single spore isolation or by culturing of the hyphal tips and was transferred to fresh agar slants of CDA medium. Most of the fungal forms which sporulate heavily were abundant on dilution plates.

Fungi act as major decomposers of dead organic matter and contribute significantly in recycling of nutrients in natural and modified ecosystems (Gadd, 2004). Altogether six soil samples from six different locations were examined for fungal diversity. The study resulted the presence of 19 species of fungi were identified and characterized from PDA plates (Table: 2). the maximum fungal species belonged to Ascomycotina and Deuteromycotina (191 colonies) and

Zygomycotina (18 colonies) and 21 colonies were left unknown on the plates containing PDA medium (Table: 2)

PDA medium is the most frequently used culture media and was stated to be the best media for mycelia growth by several workers worked with it earlier (Maheshwari *et al.,* 1999; Saha *et al.,* 2008), due to its simple formulation and potential to support wide range of fungal growth. CDA medium preferred for pure culture to minimize the contamination of *Rhizophus stolonifer*. Characterization of the isolates up to genus level and to the species level was made based on the macro-morphological (Colony characters) and micro-morphological characters by using authentic manuals of soil fungi.

Our findings are in accordance with the results of Noor Zaman and Sakil Ahmed, (2012) as the microbial analysis of different samples in rainfed areas of Punjab, Pakisthan. They isolated genera like *Aspergillus, Alternaria, Curvularia, Fusarium, Penicillium* and *Rhizopus.* Similar genera were isolated during our investigation. These findings were similar to those isolated by Rasheed *et al.,* (2004). *Aspergillus* species particularly like *A.flavus* and *A.niger, Penicillium* and *Rhizopus* were isolated only from the soil where as *Alternaria alternata, Curvularia lunata* and *Fusarium* species were obtained from both soil and plant parts. Hence it is considered that isolation of soil samples yielded more fungal species than from plants (Noor Zaman Sakil Ahmed, 2012).

In our investigation among the obtained fungal isolates the genera *Aspergillus, Fusarium, Rhizopus* and *Penicillium* were dominant on media used (Tables: 2). The most common isolates among them viz., *A. candidus, A. flavus, A. fumigatus, A. granulosus, A. nidulans, A. niger, A. ochrasius, A. terreus, Curvularia clavata, C. lunata, C. lunata, Fusarium oxysporium, F. solani, Penicillium chrysogenum, P. digitatum, Rhizopus stolonifer, R. oryzae, Trichoderma hamatum, T. viride* were isolated and characterized.

The percent contribution of different soil mycoflora of all the six Rice fields was evaluated. The fungi were mostly observed in the months of June to October as it has been reported that the diversity of fungal population occurred during the monsoon season where the soil moisture was significantly high (Bissett & Parkinson, 1979; Deka & Mishra, 1984).

Isolation of fungal species from soil samples by repeated screening and plating on starch agar medium by Ratnasri *et al.,* 2014 yielded *Aspergillus fumigatus* and *A.niger* along with other fungal species. *Fusarium solani* was isolated from the soils of infected fields and showed 100% frequency (Javed *et al.,* 2008). Recent study on Soil Microflora in National Parks in Gujarat yielded fungal species like *Aspergillus niger* and *Fusarium* species (Megha *et al.,* 2015). The conservation of diversity of mycoflora in agricultural fields becomes very essential for the development of sustainable agriculture (Gaddeyya *et al.,* 2012). Natural and anthropogenic disturbances can alter the species composition or may have negative effect on species diversity of the decomposer fungi (Dong *et al.,* 2004). These changes may directly or indirectly affect the vital functions of the soil such as decomposition and mineralization and may result in disturbances. Graphical representation of percent contribution of fungal species diversity in various paddy fields on the media PDA is represented in (Graph:1).

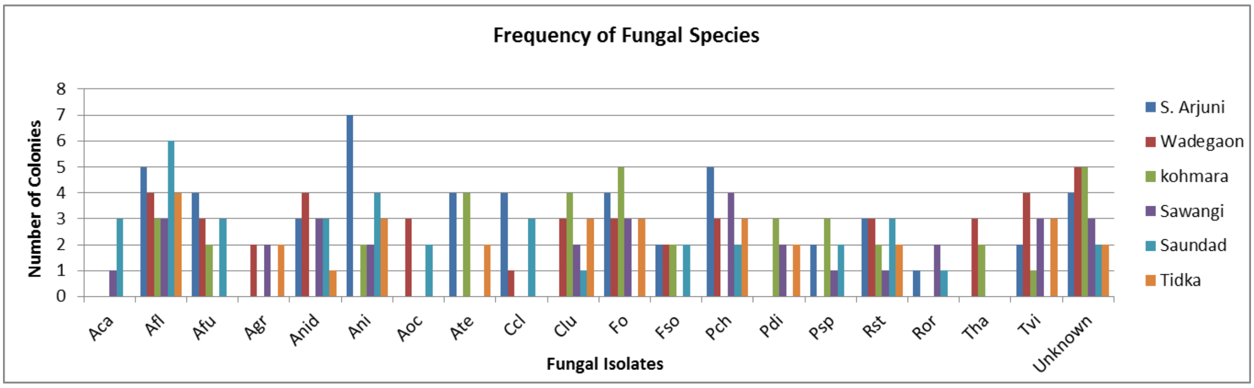
The studies on fungal diversity and percentile contribution and periodic occurrence of soil mycoflora are useful for farmers, agronomists, researchers and microbiologists for future activities in the view of conservation of soil ecosystem, conservation of soil microbial diversity and sustainable agriculture (Gaddeyya *et al.*, 2012).

Table 1: Agricultural soil samples collected from different places in Sadak Arjuni Tehsil

Sample No.	Agricultural field	Place
1	Paddy	Sadak Arjuni
2	Paddy	Wadegaon
3	Paddy	Kohmara
4	Paddy	Sawangi
5	Paddy	Saundad
6	Paddy	Tidka

Table 2: Frequency of Mycoflora in different Agricultural Fields as on Potato Dextrose Agar Medium

Sr. No.	Rice Fields	Total No. of Colonies	Average Number of Individual Colonies																			
			Aspergillus								Curvularia		Fusarium		Penicillium		Phoma	Rhizopus		Trichoderma		Unknown
			Aca	Afl	Afu	Agr	Anid	Ani	Aoc	Ate	Ccl	Clu	Fo	Fso	Pch	Pdi	Psp	Rst	Ror	Tha	Tvi	
1	S. Arjuni	50		5	4		3	7		4	4		4	2	5		2	3	1		2	4
2	Wadegaon	43		4	3	2	4		3		1	3	3	2	3			3		3	4	5
3	Kohmara	38		3	2			2		4		4	5	2		3	3	2		2	1	5
4	Sawangi	32	1	3		2	3	2				2	3		4	2	1	1	2		3	3
5	Saundad	37	3	6	3		3	4	2		3	1		2	2		2	3	1			2
6	Tidka	30		4		2	1	3		2		3	3		3	2		2			3	2
Total		230	4	25	12	6	14	18	5	10	8	13	18	8	17	7	8	14	4	5	13	21
% Contribution			1.7	10.8	5.2	2.6	6.08	7.8	2.1	4.3	3.4	5.6	7.8	3.4	7.3	3.04	3.4	6.08	1.7	2.1	5.6	9.1



Graph 1: Frequency of Fungal species in different crop fields on PDA

Aca:-*Aspergillus candidus*, Afl:-*A. flavus*, Afu:-*A. fumigatus*, Agr:-*A. granulosus*, Anid:-*A. nidulans*, Ani:-*A. niger*, Ate:-*A. terreus*, Afu:-*Curvularia clavata*, Afu:-*C. lunata*, Afu:-*C. lunata*, Afu:-*Fusarium oxysporium*, Afu:-*F. solani*, Afu:-*Penicillium Chrysogenum*, Pch:-*P. chrysogenum*, Pdi:-*P. digitatum*, Rst:-*Rhizopus stolonifer*, Ror:-*R. oryzae*, Tha:-*Trichoderma hamatum*, Tvi:-*T.viride*

Fig. 1**: Fungi isolated by Soil Dilution Method**

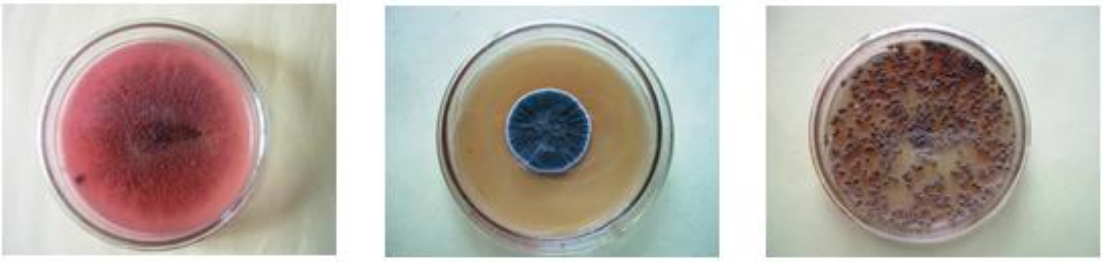


Fig. 2**: Pure culture of some fungal species**

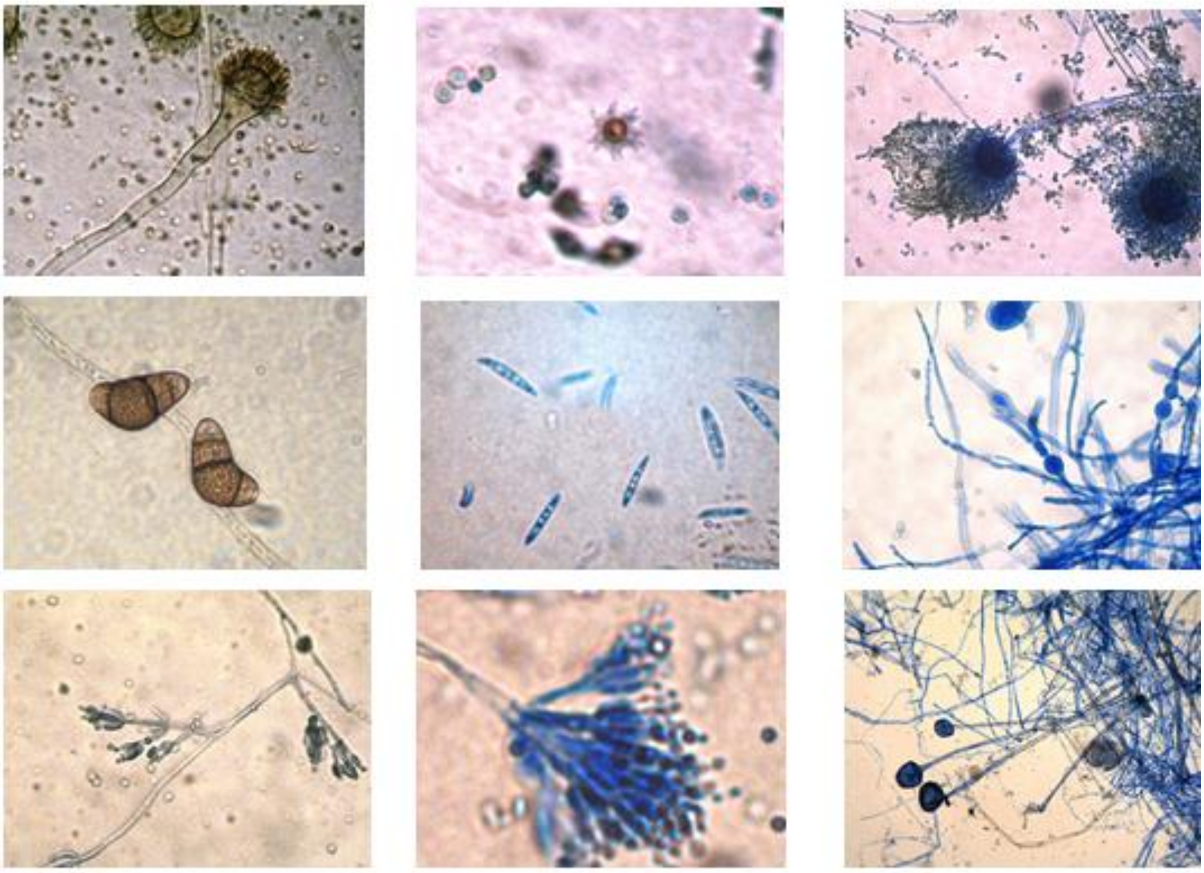


Fig. 3: Some of the isolated fungal species

Conclusion:

In the present study the soil sample of six different paddy fields of viz; Sadak Arjuni, Wadegaon, Kohmara, Sawangi, Saundad and Tidka studied for detecting the fungal diversity. The greater fungal population was observed mostly in the monsoon season as the soil moisture was high. Among the isolates *Aspergillus, Fusarium, Penicillium, Rhizopus* and *Trichoderma* were dominant in all agricultural fields of all areas mentioned due to high sporulation and production of bacterial antibiotics from the *Penicillium* species and production of different types of toxins from the *Aspergillus* species may prevent the growth of other fungal species. This study is an effort to understand the soil microbial diversity in the agricultural fields of Sadak Arjuni as soil microflora not only plays an important role in decomposition and contribute to biogeochemical cycling but also are responsible for the prevalence of diseases in the crop fields.

The findings of the study could have implications for the development of sustainable agricultural practices and the promotion of soil health. The study could also contribute to our understanding of the role of fungi in soil ecosystems and their interactions with plants and other soil organisms.

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AGRICULTURE'S PRODUCTIVITY AND SUSTAINABILITY: LEVERAGING *TRICHODERMA*

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Abstract:

Expanding agricultural activity, driven by increased food demand, has resulted in environmental issues, primarily due to the high amounts of external inputs and resources required. Furthermore, environmental changes, such as global warming, can cause a variety of biotic and abiotic pressures that have a negative impact on crop yield. To address these issues, numerous remedies and agricultural practices have been proposed. Using helpful bacteria as soil inoculants is one method for increasing plant production as well as tolerance to biotic and abiotic challenges. A greater knowledge of *Trichoderma's* potential to boost crop yield and the mechanisms involved is critical for reaping the most benefits from its use. Several studies have been written about the sustainability of utilizing *Trichoderma* as plant growth regulators, the impacts on plant growth and yield, and their effects on regulating both abiotic and biotic stressors.

Introduction:

Persistent growth in populations has resulted in an increase in food consumption, necessitating the mass production of agricultural products [1]. By 2050, there will be more than 8 billion people to feed. Not only must we enhance food availability, but we must also ensure that supplies are generated in a sustainable manner, without jeopardizing the benefits that nature can supply. Beneficial microbes use a variety of mechanisms to increase plant productivity by promoting plant growth and health, such as colonizing soil and/or plant parts, thereby occupying space and limiting phytopathogen proliferation; producing enzymes, antibiotic substances, and volatile organic compounds that suppress phytopathogens; facilitating nutrient and water uptake; producing phytohormone; inducing local or systemic resistance responses [2]. *Trichoderma* is also a popular biocontrol tool for phytopathogenic bacteria. *Trichoderma*, for example, was discovered to endophytically colonize *Brassica oleracea* and activate kale plants' systemic resistance against the bacterial disease *Xanthomonas campestris* [3]. Some of the mechanisms involved in promoting plant growth and disease resistance via endophytic fungi include increased access to nutrients (nitrogen, phosphorus, potassium, zinc, iron, etc.), antibiotic production, plant hormone production, ethylene reduction, or an increase in water acquisition rate. Over the years, scientists and agricultural practitioners have concentrated on finding ecologically acceptable crop management alternatives. Finding the optimum way for enhancing agricultural output is critical for ensuring a sufficient food supply for all. Agroecology has been a prominent way of redesigning food systems to achieve greener agriculture approaches with higher sustainability.

Trichoderma's **importance to sustainable crop production**

The effects of *Trichoderma* root inoculation are not limited to the site of colonization, but occur throughout the entire plant system. Colonization is a complex process in which the fungus can infiltrate plant cells but can only survive symbiotically without harming the plant. *Trichoderma* lives on the roots' outermost layer and does not reach the inner vascular tissue [18]. In *Trichoderma* research with Arabidopsis, the presence of metabolites such as salicylic acid (SA) and glucosinolates (GSLs) was found to limit *Trichoderma* invasion in the vascular bundle. *Trichoderma* spp. increased the growth and yield metrics of treated plants in a chickpea research when compared to ninoculated controls. This outcome was discovered to be driven by increased phosphate solubilisation and absorption. Furthermore, when the seeds were pre-treated with *T. harzianum* and its foliar sprays, a maximum yield of chilies was achieved. In the scenario of sugarcane, both *T. harzianum* and *T. viride* were considerably effective in increasing phosphorus intake as well as other micronutrients, resulting in improved germination, tiller population, millable cane production, and commercial cane sugar yield (CCS t/ha). When tomato plants were grown in *Trichoderma*-fortified soil, their shoot and root growth characteristics, as well as chlorophyll content, increased dramatically. Mineral content was greater in both shoot and root compared to control plants. *T. virens* increased the efficiency of nitrogen uptake in lettuce and rocket plants, resulting in increased crop output and quality. These acids lower soil pH, enabling for greater nutrient solubility and uptake [4]. Numerous researches are being done to elucidate the methods by which *Trichoderma* stimulates plant growth and development. Some of these mechanisms can be explained by the overexpression of photosynthesis-related proteins, which results in a higher photosynthetic rate, increased plant nitrogen usage efficiency, and improved plant nutrient uptake. While molecular research on *Trichoderma* impacts is still in its early stages, some first findings are intriguing. For example, after *Trichoderma* inoculation, a considerable fraction of the genes involved in carbohydrate metabolism, stress regulation, and photosynthesis were up-regulated in maize plants. Similarly, the presence of *T. asperellum* in rice was discovered to be associated with the up-regulation of many genes, some of which have been linked to photosynthesis and chlorophyll biosynthesis [5].

Trichoderma's **roles in sustainable plant disease management**

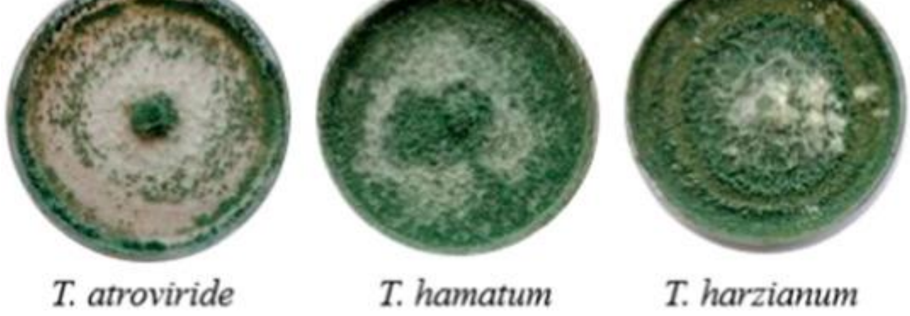
Trichoderma has been shown to control a wide range of plant pathogenic microorganisms, including bacteria (*Pseudomonas* and *Xanthomonas*), fungi (*Fusarium*, *Curvularia*, *Colletotrichum*, *Alternaria*, *Rhizoctonia*, and *Magnaporthe*), oomycetes (*Pythium* and *Phytophthora*), and at least one virulent virus (green mottle mosaic virus on cucumber).

Bacterial disease management:

Plant diseases produced by bacteria are notoriously difficult to eradicate. Plant breeding and cultural, chemical, biological, and physical control strategies are the most prevalent methods used to effectively control these diseases. Biocontrol agents are more successful than chemical bactericides at controlling bacterial pathogens and are safer for the environment. *Trichoderma* inhibited the development and survival of *Ralstonia* spp., a pathogenic Gram-negative bacterium, in tomato plants, which was linked to the release of different chemicals such as lysosime, viridiofungin, and trichokonin. Furthermore, the application of *T. asperellum* suppressed bacterial wilt produced by the soilborne bacterium *R. solanacearum*, and the disease incidence was subsequently reduced with associated improvement in plant growth and production under field circumstances. This was accomplished by inducing a high level of defence enzyme activity, such as POX, PPO, and PAL, -1, 3-glucanase, and total phenolic content in plants [6]. Other examples of bacterial phytopathogen biocontrol include *Trichoderma* induction of resistance in tomato plants against *Xanthomonas euvesicatoria*.

Fungal disease management:

Trichoderma species mycoparasitism involves an attack on the pathogen's cell or structures. *T. koningii* was shown to colonize diseased or injured onion root tissues as a secondary colonizer, where it reduced *Sclerotium cepivorum* infection by eliminating the hyphae [7]. *T. virens*, on the other hand, not only parasitized the hyphae of many pathogenic fungal species, but also entered and destroyed several of these fungi's resting structures, lowering their inoculum potential in soil. The treatment with *T. virens* prevented the emergence of damping-off disease in cotton seedlings caused by *Rhizopus oryzae*. This fungus metabolized pathogen propagule germination stimulants released by sprouting cotton seeds. Several *Trichoderma* species also produce volatile and non-volatile antibiotics and enzymes that have antagonistic effects on phytopathogenic fungi. *T. harzianum*-released proteases, endochitinases, glucosidases, mannosidases, and phosphatases were discovered to be involved in the biocontrol of several diseases, including *Guignardia citricarpa* (the causative agent of citrus black spot). These enzymes are responsible for the breakdown of pathogen cell wall membranes and proteins. *Trichoderma* also produces compounds capable of inhibiting or antagonizing harmful microorganisms. *T. virens*-produced fungal terpenoids (desoxyhemigossypol, hemigossypol, and gossypol) were discovered to be involved in the control of *R. solani*-incited cotton seedling. *Trichoderma* application to *R. solani*-infected chilies increased plant growth and yield [8]. *Trichoderma* species have been reported to generate resistance against several plant diseases in addition to their direct antagonistic actions against fungal and bacterial plant pathogens. Resistance can be induced locally or systemically. The consequences of *Trichoderma*-induced systemic resistance were studied using a model rhizobacterium. *T. virens*, for example, successfully developed plant-systemic resistance against *Colletotrichum graminicola* in maize. Aside from that, *T. virens* was capable of establishing localized resistance against *R. solani* infection of cotton roots by stimulating the plant's terpenoid synthesis. The mechanisms underlying these inductions are linked to a variety of changes at the biochemical and molecular levels in plants.



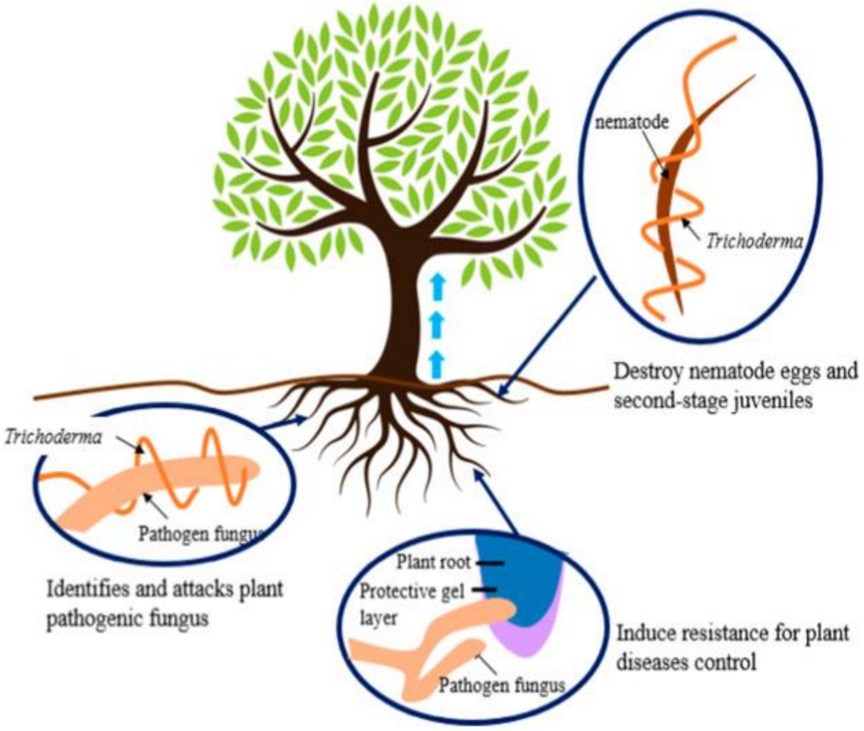
Nur et *al.*, 2020 [14]

Table 1: *Trichoderma* species and their biotic stress control mechanisms

Species	Plant	Pathogen	Effect
T. harzianum	Tomato	*Clavibacter michiganensis*	Prevented the incidence of bacterial canker.
T. harzianum	Tomato	*Alternaria solani*	Bacterial spots are reduced, triggering systemic acquired resistance (SAR) or induced systemic resistance (ISR).
T. harzianum	Tomato	*Ralstonia spp.*	Trichoderma spp. AA2 inhibited the growth.
T. atroviride, T. koningii,	Chickpea	*Ascochyta rabiei*	Suppressed fungal infections by mycoparasitism, antibiosis, and competition for space and/or nutrients.
T. harzianum, T. aureoviride, T. koningii	Wheat	*Pyrenophora triticirepentis*	Pathogen mycelium on the leaf surface collapsed or disintegrated

Pest and plant parasitic nematode management:

Plant diseases caused by insect pests and plant-parasitic nematodes (PPNs) are also a major threat to worldwide agricultural productivity and sustainability. Insect pests can cause agricultural losses of up to 70% [82], while plant-parasitic nematodes (PPNs) represent 12% of global food production losses. *T. harzianum, T. viride*, and *T. lignorum* are common nematode antagonistic fungi, sometimes known as nematophagous fungi that have been commercially developed as fungal biocontrol agents for the management of phytonematodes. An investigation using *Trichoderma* to inhibit the root-feeding nematode *Meloidogyne hapla* in tomatoes indicated that tomato plants that had previously been treated with *Trichoderma* had roughly 1000 (2%) less nematode eggs laid on or near the roots [9]. *Trichoderma* fungi are also well-known for their helpful benefits in providing plant protection against insect pests and parasitic nematodes. *Trichoderma* species can function directly as an entomopathogen through parasitism and the formation of insecticidal secondary metabolites, antifeedant chemicals, and repellent metabolites, according to prior research on the mode of action of *Trichoderma* as the mycoparasite fungus. Furthermore, this adaptable fungus can operate as a mycoparasite indirectly by activating systemic plant defensive responses, attracting natural enemies, or parasitizing insect-symbiotic microorganisms. *T. longibrachiatum*, for example, has been reported to be able to suppress the insect pest *Leucinodes orbonalis* in brinjal plants while also boosting crop yield [10]. *T. atroviride* inoculation in tomato plants resulted in plant resistance to the insects *Spodoptera littorali* and *Macrosiphum euphorbiae*. These protective abilities were attributed to a *T. atroviride*-induced plant response that was connected to molecular and metabolic alterations in tomato plants. *T. atroviride* also caused changes in plant metabolic pathways, which resulted in the production and release of volatile organic compounds (VOCs), which are involved in the attraction of the aphid *Aphidius ervi* (a parasitoid with anti-pest activity), thereby reinforcing indirect plant defence barriers. *T. harzianum's* insecticidal efficiency in combination with natural protectants was also proven to be an appropriate technique for managing stored product damage caused by the insects *Callosobruchus maculatus* and *C. chinensis* in cowpea seeds [11].



***Trichoderma* species as crop abiotic stress relievers**

Drought is one of the most serious abiotic stresses caused by a lack of water, and it is exacerbated by increased evapotranspiration. Drought has negative impacts on plant growth and can lead to plant mortality. The inoculation of plants with *Trichoderma* causes a variety of drought-related reactions. *T. harzianum*, for example, was discovered to postpone or prolong drought responses in rice. This was attributable to the delayed increase of the stress-induced metabolites proline, malondialdehyde (MDA), and hydrogen peroxide content, as well as increased phenolic compound concentration, regardless of water deficiency. *T. atroviride* inoculation in maize plants may reduce the harmful effects of drought and may have a role in stress adaptation. Aside from drought, cold is an example of high temperature conditions that pose a considerable danger to agricultural output sustainability and can result in significant crop losses. This stress occurs when plants are subjected to low temperatures, such as those induced by late-season frosts, freezing temperatures in winter, and late-spring frosts. *Trichoderma* can reduce the drop in plant development caused by cold weather. *T. harzianum* colonization, for example, was found to ameliorate the negative effects of cold stress on most commercial cultivars of tomato, a cold-sensitive plant. *T. harzianum* inoculation increased the fresh and dry weights of tomato leaves and roots when compared to cold-treated plants. Soil salinity stress is another growth limiting factor for plants, as it is associated by high osmotic potential and specific ion toxicity. *T. harzianum* treatment on wheat plants, on the other hand, was able to lessen the severity of salty conditions. *T. asperelloides* administration prior to salt stress imposition considerably increased seed germination in both Arabidopsis and cucumber plants. Salinity increases the photosynthetic rate, lowering the supply of carbohydrates required for plant growth. *T. harzianum* inoculation of the Indian mustard plant restored the photosynthetic pigment to an appreciable level [12]. Furthermore, during *Trichoderma* inoculation, several genes related to the rice plant's response to biotic and abiotic stressors were elevated. *T. asperellum* inoculation, for example, increased the expression of genes involved in plant defence response and ROS metabolism.

***Trichoderma* production in industry**

The ability to mass produce the greatest number of effective propagules (chlamydospores, conidia, microsclerotia) in the shortest amount of time is the most important feature for a selected endophytic fungal to be commercialized as a biocontrol or biofertilizer product. A higher manufacturing cost as a result of expensive substrate, poor biomass output, or limited economies of scale can be a limiting factor in the commercialization of the end products [13]. *Trichoderma* industrial production can be carried out in the following steps: optimization of culture conditions at the laboratory scale to obtain high yield and active biomass, optimization of biomass production at the pilot-plant level to determine and solve various engineering variables; the resulting products can be tested for field application, integration of selected unit operations from fermentation, bio separation, and formulation into a single process.

Challenges and future prospects:

Trichoderma species used in crop production can improve plant health, growth, yield, and disease resistance. According to one study, using *Trichoderma* biofertilizer (composted cattle dung + inoculum) efficiently regulated soil chemistry and microbial populations, resulting in much higher aboveground plant biomass than using organic fertilizer alone. Furthermore, *Trichoderma* can enhance the relative abundance of helpful fungus while decreasing the quantity of phytopathogenic bacteria substantially. This was demonstrated by an increase in the abundance of *Archaeorhizomyces* and *Trichoderma* while a decrease in the abundance of *Ophiosphaerella*. *Trichoderma* was found to reduce the development of *Fusarium solani* in one in vitro investigation, however no inhibitory area was seen when it was cultivated with Pseudomonas strains. *Trichoderma* seems to be compatible with and coexist with helpful bacteria.

Conclusion:

Trichoderma can safely and sustainably boost the growth and development of numerous plant species. This includes battling both biotic and abiotic stressors, which frequently impair plant development and result in crop losses. *Trichoderma's* beneficial impacts on plant growth and development have demonstrated that this fungus can be widely exploited to enhance sustainable agriculture. There are currently strong efforts underway to accelerate their integration into agricultural production systems in order to produce successful inoculation systems and workable modalities of administration. Improved understanding of the mechanisms involved in diverse *Trichoderma* activities is critical for developing practical goods for a sustainable agriculture sector. Furthermore, the use of several omics techniques in phytobiome research has proven to be useful in revealing a holistic picture. Acceptance of viable *Trichoderma*-based products will aid in the reduction of chemical fertilizers and pesticides, resulting in better, cleaner food production and more sustainable agricultural practices.

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MOISTURE CONSERVATION PRACTICES IN ARID AND SEMIARID REGION UNDER CHANGING CLIMATE OF INDIA

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Due to change in climatic condition different soil and plant processes will be affected so there will be a serious threat to food security. The impact of climate change is clearly seen on soil health *viz.*, increase in salinity, decrease in organic matter, decrease in water table, temperature regimes. Another source which is very vital for proper growth and Soils are directly linked to the atmospheric system through the carbon, nitrogen and hydrologic cycles. Because of this, changing climate conditions there will be effect on soil processes and properties. Moreover, some other dynamics issues such as *viz.*, desertification, deforestation, and erosion, degradation of water quality and depletion of water resources, complicating the challenge of food security. The earth's average surface temperature has increased by 1.3^{o} F in last century and is subjected to increase by 3.2 to 7.22^{o} F in 21st century as projected by the Inter-Governmental Panel on Climate Change (IPCC) [7]. Due to change in climatic condition which ultimately increase the potential erosion rates will directly decrease the cop productivity by 10 percent to 20% in extreme cases. Moreover, climate change could also contribute to higher temperatures lower precipitation and evapotranspiration in some regions. Adding additional pressure to draw irrigation water from aquifers which are already overexploited and having lower rate of water recharge than withdrawal rates. Natural resource conservation and management is crucial for country like India where sustainable agriculture is much important to meet the requirements of the future generation under changing climate. It is very necessary where development of sustainable agriculture is essential for overall growth, removal of poverty and food security. In India the land under rainfed condition is about 70% which supports about 44% of the human population and contributes 90 % of coarse cereals and pulses, 80 % of oilseeds and 65 % of cotton which clearly shows that production and productivity comes only from rainfed regions. The crop yields in semi-arid areas depend more on rainfall distribution than on total rainfall. In India the total available water is about 4000 billion m^3 per annum. Out of this total available water is lost in various form viz. transpiration, evaporation and runoff which is about 1047 billion m^3. This simply shows that the available water is only 1953 billion m^3. It is essential to supply irrigation water to enhance the food production and livestock to ascertain the food sustainability and security. In India due to presence poor infrastructure and lack of awareness amongst the people they are unable to make the good use of water. Area under arid and semi-arid region is about 48 percent in India.[12].

If climate change dynamics continues *viz.*, rise in temperature, irregular rainfall, low precipitation the area under arid and semi-arid region will be increased by 2100 [3]. Farmers of Maharashtra region has changed the cropping system with sugarcane instead of Jowar and chickpea which was grown earlier. As sugarcane require 25 million liters of water per hectare for the proper growth and development it has decreased the water level. Due to drought condition the area under sugarcane has reduced to 6.3 lakh hectare in year 2015-16 from 10 lakh hectare in the year (2014-15). Similarly in pulse production due to drought production has decreased to 17 million tons from 23 million tons in year 2016. Management of water resources by scientific knowledge is the only way to resolve the problem. We have to study the techniques which are used for conserving the maximum amount of rainfall either by collecting or by recycling it. Soil moisture conservation management is very important not only for the conservation water and soil but to increase the crop yield by supplying adequate amount of water to the field. So, moisture conservation practices should be adopted so, meet the requirements of the crop throughout life for better crop production.

Impact of altered moisture availability

Impact of global warming and climate change will directly affect the rainfall volume and its frequency too thus the extent of soil erosion will increase so high risk of flow of fertile soil and beneficial nutrients from the soil. But in some regions there is only increase in peak rainfall intensities. Moreover, due to increase in heavier rainfall events soil is unable to absorb or retain more water hence more erosion and runoff as it is due to prolonged droughts which decrease plant cover and make the soil harder to retain organic matter in it in heavy rainfall conditions. So, due to increase aridity it will inhibit surface decomposition and nutrient cycling hence decreasing plant productivity and increase in soil erosion. [10].

Impact of global warming on soil moisture

The amount of water stored in the soil is fundamentally important to agriculture and has deep influences on evaporation, groundwater recharge and runoff generation. The water-holding capacity of soil affected possible changes in soil moisture deficits; the lower the capacity, the greater the sensitivity to climate change. Climate change also affect soil characteristics, which in turn increase in waterlogging or cracking hence affect soil moisture storage properties. Intensity of freezing is directly proportional to water holding capacity of soils. The effect of global warming are change in regional precipitation levels and temporal availability which will directly affect the water flow and soil moisture dynamics [5]. Understanding, measuring and assessing how water flows around the farm, will help the farmers in proper management of water flow in the farm land more efficiently. One of the natural effects of a rise in temperature on soil moisture is water evaporation. Precipitation and change in temperature have different effect on different type of soils. The amount of moisture in soil depends on the type of soil, amount of rainfall in a particular area and depth of water table. Sandy soils have high number of macropores which will directly leads to less retention of water and high evaporation. On other hand, clay soils have more micropores and it will hold more water. So, if an area was to get hotter, it would likely become drier (less rain). The water table would become low and the soil would dry out (i.e. have less moisture). In soils which support lot of vegetation due to increase in carbon dioxide associated with global warming may also increase soil moisture. Vegetation plays an important role in high organic matter and absorbs carbon dioxide. Precipitation and temperature will affect the ground cover, which will directly affect the soil moisture. Global warming is expected to intensify regional contrasts in precipitation that already exist: dry areas are expected to get even drier, and wet areas even wetter. Due to warmer temperatures, there will be increase in evaporation from oceans, lakes, plants, and soil and ultimately increases the amount of water vapor in the atmosphere by about 7% per 1°C (1.8°F) of warming.

Rainwater and groundwater resources in India

Average rainfall of India is 1100 mm, which ranges between 100 mm in Western India (Thar desert) and 10,000 mm in the northeastern parts. India can be divided into four major zones based on the average rainfall. Nearly, one third of India's rainfed areas are in arid and semi-arid, remaining area is about equally divided between medium and high rainfall zones. India accounts for about 400 million hectare meters (Mha-m) of rainwater. India’s share is about 4 percent which is largest received rainwater among the country’s which are comparable size of it. The southwest monsoon (June-September rains) contributes 74% of the total precipitation. Out of 400 M ha-m rainwater, 178 Mha-m is available as surface flows. Big reservoirs can store about 70 Mha-m. Nearly 24 Mha-m surface flows is possible to store at the donor areas. Approximately 6.32 Mha-m is harvestable through field level structures in low to medium rainfall regions (<1000 mm) where agricultural productivity is often uncertain.

A country is considered to be under regular water stress when the renewable water supplies drop below 1700 m^3 per capita per year and due to which the scarcity of water drop below 1000 m3 per capita per year. In the last few years the increased demand of water has been met from aquifers and groundwater [13]. Today, contribution of groundwater is ~62% in irrigation, ~85% in rural water supply and ~45% in urban water consumption. Due to high dependence of underground water various parts of country is facing stressed condition. Groundwater resource assessment for the year 2011[14] records that total estimated annual availability of groundwater resources of the phreatic aquifers in the country is $398 * 10^9$ m^3 of which recharge from rainfall accounts for nearly 70% and other sources contribute nearly 30%. Availability is much higher in the Indo-Ganga and Brahmaputra plains (>200 mm) in comparison to the peninsular part (mostly 100–200 mm). Annual availability is very poor (<50mm) in Rajasthan, which receives scanty rainfall. Lower availability (<50mm) in some parts of Gujarat is because it is the Rann area, where groundwater is mostly saline. Similarly, in south-eastern part of West Bengal also availability has been shown as <50mm as in this part fresh water availability in the phreatic aquifer.

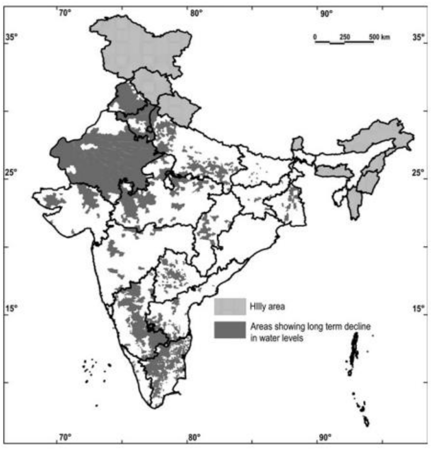

Fig. 1: Areas showing long-term decline in water levels during either of the one or both pre-monsoon and post-monsoon periods. (Adapted from CGWB, 2014)

Table 1: Distribution of rainfed area in different rainfall zones

Rainfall zone (mm rain/annum)	Category	Net sown area (million ha)	Rainfed area (million ha)
<500	Very low (arid)	14.3	10.4
500-700	Low (semi-arid)	33.9	23.4
750-1150	Medium	48.2	32.5
>1150	High	42.4	33.5

Moisture conservation practices for mitigating climate change:

In-situ moisture conservation: The 'in situ' moisture conservation techniques are cheap and it will help in the rain water use efficiency in dryland area. If the runoff will be reduced the volume of moisture will be increased in the soil profile. The in situ water harvesting provides better plant population, especially for small seeded crops like pearl millet by mitigating the adverse effects of crusting on germination, emergence and burying of seedling due to rain during germination. Some promising techniques under ‘in situ’ moisture conservation depend on the slope and it includes contour farming and installing barriers on the contour. Various techniques under 'in situ' moisture conservation are as follows:

- Off season tillage
- Strip cropping
- Tied ridging
- Dead furrows
- Terracing
- Conservation tillage
- Contour Farming
- Vegetative hedges
- Broad bed and furrows
- Bunds
- Mulching

Off-season tillage: Off season tillage helps the rain water to enter into the soil profile more effectively and in addition, helps in weed control. This practice in alfisols (highly leached red brown soils) of the Telengana region in the state of Andhra Pradesh increased the sorghum yield by 43 per cent but it is not suggested for aridisols (sandy soils of the desert regions) as it accelerates wind erosion. Deep ploughing, once every two or three years done, that helps to increase crop yield in soils with hard subsoil below the plough layer.

Contour farming: It comes under agronomic practices where slope is <2%. It is one of the easiest, low cost and most effective methods of controlling erosion and conserving moisture. The tillage operations carried out along contours will enhance the infiltration rate, decrease the rate of runoff and ultimately helps in increasing the crop yield by creating numerous ridges along the contour. Contour farming is effective on gentle slopes of up to 6%. The main constraint of this technique is that it is not been suitable for high slope.

Strip cropping: Strip cropping is a technique in which erosion permitting crops like maize grown with erosion resistant crops like moong bean, soyabean. This is the major technique to conserve the soil and water erosion. It is very cheap and requires less labour. It is also important to establish buffer strips on the contour. On the basis of objectives, vegetative materials used and field design adopted, buffer strips are called contour strip cropping, buffer strip cropping, barrier strips, border strips, or field strips. In addition to reducing runoff amount, it will also help in controlling wind erosion.

Vegetative hedges: Vegetative hedges are established on the contour to create a barrier against the soil to prevent from erosion and will helps in increasing the rate of runoff and increase time for water to infiltrate into the soil. Vetiver grass is the vegetative hedges which is widely adopted for tropical eco-regions. Some woody perennial plants like *Leucaena leucocephala, Gliricidia sepium,* etc. are also used in controlling erosion. If they are closely spaced with narrow strips of grasses it is most effective in reducing runoff and controlling soil erosion.

Tied ridging: This is modified version of ridge-furrow system; in which ridges are connected at 15 to 20 m interval to allow rainwater in the furrows and its infiltration into the root zone. One of the main advantages of this system is that it not only conserves soil water but it will also help in reducing the nutrient loss which occurred due to leaching.

Broad bed and furrows: Broad bed and furrow system is mainly adopted in black soils in Maharashtra, Karnataka and Gujarat region. The planting is done on the bed. Generally, the depth of each furrow is kept 0.15 m and the inter furrow spacing is maintained at 1.5 m.

Dead furrows: Dead furrows are laid across the land slope to intercept the run-off. The spacing between dead furrows varies between 2 to 5 m or 4 to 7 crop rows. This system serves as the best technique under shallow alfisols soil order and related soil under alfisols.

Bunds: These are low height earthen embankments constructed across the slope in cultivated lands after deciding location of waterways. The bunds help in decreasing the velocity of the run-off, use of rain water safely, increasing infiltration in the soil. Bunds can be classified into Contour bunds and graded bunds. Contour bunds are generally used when the slope is less than 6% and rainfall is about 600 mm and graded bunds are used in the areas where slope is 16-33% and in high rainfall areas greater than 750 mm. They are designed for an expected run-off of 24 hours duration and 10 years frequency. The main advantage of constructing the bund is that it provides the safe area for storage of excess runoff. The cross-section area of contour bunds follows the depth and type of soil, however, 0.5 m is minimum.

Table 2: Choice of bunding programs as influenced by mean annual rainfall and type of soils

Treatment	Rainfall region	Remarks
Contour bunding	Low rainfall region (<750 mm)	Suitable for medium soils of slope
Graded bunding	Maximum to high rainfall regions (>750 mm)	Upstream channel- Vertsiols No upstream channel- Alfisols
Graded border strips	Medium rainfall regions (750-1150 mm)	Suitable for deep alfisols and vertic-inceptisols

Graded bunds: These are constructed in areas where slope is 2-6% in medium to high rainfall areas. They are quite suitable in red soils. By and large graded bunds with 0.3 to 0.5 m^2 section are constructed with longitudinal gradient of 0.2 to 0.4% depending on the site condition. Main aim is to reduce the run-off and divert the run-off hence prevent from erosion. For making bunds, soil should be taken from lower side. Sometimes, pits for making bunds in deep black soils are made on upper side. They should be leveled or ploughed up as early as possible after bund construction. Bunds should be covered with natural grass. In some places loose stones are easily available, so stone-bunds should be advisable.

Compartmental bunds: Main aim is to conserve the moisture so convert the area into square/rectangular- useful for temporary impounding of water. It is generally adopted in the medium deep black soils especially in the rainy season and therefore it will be further used in the *rabi* season to supplement the irrigation. The size of the compartments may be fixed. The harvested water in these compartments conveniently infiltrates into the root zone and conserved *in situ*.

Terracing: It is generally adopted in the lands having slope above 10% particularly in hilly areas should be put under bench terracing by converting the lands into series of platforms. The dimension for the bench terrace will depend upon the land slope and is very much effective in reducing soil erosion in hilly areas. At places where scattered stones are available, loose stonewalls can be made to act as risers for bench terrace construction.

Mulching: Mulching of soil surface with crop residue, plastic sheet or grass cover is an efficient agricultural technology to conserve soil moisture by reducing evaporation and catching water running over the agricultural land. Applying the right type of mulch not only conserves soil moisture, but can cool the soil as well. Further, mulches keep the soil underneath moist longer than bare soil and prevent evaporation. Actually, surface mulch prevents the soils against beating action of raindrops and avoids clogging of soil pores, thus increasing infiltration rate. Plant residue mulch controls soil erosion and conserves soil moisture. Mulch also help keep weeds under control, thus reduce the competition for water. Good mulch is one that is clean of weed seeds, insects and other pests, easily applied, and economical. Plastic mulches are completely impermeable; therefore prevent direct soil evaporation and limit water losses and erosion via the soil surface. Sabyasachi and Bhattacharya (2005) registered 1.6- 2.4 times higher water-use-efficiency and 20-28 % less water consumption in green gram due to mulching.

Conservation tillage: Tillage has deep influences on crop yields and water use efficiency. Actually, tillage break the continuity of soil pores, thus has an impact on evaporation and infiltration rate. Erratic rainfall behavior can be a serious limitation to agricultural production especially in rain fed areas causing low yields and sometime even crop failure. In other words, a significant cause of low production and crop failure in rainfed agriculture is lack of water in the soil. In most instances, a great deal can be done to improve the efficiency of rainwater use. Soil moisture management is therefore a key factor to enhance agricultural production. In this context, conservation agriculture is one way of improving soil moisture management [1]. The conservation agriculture maintains permanent soil cover either with plant residue or growing crops, thus protects the soil surface from the adverse effect of raindrop. On other hand, it reduces direct water loss through evaporation from the upper layers of the soil. Similarly, in case of reduced tillage soil is less disturbed, so the moisture loss and soil compaction that follows tillage is avoided. This increases the infiltration and percolation of water through the soil, leading to better root development and crop growth. Minimum disturbance of soil in turn improves the living conditions of beneficial organisms and enhance their activity significantly. Microorganisms secrete various enzymes, hormones, vitamins and organic acids that causes aggregation of soil particles, thus improve soil structure. Further, following crop rotation and cover cropping preferably with legumes helps to increase soil organic matter, reduce erosion and enhance microbial activities in soil. Moreover, rotation with crops of different root system say legumes develop a network in the soil, thus enhances water penetration, water holding capacity and in turn water availability to crops from deeper layers. Minimum tillage practice especially in case of wheat has been found useful for conservation and carryover of residual moisture for sowing of said crop on time. Presoaking of seed in 1% salt solution before sowing is another package that has proved to be a good alternative for efficient utilization of soil moisture before depletion.



Contour Farming **Dead Furrow** **Tied ridging**

Ex-situ moisture conservation: In rainfed areas, after the occurrence of two or more heavy rainfall run-off started. It is generally about 60% and 40% in vertisol and alfisols soil order. Hence, efforts should be made to conserve the moisture**.** The methods of water harvesting are follows:

- Runoff farming
- Water spreading
- Micro catchments
- Dug wells
- Tanks
- Farm ponds

Runoff Farming: Ancient runoff fans in the Negev desert in Israel had several cultivated fields fed by water from watersheds of 10 to 50 hectares. Watershed are divided into small catchment area of 1- 2 hectare of land that allow run-off water and collected at common point and use for future use. Run-off is collected at hill sides. The channels that led the water to cultivated fields were terraced and had stone spillways so that surplus water in one field could be led to lower ones. Farmers constructed small check dams with rocks across the small gullies and guided the water to fields.

Water Spreading: In arid areas, the limited rainfall is received and that water will gently flows down through gullies or it is lost in the region. So water spreading technique is beneficial which is spread over adjacent plains. Flow waters are deliberately diverted from their natural courses and spread over adjacent plains. The water is diverted or retarded by ditches, dikes, small dams or brush fences. The wet flood plains or valley floods are thereby used to grow crops.

Micro catchments: A plant can grow in a region with too little rainfall for its survival if a rainwater catchment basin is built around it. Micro catchments used in the Negev desert range from 16 m^2. Each is surrounded by dirt wall of 15.20 cm height. Micro- catchments should be made so that in little rainfall condition plant is able to grow. At the lowest point within each micro-catchment, a basin is dug about 40 cm deep and a tree is planted in it.

Dug wells: Hand dug wells have been used to collect and store underground water and this water is lifted for irrigation. The quality of water is generally poor due to dissolved salts.

Tanks: Runoff water from hillsides and forests is collected on the plains in tanks. The traditional tank system has following components viz. catchment area, storage tank, tank bund, sluice, spillway and command area. The runoff water from catchment area is collected and stored in storage tank on the plains with the help of a bund. To avoid the breaching of tank bund, spillways are provided at one or both the ends of the tank bund to dispose of excess water. The sluice is provided in the central area of the tank bund to allow controlled flow of water into the command area. The command area of many tank ranges from 25 to 100 hectares. In areas receiving annual rainfall of about 1000 to 1500 mm with runoff around 50 per cent, where canal and well irrigation is not feasible due to topography and underground water table, tanks are found suitable. The tank can provide supplemental irrigation for 20 hectares of rainfed farm land. However, there are a few tanks with command area of more than 1,000 hectares. Unlike wells, the quality of water is good in tanks. Water from the tanks is used to irrigate the command area by gravity flow.

At present in southern India, large number of tanks exists which are water collection points of large catchments. Due to silt load that is carried into the tank bed, natural sealing takes place and Percolation losses are reduced in due course. A study conducted by ICRISAT in the alfisol area of Mahaboobnagar District revealed that seepage losses are quite low, ranging from 0.20 to 0.37 mm/day due to silting. The losses due to evaporation and seepage from tanks are less important than losses after water leaves the tank sluice gate. It was infected that the major source of losses were from paddy fields and from the delivery system.

- **Percolation tanks:** Flowing gullies are collected in ponds and that water from the ponds percolates into the soil and raises the water table of the region so that this water level is used for supplemental irrigation.
- **Minor irrigation tanks:** Minor irrigation tank are generally constructed across the main stream of the canal system for irrigation by constructing low earthen dams. Height of the dam may vary from 5 to 15 meter. It will provide the safety against side- cutting. In micro-watersheds, water harvesting *bundhies*, similar to small scale irrigation tanks are also recommended. By and large, the water harvesting *bundhies* are not integrated with extensive canal system.
- **Nala bunds and percolation tank:** Nala bunds and percolation tanks are located in the nalas. The main aim of the nalas tank is to recharge the ground water. A strict regulation on the silt load entering the downstream reservoirs is an additional advantage of percolation tanks. The nalas and percolation tank are directly used for irrigation purpose and supplemental irrigation. The percolation tanks also provide the emergency spillways for safe disposal of flow during floods.

- **Stop dams:** Main aim of stop dams is also same like nalas or percolation tanks i.e. to provide the life-saving irrigation at the time of drought. This type of dam is permanent engineering structures constructed for raising the water level in the nala for the purpose of providing life-saving irrigation during drought periods. These are located over flat nalas at narrow gorges carrying high discharge of long durations. For the stop dam, a site with larger water storage capacity should be adopted.

Farm ponds: Farm ponds are typical water harvesting structures constructed by raising an embankment across the flow. Dug out ponds in light soil require lining of the sides as well as the bottom with suitable sealants but is not adopted in heavy black soils. Lining is of different type i.e. brick, HDPE, concrete etc.

Table 3: Surface area, perimeter and storage capacity of different shaped ponds

Shape of pond	Side slope	Surface area (m^2)	Perimeter (m)	Storage capacity (m^3)
Circular	1.5:1	900	106	1499
Square	1.5:1	900	120	1464
Rectangular	1.5:1	900	122	1458

Water harvesting and recycling

Harvesting of excess runoff in high rainfall areas in small ponds, rivers, artificial catchment areas, and use for the future use in critical stages of crop growth. This water also can be used for pre-sowing irrigation of a *rabi* crop in potential double-cropping regions. This water can be widely used in arid and semi-arid areas for irrigation and field purpose. Existing water harvesting systems suffer from the fact that the donor catchment (actual area that is contributing the runoff) does not benefit from the runoff water. In a modified system with small dugout ponds, the water can be used for the donor catchment. The appropriate pond size varies with rainfall, ranging from 200 to 3000 m^3. Seepage losses are one of the major problems in the ponds. To overcome the problem natural silting should be practiced but it will reduce the storage capacity in small ponds. Ideal sealant has not been found yet which is most cost efficient by 1:8 (cement: soil) which is somewhat more efficient. In small ponds of about 200 m^3 water is lifted out by the manual method to make available for cropped area. But for biggest size of pond 3000 m^3 mechanical pumps are used. The main disadvantage of water harvesting system is initial cost of construction is high that's why less spread of this technology. But sometimes horticulture crops like ber (*Zizyphus mauritiana*) will immediately give the repayment as it is a short duration crop. Another important practice i.e. pisiculture which also give the quick returns. There are various benefits accruing out of supplemental irrigation from harvested water:

- The main benefit of yield if supplemental irrigation is provided at flowering stage.
- In crops like wheat and barley CRI stage is most appropriate for supplemental irrigation.
- At the time of irrigation supply of fertilizer will enhance the yield.
- About 5 cm of supplemental irrigation will increase the yield by 35% in aridisols or light textured soils.

- Supplemental irrigation is found to be more effective in shallow rooted crops the deep rooted crops as shallow rooted crops require more water.
- Alternate furrow system is effective method among the water application method.

There are many constraints in adopting the water harvesting technology or in-situ moisture conservation. It may be financial or technological. But the mains constraint in our country is that farmers have less land holding i.e. about 1.8 hectares which limits the application of conservation methods Therefore, it is now realized that water conservation development projects should be undertaken on a watershed basis. The impact of water resource development can be better seen when improved practices are adopted in a watershed as a whole (a unit of land and a drainage area contributing runoff water to a common collecting point).

Organic matter as a key for long term soil moisture conservation

Soil organic matter plays a very important role in maintaining soil fertility as organic matter has the ability to hold 90% of its weight in water which will ultimately help in increase in crop production. The main advantage of water which is hold by organic matter is that it is present in plant in available form which will be directly absorbed by the plants. But, clay holds great quantities of water, but much of it is unavailable to plants. Furter, organic matter increases soil aggregation, which improves soil structure which will ultimately improves the permeability of air and water which will increase the ability of the soil to take up and hold water. About 1% increase in soil organic carbon increases field capacity by 2.2%, permanent wilting point by 1% and available water capacity by 1.5% [6]. So, incorporation of Farm yard manure (FYM), compost, green manures, wastes plant residues improve soil organic matter status and soil water retention. Thus, improvement in water retention capacity of soils through build up in soil carbon content holds the key to conserve moisture.

Conclusion:

Proper soil management is a key to conserve the soil water. It is the soil that absorbs, transmits and holds the water for crops to use. Conservation agriculture practice has potential to improve the resilience of agricultural cropping systems as it will increase soil organic matter thus increase in water holding capacity. Mulching of soil surface with crop residue or plastic mulch is very good method for conserving soil moisture. Rainwater harvesting helps in recharging groundwater. Recycling of water is also best alternate to overcome the shortage of water. So, all the soil conservation techniques have the potential to increase the water table, ultimately meet out the requirements in crop production. It can be concluded that water conservation is very important now a days as water table is going down and down day by day that will badly effect the crop production and will leads to the yield loss. It not only affects the cropping system but it is very harmful for human beings too. So, using new techniques whether in-situ or ex-situ will help in water conservation and also helps in preventing soil loss too.

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WEED MANAGEMENT IN DIFFERENT ECOSYSTEMS OTHER THAN AGRICULTURE SECTOR

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Abstract:

A weed is an unsightly, useless, injurious plant growing where it is not desired and something else should grow. Weeds interfere with a variety of human activities, and many methods have been developed to suppress or eliminate them. These methods vary with the nature of the weed itself, the means at hand for disposal, and the relation of the method to the environment. Different physical, mechanical, chemical and biological strategies were used alone and in conjunction to mitigate the weed menace in various ecosystems.

Introduction:

A weed is a plant growing where it is not desired (Jethro Tull, 1731). Also a weed is a plant whose potentialities for harm are greater than its potentialities for good. Weeds accounts for 43% loss in agricultural food production. Weeds also invade non-cropped lands particularly roadways, railways, airways, aquatic ecosystems, etc. and pose a severe threat in its management.

Usually for financial and ecological reasons, methods used on a golf course or a public park cannot be applied on rangeland or in the forest. Herbicide chemicals sprayed on a roadside to eliminate unsightly weeds that constitute a fire or traffic hazard are not proper for use on cropland. Mulching, which is used to suppress weeds in a home garden, is not feasible on large farms. Weed control, in any event, has become a highly specialized activity. Universities and agricultural colleges teach courses in weed control, and industry provides the necessary technology. In agriculture, weed control is essential for maintaining high levels of crop production.

The many reasons for controlling weeds become more complex with the increasing development of technology. Plants become weeds as a function of time and place. Tall weeds on roadsides presumably were not problematic prior to the invention of the automobile. However, with cars and increasing numbers of drivers on roads, tall weeds became dangerous, potentially obscuring driver's visibility, particularly at intersections. Sharp-edged grasses are nominal nuisances in a cow pasture, when the area is converted to a golf course or a public park, they become an actual nuisance. Poison oak (*Toxicodendron diversilobum*) is rather a pleasant shrub on a sunny hillside in the open country, in a camp ground it is a definite health hazard. Such examples could be given ad infinitum to cover every aspect of agriculture, forestry, highway, waterway and public land management, arboretum, park and golf-course care, and home landscape maintenance.

Weeds compete with crop plants for water, light, and nutrients. Weeds of rangelands and pastures may be unpalatable to animals, or even poisonous, they may cause injuries, as with lodging of foxtails (*Alopecurus* species) in horses mouths, they may lower values of animal products, as in the cases of cockleburs (*Xanthium* sp.) in wool, they may add to the burden of animal care, as when horses graze in sticky tarweeds (*Madia* species). Many weeds are hosts of plant disease organisms. Examples include wild mustards (*Brassica species*), prickly lettuce (*Lactuca scariola*), and sow thistles (*Sonchus species*), which act as hosts for downy mildew that host club root of cabbage and salt brush (*Atriplex* species) and Russian thistle, in which curly top virus overwinters, to be carried to sugar beets by leafhoppers. Many weeds are hosts of insect pests, and a number are invasive species.

- Problems due to weeds
- Nutrient losses
- Water losses
- Competition for light
- Space competition
- Insects and diseases
- Increase cost of production
- Low quality crop and
- Allelopathic effect

Extent of losses due to weeds depends on intensity of infestation, time of occurrence and type of weeds. Weed bloom for a period of time weed density, weed type and crop type are only a few of the variables that affect the yield losses in crops caused by weeds. Weeds have the potential to reduce yield by 100% if not managed. According to Llewellyn *et al.* (2016), weeds in Australia are predicted to cost grain farmers AUD 3.3 billion yearly.

Over two billion metric tonnes of grain are produced globally at the moment. The entire loss in grain output, assuming a 10% overall yield loss from weeds, is around 200 million metric tonnes. The output of grains would rise by 100 million metric tonnes if the reduction could be cut in half, which might help end hunger globally.

The different ecosystems include

1. **Terrestrial ecosystems:** A terrestrial ecological system is a population of land-based species and the relationships between biotic and abiotic elements in a specific space. The tundra, taigas, temperate deciduous woods, tropical rainforests, grasslands and deserts are a few examples of earth's ecosystems. A location's temperature range, average annual precipitation, soil type and amount of light all affect the sort of terrestrial ecosystem that may be found there. Which includes the follows:
   - Airports
   - Railways
   - Municipal and Roadways
   - Industries
   - Grasslands
   - Forest

2. **Aquatic ecosystems:** An aquatic ecosystem includes freshwater habitats like lakes, ponds, rivers, oceans and streams, wetlands, swamp, etc. and marine habitats include oceans, intertidal zone, reefs and seabed so on. The aquatic ecosystem is the habitat for water-dependent living species including animals, plants, and microbes.

Why weed management is essential in different ecosystems?

- ✓ Weeds along the road sides block the traffic signals and provide shelter for poisonous snakes and animals.
- ✓ Weeds along the runway of air lines are of quarantine importance.
- ✓ Weeds along the railway tracks reduces track durability and interfere with the visibility of track.
- ✓ Weeds in the public gardens reduces its aesthetic value.
- ✓ Weeds grow luxuriantly during rainy season and blocks the roads.
- ✓ They also cause several health problems to humans and livestock.

The term 'non-crop area' in its strictest interpretation could refer to all areas where a crop, or any intentionally planted vegetation, is not grown. We'll talk about places that have been specifically planted with a certain type of vegetation along with areas that are largely maintained to keep a particular type of vegetation from growing there.

In wasteland, non-cropped areas, along railway tracks, water channels and roadsides, the use of glyphosate and metribuzin has been shown promising results. Parthenium plants should be sprayed at the rosette stage because the stage/time of parthenium weed for herbicidal control is crucial. The results lead to the conclusion and suggestions that are listed below. At 4 weeks after treatment (WAT), glyphosate had the highest control over parthenium weed at the rosette stage (96%), followed by metribuzin (87%) and pendimethalin (42.5%). The findings showed that glyphosate can successfully control parthenium weed, but other herbicides employed in the study did not offer enough control when sprayed at the bolting stage. Compared to herbicides with other mechanisms of action, parthenium weed is extremely susceptible to inhibitors of amino acid synthesis and photosynthesis. Glyphosate and metribuzin are suggested for the management of parthenium weed in Pakistani non-cropped areas in light of recent studies. To avoid the harmful consequences of parthenium weed on crop productivity, the environment and human health, it is advised that its expansion be stopped.

I. Weed management in forest ecosystem

Forest weed control methods aim to encourage the development of the target tree species, increase road visibility, eradicate noxious weeds and enhance animal habitats. To maximise each element while maintaining a balance, wood species, ground vegetation and animals must all be managed. A productive forest is mostly achieved through vegetation control. To reduce losses and negative impacts brought on by weeds, managers must incorporate the best cultural, mechanical and chemical practises into suitable and cost-effective management strategies.

Aims of controlling weeds in forests

- Removing undesirable plants from planting locations in order to benefit the trees that are there.
- Releasing more desirable species from overtaking those that are less desired.

- The removal of extra plants from a stand. Preventing the spread of illness via root transplants.
- Preventing the encroachment of woody and/or herbaceous plants into open spaces for wildlife and pleasure.
- Weeding out the vegetation around structures and amenities as well as along forest routes.
- Removing harmful plants from outdoor spaces.
- Controlling weeds in a tree nursery or seed orchard that are a productivity hindrance.

In order to build a forest, just a small number of seeds or seedlings are brought into an area where an almost infinite number of other plants already exist or have the ability to do so. The survival of species is the forest manager's first priority and this is accomplished via the rivalry between weeds being lessened. The processes that minimize the density and lessen the vitality of the competing plants in the year and throughout the years immediately following planting are site preparation and tree release. The intended (planted) species' vitality as well as the native species' weed control in grasslands rely on the type and extent of management practices.

a. Integrated control

Plans for effective vegetation management include the appropriate set of procedures into well-organized schedules that are promptly carried out. Each site must be carefully evaluated since no one plan is best suited for all sites. To guarantee effective control, regularly evaluate the outcomes gained and adjust the plans as necessary.

b. Cultural control

Simply implementing practises that favour the desired tree species and make them more competitive with weeds is cultural weed control. Several examples are as follows:

Choose the species and kinds that are best fitted.

- Practice thorough site preparation.
- Establish seedlings that are robust, big and healthy, spaced properly and replace those that perish.
- Use the appropriate pest, disease and rodent management techniques.
- At each stage of stand development, continue the site's optimal stocking levels.

c. Mechanical control

In the management of forest vegetation, a variety of specialised equipment and attachments are employed, such as brush rakes, angle blades, shearing blades, rolling brush cutters and shredders. Integral ploughs and large offset discs are occasionally employed. In addition, weeding activities can make use of chainsaws, axes, brush hooks, motorised brush cutters, hatchets and other hand instruments. Mechanical site preparation and rehabilitation methods are often sufficient for clearing debris, controlling weeds, preparing seedbeds, reducing soil compaction brought on by logging and performing small land levelling activities on mild slopes.

Mechanical thinning is occasionally used, especially in extremely thick woods when clearing in uniformly spaced strips is preferred and no individual tree selection is required. When intended little trees are obscured by larger, brushy trees or when individual tree selection is required, mechanical thinning is not appropriate for release. Some sites are not suitable for mechanical control. Unsuitable topography, the potential for soil erosion, and relatively high operating expenses are the main barriers to the adoption of mechanical vegetation control. In places that are inaccessible to machinery, manual vegetation clearance can be used to supplement or replace the usage of heavy equipment. When the species that must be cut aren't too thick and do not resprout, manual cutting is most successful. Conifers are readily managed by cutting since they do not resprout. However, many brush species easily resprout compared to the trunk or firmly established roots, which lowers the effectiveness of cutting. Manual chopping can be used in combination with herbicide treatments for stumps to efficiently eliminate certain trees and stop regrowth even if it may not always be ideal for site preparation or release.

d. Chemical control

In the course of a forest stand, chemical-based weed management is typically only feasible once or twice. If the use of herbicides is complemented by all the other excellent forest management practises, their advantages may be visible throughout the lifespan of the stand. Herbicide use is just one element of a comprehensive production strategy. The use of herbicides must be required and work well with every other component of the strategy. The right herbicide, formulation, pace, water volume, administration technique and period of treatment must all be decided after the target weed species have been identified. Read the whole label of any pesticide before using it.

Adverse effects of weeds on forest ecosystems

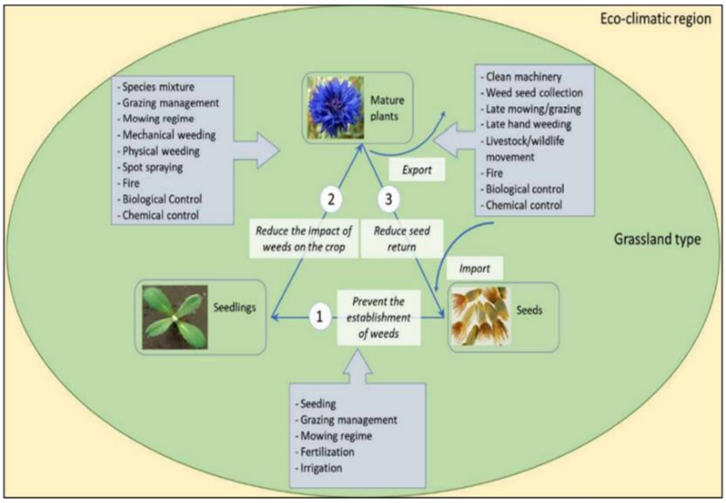
- Loss of native biodiversity
- Contributing to erosion of soil
- Adversely impacting the regeneration of forests
- Harboring vectors that carry infectious diseases
- Promoting fire hazard

The optimum locations for weed flora that is both floristically varied and rich are forest seedlings and plantations. Because they produce a large number of seeds that allow for rapid expansion, weeds have a remarkable capacity for adjusting to their surroundings. When considering weed control attributes, perennial weeds present are far greater challenge due to difficulties employing mechanical means, because perennials are often stimulated to grow and disperse even more intensively. With well-developed subsurface organs, perennial weed species including *Sorghum halepense*, *Convolvulus arvensis*, and *Cynodon dactylon* pose serious issues not only for agriculture but also for the development of nursery-grown forest planting materials. As more focus has been placed on establishing and restoring forests in recent years, the issue of forestry weeds has come to light. Young seedlings' survival and development in wooded regions may be endangered by the luxuriant growth of weed plants. The negative consequences of weeds are manifested not only in the removal of essential living circumstances such moisture, light and nutrients but also in the poor development and receipt of seedlings.

II. Weed management in grasslands

According to Veldman *et al.* (2015), grasslands are habitats in which graminoids, forbs, and shrubs create a generally continuous layer of herbaceous vegetation which can cover some 40% of the Earth's land surface, extending over large areas on all continents except Antarctica.

Regional differences in the evolution of grasslands, the species that inhabit them and the difficulties associated with managing them sustainably for both productivity and conservation are significant (Olson *et al.*, 2001). Globally in different parts, such as in North America, Central Asia and Sub-Saharan Africa, primary grasslands dominate. Similar "old-growth" grasses are frequently found in areas where shallow soils, a lack of available soil moisture, low temperatures, frequent fires or herbivorous animals by big grazers restrict the establishment of trees (Veldman *et al.*, 2015). While Eastern European steppes are considered to be a climax vegetation, large parts of temperate grasslands in western and central Europe are associated with human activity, and their origin and maintenance are mostly linked to forest clearing and subsequent management such as mowing, grazing by domestic livestock or fire. Due to their anthropogenic origin, these grasslands are called secondary grasslands (Bredenkamp *et al.*, 2002)



University of Fribourg, Switzerland | Kudsk (2021)

Fig. 1: Framework for integrated weed management (IWM) in grasslands

1) Limit the development of seedlings in grasslands from the earth's seed bank or underground vegetative organs,
2) Limit competition due to the supplies like nutrients, light and water by removing weeds or reducing their competitive impact, and/or
3) Limit return of seeds or vegetative organs to the soil seed/vegetative organ bank or their export to or input from other grasslands. Suitable tools may depend on grassland type and ecoclimatic region (adapted from Kudsk *et al.*, 2021).

III. Weed management in airports

The major function of grass in airports is to minimize wind and water erosion and to reduce dust, which is an essential thing to keep in mind while managing plants in airports. To handle problematic plants at the airport, the airport manager should have some familiarity with plants, weed-control techniques, and the appropriate application of herbicides. This chapter will cover a variety of topics related to controlling vegetation in an airport, including the many airport locations that require weed management, the safety measures required when using herbicides, information on problem weeds and their recommended treatments and more.

The two main elements that influence the choosing of any grass are temperature and rainfall. Any of the species advised for non-irrigated sites may be swapped out for one that is suited to more humid climates as long as it belongs to the right temperature range.

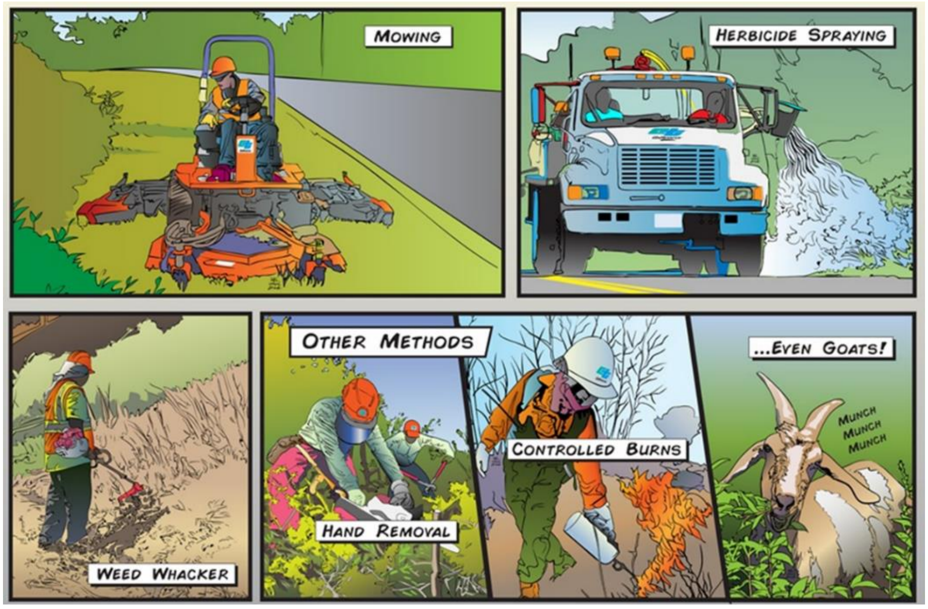
In order to get an acceptable foundation turf-one that will safeguard the soil and be free of eroded or dead spots-if you plant a turf from seed on a new airport or on a new building site, at least two growing seasons must pass after the original sowing. Additionally, freshly graded areas will be very prone to erosion until the turf has a good foundation. All of Louisiana is home to Bermuda grass, an aggressive warm-season grass. It may grow through asphalt surface or encroach from the outside. Johnson grass is an energetic, aggressive weed that spreads by seeds and by growing longer roots. The following are some suggested Johnson grass controls.

IV. Weed management in roadsides

Weeds spread by many pathways, each with a different level of risk. The highest risk is from pathways along which many seeds can disperse long distances to sites where they are likely to germinate, establish, reproduce and spread. Transport corridors and hubs, including roads, railways, ports and airports, are among the most important pathways for weed introduction and spread in across the countries. Vehicles of all kinds often carry mud and soil on their chassis, wheels and especially under the mudguards. This has been shown to carry large numbers of viable seeds. Earthmoving and agricultural machinery can carry large amounts of mud, soil and compacted plant material. Seeds can also be carried within loads of hay, produce or livestock on trucks, where they are difficult to detect.

Roadsides are high risk pathways because they usually have:

- Traffic that can carry soil, seeds, and other plant material long distances
- Frequent disturbances that may help weeds establish and grow
- Additional water from run-off that helps weeds germinate, grow and reproduce
- Little or no grazing pressure
- Less intensive weed control than the adjoining land
- Weed populations that are difficult to detect



V. Weed management in aquatic ecosystems

Aquatic plants are essential parts of natural aquatic systems and form the basis of a water body's health and productivity. Aquatic vegetation will always overproduce or grow unattractive and need to be controlled (Whetstone, 2005). According to Lancar and Krake (2002), aquatic weeds are unchecked plants that thrive and complete their life cycle in the water while also posing a direct threat to the aquatic ecosystem.

Major aquatic weeds of the world

Scientific name	Common name	Scientific name	Common name
Eichhornia crassipes	Water hyacinth	*Alternanthera philoxeroides*	Alligator weed
Typha spp.	Cattail	*Mollugo verticillata*	Carpet weed
Ipomoea carnea	Besharam	*Sagittaria spp.*	Arrow head
Hydrilla verticillata	Hydrilla	*Potamogeton spp.*	Pond weed
Salvinia spp.	Water fern	*Pistia stratiotes*	Water lettuce

Gupta *et al.* (2013)

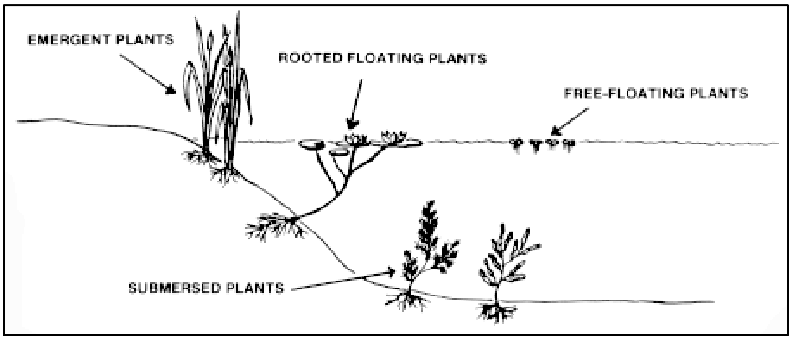
Classification of aquatic weeds/ aquatic weed identification

The first step in controlling aquatic weeds is identifying them. The majority of weed management techniques target particular weeds or groups of weeds with comparable development patterns. Algae and flowering plants are the two botanical categories under which aquatic weeds fall. Algae often have a fairly straightforward structure without any visible leaves or stalks. Some, like Chara, can, however, resemble flowering plants. It's crucial to distinguish between algae and blooming plants for efficient chemical management. Aquatic weeds are categorized in accordance with the many habitats that make up their eco-environment and facilitate their development, reproduction and spread.

i. Algae

a. The scums and/or green or yellow-green color of the water are caused by **microscopic algae**. "Blooms"-red, black, or greasy streaks-can occasionally be seen in the water as a result of them. Blooms often happen when a lot of nutrients are getting into the water. They should be chemically treated before them because these algae, which have a distinct color but suddenly die off, can result in fish kills. The floating, mat-like growths of filamentous algae, often known as moss, typically appear along the margins and bottom of ponds in the beginning of spring.

b. Stonewort, also known as **chara**, typically develops in extremely hard water and is brittle and calcified. The plant is rooted, and whorls of leaves are positioned along the stem. It smells musty and grows entirely underwater. Once developed and covered in a thick layer of calcium carbonate, chara can be challenging to manage. When the plants are young and not severely calcified, use contact herbicides. This plant looks like certain blooming plants, but it's actually an alga.



ii. Flowering weeds

a. Emergent weeds

These weeds thrive in areas with shallow waters and those that are close to bodies of water that experience seasonal water changes or regular discharges from larger bodies of water or reservoirs. Most of these circumstances are of a permanent character, with constant low and high water levels. These circumstances include canal and river banks, the edges of bodies of water that are primarily contained in earthen dams and partially in masonry dams, drainage channels and water ponds close to villages. Although these weeds are semi-aquatic, their proper name is emergent aquatic weeds.

b. Floating weeds

These are types of plants that develop throughout their whole life cycle in water. They can be as little as single cells (algae) or as vast as vascular plants. Most water bodies produce seeds and other vegetative reproductive organs on base ground areas in the event of dryness. vast, deep and shallow bodies of water, deep continually running canals, continuously flowing rivers, vast ponds, tanks, etc. all have these weeds growing on the surface. Some of the weeds in this environment may float freely and travel great distances, while others can float on the top of the water yet attach to the earth underneath the body of water. Along with obstructing water flow, both of these species of weeds cause evapotranspiration, which results in water loss. As a result, these weeds may be divided into two subgroups: (1) Free-Floating Weeds and (2) Rooted-Floating Weeds.

c. Submerged weeds

This group of plant species that produces offspring, grows and germinates below the water's surface. The dirt at the bottom of the body of water still contains its roots and reproductive organs. Since they are not apparent on the surface and obstruct the flow of water to varying degrees depending on their intensity and development, these unwanted plants cause the most damage. The majority of these weeds may be found in continuous-flowing canals, drainage ditches and shallow to medium-depth water bodies. The ecosystem provides situations which allows the growth of algae, filamentous algae, higher algae in shallow water situations and under deep water situations and consequently, completely submerged weeds could also be classified as

i. Shallow water submerged weeds, and

ii. Deep water submerged weeds.

Damages caused by aquatic weeds

Aquatic weeds are unchecked plants that develop and finish their life cycle in water, harming the aquatic environment directly as well as more generally the connected ecosystem. Water is one of the most valuable natural resources and the foundation of all life on Earth. In order to maintain the typical functioning of life, proper O_2 management of water is required from the point of origin to the point of use. It is a crucial element of the management of natural resources. Excessive aquatic vegetation affects how water is managed in man-made canals, reservoirs and natural waterways, which total millions of square kilometres or km throughout the world.

Aquatic weeds can take up a lot of the nutrients in the water, making them less available for planktonic algae. Additionally, they might lower oxygen levels and present gaseous exchange with water, which would negatively affect fish production. Although excessive weed growth may offer small fish in the water a protective cover for growth, it may also hinder fish harvesting. A dense population of aquatic weeds may serve as the perfect breeding ground for mosquitoes that transmit malaria and encephalitis filariasis. The visual value of water bodies from a recreational standpoint can be significantly diminished by these weeds, which may also act as carriers of pathogens. Aquatic weeds have been discovered to significantly lower the flow capacity of irrigation canals, lowering the amount of water available to farmers. Aquatic weeds can also harm turbines and pumps in hydroelectric and super thermal energy facilities, reducing the amount of electricity produced and raising the cost of power plant maintenance. Since they may momentarily help to reduce agricultural, local and industrial emissions, many aquatic plants are desirable.

Management of aquatic weeds

Given the losses brought on by aquatic weeds, controlling them is crucial to enhancing the flow of water from the source to its final users. This raises both availability and transportation effectiveness. Water storage and delivery systems, upkeep of canals, drains, barrages, lakes, ponds and other irrigation-related infrastructure are all hampered by aquatic weeds that thrive in the favourable conditions created by irrigation and drainage systems. These systems frequently become overgrown and pollute the environment. Soil salinity and alkalinity issues can occur around irrigation and drainage canals as well as low-lying places. Two strategies are used to manage aquatic weeds: preventative measures and infestation management.

Preventive approaches

The plant life of underwater weeds and their intensity affect the harm that they do. The habitat and the type of aquatic weed flora influences the technique of weed control. Weed "management" in a broader meaning refers to controlling weeds at a level where they do not cause financial harm. Diverse techniques can be used to control aquatic weeds to manageable levels. These techniques may be broadly divided into four groups:

(I) Mechanical or physical techniques

(II) Biological methods

(III) Chemical methods and

(IV) Cultural and physiological methods

There is rarely a situation when weeds can be ‘eradicated’ but often can be ‘prevented’ from infesting other areas. Prevention can be useful for a certain weed species or may include a group of aquatic weeds in a given aquatic environment. Once prevention fails the next step is to eradicate it, i.e., treating them in a way that they do not emerge again.

Legislative mechanisms like quarantines can be used to lessen the impact of weeds. In order to prevent or control the propagation or spread of a pest, authorities that have been duly constituted may impose restrictions on the production, movement or existence of plants, plant products, animals, animal products, other articles or materials, or normal human activity.

Quarantine is required if a pest has already been introduced and established in a limited region in order to manage, remove or stop its spread to fresh areas, hence minimizing losses that might otherwise result from damage caused by insects (Sand, 1987).

Control of existing infestation

a. Physical or mechanical methods

i). Manual cleaning: The first technique for controlling aquatic weeds is manual cleaning. Weeds can be manually pulled in regions that are just lightly infected. With or without the help of basic tools, this approach uses human work. Typically, this method is used to remove emergent weeds like *Typha* spp., *Phragmites* spp., and *Justicia* spp. (Willow), where men use powerful knives and hooks to remove the vegetative growth. The propagules, rhizomes, and other subsurface reproductive organs can be cut out in shallow water. The marginal and emergent weeds are pulled out by hand, or they can be controlled by continuously chopping off their floating leaves.

ii). Hand operated tool: It is manual control of weeds with hands by using heavy knives and hooks. Possible in small, lightly infested areas willows and some marginal weeds are slashed and burnt with other weeds

iii). Cutting: With the use of large knives or motorized weed eaters, the biomass is physically chopped above and beneath the water using this technique. It has been discovered that typha can be controlled if plants are cut underwater and left submerged for more than a week to 10 days. This may also apply to *Phragmites* species. Additionally, water hyacinth, *Chara* spp., filamentous algae, and *Potamogeton* spp. mechanically cutting will provide a brief respite from weed infestations.

iv). Water weed cutters and harvesters: In high discharge canals and very large water bodies weed cutters/ harvesters are used to control rooted submerged weeds.

v). Under water cutters: The aforementioned are typically fastened to a boat with a motor. Robust and precise cutter bars with hefty reciprocating blades slide against a fixed cutting edge in the apparatus.

vi). Harvesters: a machine that alternately cuts and removes weeds from water bodies and transports them to the coast.

vii). Chaining: Weeds are broken off by the chain as it drags over surfaces.

- It is most effective for submerged aquatics
- It cannot be done near the structure
- It will not eradicate weed growth above water
- Both the banks must be accessible

The chain rips the weeds up by the roots and loosens them. Where weeds that are emergent and submerged are prevalent, this method has been found to be effective. When weed growth has yet to reach 30 to 50 cm or more above the water, chaining should be used. If the practice is successful, it should be performed frequently for good weed control. The requirement that ditches be regular in width, tractor-accessible from all sides, and clear of trees and other such impediments is one of the methods restrictions. To prevent infection by plant propagules farther downstream, the detritus so gathered at the end should be removed.

Chaining involves dragging a large iron drag chain along a medium canal or ditch that is heavily overgrown with weeds. The chain is attached between two tractors. The chains rip the weeds up by the roots and loosen them. Where weeds that are emergent and submerged are prevalent, this method has been found to be effective. When weed new shoots are about 30 to 50 cm above the water's surface, chaining should be used.

viii). Dredging: Most common way of cleaning from weeds in drains and ditches.

Among the methods for removing the weed plants and extra silt is dredging. A machine having a forked bucket that can be opened and closed at will is called a dredger. The device may be operated from a boat on water or from the land. Large water bodies, canals, and sewers all undergo dredging. It is a labour-intensive, expensive, and tedious process. If the region surrounding them is being farmed or is surrounded by erodible soils with inadequate afforestation, small lakes, water reservoirs, etc. get silted. *Typha*, *Scirpus* spp., and other emerging weeds take hold as a result of poorer water retention brought on by silt deposition at the bottom. In such a case, dredging equipment is required to remove silt and raise lakes' water levels. Additionally, this lessens the issue of emergent weeds.

b. Cultural methods

Pond dyes and light management: The photosynthetic mechanism, which is vital for the establishment and development of plants that grow in water, particularly submerged aquatic weeds, depends on light. By decreasing light penetration, submerged aquatic plant growth in small tanks and ponds may be controlled. Fibreglass screens are often used in several nations.

Water drawdown /water level manipulation: Underwater weeds may be managed easily and successfully with this technique. The majority of aquatic weeds react to changes in water level fast. Dehydration of the plant or exposure to cold temperatures are two methods for controlling it. It is common practice to regularly drain the water from tanks, fish ponds and canals to remove weeds that are prone to desiccation.

Booms and barrier: Floating Garbage Booms are used to keep aquatic vegetation and debris out of rivers. Once in place, the boom restricts the movement of floating weeds and plants in an aquatic system by forming a barrier that they can't pass through. This reduces the spread of waste and floating freely aquatic vegetation and plants.

Checking weeds through irrigation water: Aquatic weed seeds including *Eichhornia crassipes*, *Pistia stratiotes*, and *Salvinia molesta* are frequently carried by irrigation water. To stop them from dispersing seeds into water bodies, weeds must be kept under control around, in, and around reservoirs and canals for irrigation. Screens can be used to gather weed seeds and remove them from the source of supply.

c. Chemical control

Underwater plant managers frequently utilize chemical management through the use of licensed aquatic herbicides and algaecides in both privately owned and publicly owned water bodies across the world. Since long time, many herbicides have been tested in many countries to control hyacinth and many other water weeds. No one chemical has been developed so far which would control all aquatic weeds. So, it is essential to know the weed species, appropriate herbicide and their rate and time of treatment. Many countries of Europe and UK are keeping extremely vigilant control on the use of herbicides. In developed countries, herbicides have been exclusively registered for control of several of unwanted water plants mentioning water use after days of spray of herbicides. In India, herbicides yet to be registered exclusively for aquatic weed control, nevertheless, these helped in control of different types of aquatic vegetation. For usage in various aquatic habitats, an herbicide should meet specified requirements.

- It should have a high level of phytotoxicity to quickly eradicate weeds.

- The herbicide should cease acting on weeds and rapidly disintegrate or evaporate from the liquid.
- They should have access to technology for usage in static or flowing water systems.
- It ought to be protected against environmental harm to people, fish, and other aquatic life. Many weed killers are safe for fish to consume at the levels necessary to control weeds.

Conclusion:

Weeds invading non-cropped areas decrease the aesthetic value of the surrounding environment and impede the movement of aero planes, trains, boats, *etc*. that are coming in their way. Weeds present along the roadsides block traffic signals and harbour pests and diseases. Hence, they need to be brought under quarantine to restrict the movement of weeds through airports, railways, *etc*. Biological, chemical and physical strategies can all be used to manage aquatic weeds. Weeds that grow in waters can be contained or prevented from spreading using a number of common management methods.

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MARKETING AGRICULTURAL PRODUCE THROUGH AGRICULTURAL MARKET COMMITTEES FOR SUSTAINABLE GROWTH AND FARMER-CONSUMER CONNECTIVITY

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Abstract:

Marketing agricultural produce is a critical aspect of ensuring sustainable growth and establishing strong connections between farmers and consumers. Agricultural Market Committees (AMCs) play a pivotal role in this process by providing a platform for farmers to sell their produce and buyers to purchase agricultural commodities. Through their efforts, AMCs contribute to fair trade practices, transparent transactions, and price discovery mechanisms. They also prioritize the development of market infrastructure and enforce quality standards for agricultural commodities. By disseminating market information and facilitating licensing and registrations, AMCs empower farmers to make informed decisions and strengthen the farmer-consumer relationship. Emphasizing the significance of AMCs in marketing agricultural produce is vital for fostering sustainable growth, enhancing farmer-consumer connectivity, and promoting the overall well-being of farming communities.

Keywords: Marketing, Agricultural Produce, Agricultural Market Committees, Sustainable Growth, Farmer-Consumer Connectivity, relationship fair trade practices, transparent transactions, price discovery, market infrastructure, quality standards, market information, licensing

Introduction:

The marketing of agricultural produce is a critical component of the agricultural industry, playing a pivotal role in connecting farmers with consumers and ensuring sustainable growth. Agricultural Market Committees (AMCs) or Agricultural Produce Market Committees (APMCs) are regulatory bodies established to govern and regulate the functioning of agricultural markets. These committees act as intermediaries, facilitating fair and transparent trade practices in the buying and selling of agricultural commodities. They provide a platform for farmers to sell their produce and buyers to purchase agricultural commodities, contributing to the overall development and success of the agricultural market.

The primary objective of AMCs is to ensure a smooth and organized flow of agricultural commodities from farmers to buyers. By establishing rules, guidelines, and procedures, AMCs create a marketplace that fosters fair trade practices and prevents the exploitation of farmers. These committees oversee market operations, including price discovery, infrastructure development, quality control, and licensing and registration of market participants.

Price discovery is a vital function performed by AMCs. They provide a platform where buyers and sellers can participate in open auctions or negotiate prices for agricultural commodities. Transparent price discovery mechanisms ensure that farmers receive fair prices for their produce, reflecting market demand and supply dynamics. This enables farmers to achieve reasonable returns for their efforts while allowing buyers to access quality agricultural products at competitive prices.

AMCs also play a significant role in enforcing quality standards and grading parameters for agricultural commodities. By maintaining quality control, AMCs ensure that buyers receive products of the desired quality and prevent the market from being flooded with substandard produce. Market committees may conduct inspections, quality tests, and certification processes to maintain market integrity and build trust among buyers.

Licensing and registration processes conducted by AMCs are essential for regulating market participants. Traders, commission agents, and other market participants need to obtain licenses and registrations from AMCs to engage in agricultural trade. This helps verify the credibility of market participants and enables the committees to regulate their activities effectively. By ensuring compliance with relevant regulations, AMCs contribute to the maintenance of fair trade practices and market transparency.

Furthermore, AMCs serve as repositories of market-related information. They collect and disseminate data on prices, arrivals, market trends, and other relevant information to farmers, traders, policymakers, and other stakeholders. This information helps market participants make informed decisions regarding their production, marketing strategies, and market timing. It empowers farmers to optimize their production based on market demand and enables policymakers to formulate appropriate agricultural marketing policies.

In addition to their regulatory functions, AMCs facilitate the development of a strong farmer-consumer relationship. By establishing channels of direct communication, such as farmers' markets, community-supported agriculture programs, or online platforms, AMCs enable farmers to connect directly with consumers. This fosters trust, loyalty, and awareness about agricultural produce, promoting a mutually beneficial relationship between farmers and consumers.

Agricultural Market Committees

Agricultural Market Committees (AMCs), also known as Agricultural Produce Market Committees (APMCs), are regulatory bodies established across India to govern and regulate the functioning of agricultural markets. These committees play a crucial role in facilitating fair and transparent trade practices in the buying and selling of agricultural produce.

The primary objective of Agricultural Market Committees is to ensure a smooth and organized flow of agricultural commodities from farmers to buyers. They act as intermediaries, providing a platform for farmers to sell their produce and buyers to purchase agricultural commodities. One of the key responsibilities of Agricultural Market Committees is to establish and enforce rules and guidelines for market operations. These regulations help maintain fair trade practices, prevent exploitation of farmers, and promote transparency in the agricultural market. Market committees often specify guidelines for pricing, quality control, grading, and weighing of agricultural commodities.

Price discovery is another vital function performed by Agricultural Market Committees. They provide a platform where buyers and sellers can participate in open auctions or other mechanisms to negotiate and determine prices for agricultural commodities. This transparent price discovery mechanism ensures that farmers receive fair prices for their produce and buyers have access to quality agricultural products.

To facilitate **Market Operations**, Agricultural Market Committees oversee the development and maintenance of market infrastructure. This includes market yards, auction platforms, storage facilities, and other amenities necessary for the smooth conduct of trade. By ensuring the availability of proper infrastructure, these committees contribute to efficient market operations and enable farmers to access a wide range of buyers.

Quality Control is another significant aspect managed by Agricultural Market Committees. They enforce quality standards and grading parameters for various agricultural commodities to ensure that buyers receive products of the desired quality. Market committees may conduct inspections, quality tests, and certification processes to maintain market integrity and build trust among buyers.

Licensing and registration of market participants are also within the purview of Agricultural Market Committees. Traders, commission agents, and other market participants need to obtain licenses and registrations from the committees to engage in agricultural trade. This process helps verify the credibility of market participants and enables the committees to regulate their activities effectively.

Furthermore, in certain situations, Agricultural Market Committees may play a role in providing price support to farmers and intervening in the market. This can be particularly important during times of market fluctuations or crises when farmers' interests need protection. Such interventions help stabilize prices, ensure farmers receive reasonable returns, and maintain a stable agricultural market.

It's important to note that while the overall framework and objectives of Agricultural Market Committees are similar across India, there may be slight variations in their functioning and specific regulations from state to state. These committees are established and governed by state-level legislation, and farmers and market participants are encouraged to familiarize themselves with the specific rules and procedures of their respective state's Agricultural Market Committee.

Agricultural produce

Agricultural produce refers to any type of crop, livestock, or other agricultural products that are grown, raised, or harvested from the land. It encompasses a wide range of items that are cultivated or produced through agricultural activities. Agricultural produce can be categorized into different types based on its nature and purpose. Here are some examples:

1. **Crops**: Agricultural produce includes various types of crops grown for food, feed, fiber, or industrial purposes. This can include staple food crops such as rice, wheat, maize, millets, and pulses. It also encompasses cash crops like cotton, sugarcane, oilseeds, tea, coffee, spices, fruits, and vegetables. These crops are cultivated on farms and play a vital role in providing sustenance, raw materials, and income for farmers and consumers.
2. **Livestock:** Livestock and their products are another form of agricultural produce. This category includes animals raised for meat, milk, eggs, wool, and other by-products. Common livestock includes cattle, poultry, sheep, goats, pigs, and fish. Livestock farming contributes to the production of animal-based food products, such as meat and dairy, which are important sources of protein and nutrients.
3. **Horticultural Products**: Horticultural produce comprises fruits, vegetables, flowers, and ornamental plants. These agricultural products are cultivated in orchards, vineyards, gardens, and nurseries. Horticulture plays a significant role in providing a diverse range of nutritious food options, beautifying landscapes, and generating income through floriculture and gardening industries.
4. **Forestry Products**: Agricultural produce also extends to products derived from forests and forestry activities. This includes timber, wood products, medicinal plants, gums, resins, and non-timber forest products (NTFPs) like bamboo, rattan, honey, and mushrooms. Forest-based agricultural produce supports industries related to timber processing, furniture manufacturing, herbal medicines, and ecological services.
5. **Aquaculture Products**: With the growing importance of aquaculture, agricultural produce encompasses fish, shrimp, and other aquatic organisms that are commercially cultivated in ponds, tanks, and marine environments. Aquaculture contributes to seafood production, addressing the global demand for fish and supporting the livelihoods of coastal communities.

Agricultural produce is the outcome of farmers' efforts, who engage in various farming practices, including cultivation, breeding, raising livestock, and harvesting. These products are crucial for food security, economic development, and the overall well-being of societies. They form the foundation of agricultural markets, trade, and contribute significantly to the world's food supply.

The needs of agricultural marketing

Marketing serves several important needs in the agricultural sector. Here is an explanation of the needs of marketing:

One key need fulfilled by marketing is product promotion. Agricultural products need to be made known and accessible to consumers. Marketing creates awareness by informing potential buyers about the availability, quality, and benefits of different agricultural products. Through effective marketing campaigns, consumers become acquainted with specific products and develop an interest in purchasing them.

Another essential need addressed by marketing is market research and analysis. It helps identify consumer preferences, market trends, and demand patterns. By gathering and analyzing data, farmers and marketers gain insights into the needs and preferences of their target audience. This information enables them to make informed decisions regarding production, pricing, packaging, and distribution strategies.

Marketing also facilitates market access for farmers. It provides a means to reach potential buyers and establish distribution channels. Farmers can utilize various marketing channels such as wholesalers, retailers, direct sales, and online platforms to make their products available to consumers. Effective marketing ensures that agricultural products are easily accessible to the intended market, increasing sales opportunities and revenue for farmers.

In addition, marketing contributes to market stability. By matching supply with demand, marketing helps balance the market and prevent price fluctuations. It ensures a steady flow of agricultural products to meet consumer needs while minimizing wastage due to oversupply or shortage. Market stability benefits both producers and consumers by providing a reliable marketplace for agricultural transactions.

Marketing supports the development of strong relationships between farmers and consumers. Through branding, advertising, and direct interactions, marketing helps establish trust and loyalty between producers and their customers. This fosters long-term relationships and encourages repeat purchases, benefiting farmers with a loyal customer base and ensuring a stable market for their products.

Marketing agricultural produce

Marketing agricultural produce involves various methods and strategies to efficiently sell and distribute agricultural products from farmers to consumers or other market participants. Here are some common methods of marketing agricultural produce:

- **Direct sales**: Farmers can engage in direct sales by selling their agricultural produce directly to consumers, local markets, restaurants, or community-supported agriculture (CSA) programs. This method eliminates intermediaries and allows farmers to establish direct connections with consumers, providing them with fresher products and higher profit margins.

- **Wholesale markets**: Wholesale markets act as intermediaries between farmers and retailers or large-scale buyers. Farmers can bring their agricultural produce to these markets where wholesalers purchase in bulk and distribute the products to retailers or other buyers. Wholesale markets provide a centralized location for buyers to access a wide variety of agricultural produce from different farmers.
- **Cooperative marketing**: Farmers can form agricultural cooperatives or producer groups to collectively market their produce. By pooling resources and working together, farmers can negotiate better prices, access larger markets, and share marketing costs. Cooperative marketing enhances the bargaining power of farmers and promotes collective decision-making.
- **Auctions:** Auctions are commonly used in agricultural marketing, especially for perishable produce. Farmers bring their products to auction houses or specialized market yards where buyers bid on the products. The highest bidder wins, and the produce is sold at the determined price. Auctions promote price discovery and create a competitive environment that benefits both farmers and buyers.
- **Contract farming**: Contract farming involves farmers entering into agreements with buyers or processors to produce specific agricultural products. The buyer provides inputs, technical support, and a guaranteed market for the produce. This method provides farmers with stability, assured income, and access to better production practices. Contract farming is prevalent for crops like fruits, vegetables, and cash crops.
- **Online marketing platforms**: With the advent of e-commerce and digital platforms, farmers can now market their agricultural produce online. Online marketplaces connect farmers directly with consumers or buyers, eliminating geographical barriers. Farmers can showcase their products, set prices, and arrange for delivery through these platforms.
- **Export and international trade**: Agricultural produce can be marketed through export channels to reach international markets. Export-oriented marketing involves complying with export regulations, quality standards, and establishing trade relationships with importers in other countries. This method provides opportunities for farmers to access larger markets and obtain higher prices for their products.

It's important to note that the methods of marketing agricultural produce may vary based on factors such as the type of product, geographical location, infrastructure availability, and market demand. Farmers often employ a combination of these methods to effectively market their agricultural produce, considering their specific circumstances and target markets.

Strategies for effective agricultural produce marketing

Farmers employ various strategies to market their produce effectively and reach potential buyers. Here are some common methods farmers use to market their produce:

1. **Local farmers' markets**: Farmers' markets provide a direct platform for farmers to sell their produce to local consumers. Farmers set up stalls or booths at designated marketplaces where they can showcase and sell their fresh produce. This method allows farmers to interact directly with customers, build relationships, and educate them about their products.
2. **Community Supported Agriculture (CSA):** CSA programs involve farmers offering shares or subscriptions to consumers, who then receive regular deliveries or pickups of fresh produce

throughout the growing season. Farmers market their CSA programs to individuals or families who value locally grown and seasonal produce, fostering a direct connection between farmers and consumers.

3. **Farm stands and on-farm sales**: Some farmers set up on-farm stands or retail outlets where customers can visit the farm to purchase produce directly. This method provides a unique experience for consumers by allowing them to see the source of their food and establish a personal connection with the farmers.
4. **Online platforms and websites**: Farmers utilize online platforms and websites to market their produce to a wider audience. They can showcase their products, provide information about their farming practices, and facilitate online ordering and delivery options. Online marketing enables farmers to reach customers beyond their local area and expand their market reach.
5. **Restaurants and chefs:** Farmers establish relationships with local restaurants and chefs who prioritize using locally sourced ingredients. They market their produce directly to these establishments, supplying them with high-quality, fresh ingredients. Collaborating with restaurants can create a steady demand and provide a higher value for farmers' produce.
6. **Wholesale buyers and distributors**: Farmers may sell their produce to wholesalers or distributors who supply retail stores, supermarkets, and institutions. Establishing relationships with reliable wholesale buyers allows farmers to sell their products in larger quantities and reach a wider customer base.
7. **Agri-tourism and farm events:** Some farmers engage in agri-tourism activities, such as hosting farm tours, workshops, or events on their farm. These activities attract visitors who can purchase the farm's produce while enjoying the farm experience. Agri-tourism helps farmers market their produce directly to consumers who appreciate the farm-to-table concept.

Each marketing method offers unique advantages, and farmers often employ a combination of strategies based on their target market, product type, and local demand. By effectively promoting their produce through various channels, farmers can increase visibility, build customer relationships, and maximize their sales opportunities.

Factors influencing pricing of agricultural produce commodities

When it comes to pricing fast-moving commodities through marketing, several factors come into play. Analyzing the pricing of fast commodities involves considering various elements that influence pricing dynamics. Here are some key factors to analyze:

- **Supply and demand:** The fundamental principle of supply and demand greatly impacts pricing. When the demand for fast commodities exceeds the available supply, prices tend to rise. Conversely, when supply exceeds demand, prices may decrease. Market fluctuations, seasonal variations, and changes in consumer preferences can all affect the balance between supply and demand.
- **Production costs**: The cost of production plays a significant role in determining the pricing of fast commodities. This includes expenses related to inputs such as seeds, fertilizers, labor, machinery, and transportation. Farmers and producers consider these costs when determining the selling price of their commodities, aiming to cover their expenses and achieve a reasonable profit margin.

- **Market competition**: Competition within the market affects pricing strategies. When multiple suppliers offer similar fast commodities, they may engage in price competition to attract customers. Competitive pricing can lead to lower prices as producers strive to gain a larger market share. Conversely, limited competition may result in higher prices if suppliers have greater control over the market.
- **Quality and value**: The quality and value of fast commodities play a crucial role in pricing. Consumers are willing to pay more for commodities that offer superior quality, freshness, taste, nutritional value, or unique characteristics.

The pricing of fast-moving commodities through marketing involves a dynamic process influenced by several factors. Market demand and supply play a significant role in determining the prices of fast-moving commodities. When demand exceeds supply, prices tend to increase, whereas surplus supply can lead to price reductions. Additionally, factors like seasonality, weather conditions, production costs, transportation costs, and market competition also impact pricing.

Marketing channels and intermediaries further influence the pricing of fast commodities. Wholesalers, retailers, and distributors add their margins to the cost of the commodities, which ultimately affects the final retail price. The pricing strategy employed by market participants, such as discounts, promotions, or bundling, also plays a role in influencing consumer behavior and demand.

Market transparency and information dissemination are crucial in ensuring fair pricing. Transparent markets provide accurate and timely information on prices, allowing buyers and sellers to make informed decisions. Efforts to enhance market transparency, such as price reporting systems and digital platforms, contribute to fair pricing and facilitate efficient market operations. Government policies and interventions also impact the pricing of fast commodities. Price stabilization measures, subsidies, import/export regulations, and taxation policies can influence the final prices that consumers pay for these commodities. Governments may intervene to prevent price volatility, ensure fair competition, and protect the interests of consumers and producers.

The era of modern marketing

Modern marketing refers to the contemporary approach and strategies employed in promoting and selling products or services in today's digital and interconnected world. It encompasses the use of advanced technologies, data-driven insights, and innovative communication channels to effectively engage with target audiences. Modern marketing is characterized by its emphasis on personalized and interactive experiences, customer-centricity, and the integration of online and offline channels.

The key aspect of modern marketing is the utilization of digital platforms and tools. This includes leveraging social media platforms, websites, mobile applications, email marketing, search engine optimization (SEO), and online advertising to reach and engage with a wider audience. These digital channels provide opportunities for targeted marketing campaigns, real-time customer interactions, and data-driven decision-making.

Another important aspect of modern marketing is the focus on customer experience and personalization. Brands strive to understand their customers' preferences, behaviors, and needs through data analysis and customer segmentation. This enables them to tailor their marketing messages, offers, and experiences to individual customers, enhancing engagement and building long-term relationships.

Data analytics and marketing automation are integral components of modern marketing. By leveraging data analytics tools, marketers can gain valuable insights into consumer behavior, campaign performance, and market trends. This data-driven approach enables marketers to make informed decisions, optimize marketing strategies, and deliver personalized and relevant content to their target audience. Marketing automation tools streamline repetitive tasks, enhance efficiency, and enable personalized communication at scale.

Modern marketing also places a strong emphasis on storytelling and brand authenticity. Brands strive to create compelling narratives and emotional connections with their target audience. This involves communicating the brand's values, purpose, and unique selling propositions in a way that resonates with customers and differentiates it from competitors.

Exploring new technologies in marketing for business growth

New technologies have revolutionized the field of marketing, offering innovative tools and approaches to engage with customers and drive business growth. Here are some brief explanations of new technologies in marketing:

- **Artificial Intelligence (AI):** AI technologies enable marketers to automate processes, analyze vast amounts of data, and deliver personalized experiences. Chatbots, for example, can provide instant customer support, while AI-powered analytics tools can extract valuable insights to inform marketing strategies and campaigns.
- **Augmented Reality (AR) and Virtual Reality (VR):** AR and VR technologies create immersive experiences for customers. Marketers can use AR to overlay digital information on real-world environments, allowing customers to visualize products or try them virtually. VR, on the other hand, provides simulated environments that enable customers to have interactive and immersive experiences.
- **Internet of Things (IoT):** IoT refers to the network of interconnected devices that collect and exchange data. Marketers can leverage IoT data to gain insights into customer behavior, personalize messaging, and deliver targeted offers. For example, IoT-enabled devices in smart homes can provide data on consumer preferences and usage patterns.
- **Voice search and smart assistants:** The rise of voice-activated devices and smart assistants, such as Amazon Alexa and Google Assistant, has created new opportunities for marketers. Optimizing content for voice search and developing voice-enabled experiences allow businesses to reach customers through voice-activated devices and capitalize on this growing trend.
- **Blockchain technology:** Blockchain technology offers secure and transparent transactions. In marketing, it can enhance trust and transparency in areas such as supply chain management, customer data protection, and digital advertising. Blockchain enables verifiable tracking of transactions and ensures the authenticity of information.
- **Data analytics and machine learning:** Advanced data analytics techniques, coupled with machine learning algorithms, enable marketers to extract actionable insights from

large datasets. These insights help in understanding customer behavior, predicting trends, optimizing campaigns, and personalizing experiences.

- **Social media and influencer marketing**: Social media platforms continue to be powerful marketing tools. Marketers leverage social media for targeted advertising, customer engagement, and influencer collaborations. Influencer marketing involves partnering with social media influencers to promote products or services to their followers, tapping into their influence and credibility.

Benefits of agri-price commodity market groups for farmers

Farmers can derive several benefits through agri-price commodity market groups. These groups, also known as agricultural commodity market groups or farmer producer organizations, are formed by farmers to collectively engage in the marketing of their agricultural produce. Here are some key benefits that farmers can gain through these market groups:

- **Enhanced bargaining power:** By coming together as a group, farmers can consolidate their produce and increase their bargaining power in the market. Agri-price commodity market groups enable farmers to negotiate better prices and terms with buyers, processors, and other market intermediaries. This helps farmers secure higher returns for their agricultural commodities and reduces the risk of exploitation.
- **Access to market information:** Agri-price commodity market groups provide farmers with access to timely and relevant market information. They disseminate information on prevailing market prices, demand trends, consumer preferences, and market dynamics. Armed with this information, farmers can make informed decisions regarding crop selection, production planning, and timing of sales. Such knowledge empowers farmers to optimize their production and marketing strategies.
- **Value addition and market diversification:** Market groups often facilitate value addition activities for farmers. They support initiatives such as processing, packaging, and branding of agricultural commodities. These value addition activities help farmers capture a larger share of the value chain and command higher prices for processed or value-added products. Additionally, market groups may explore new market opportunities and facilitate market diversification, enabling farmers to reach wider consumer bases and reduce dependency on a single market.
- **Access to finance and credit:** Agri-price commodity market groups can help farmers access finance and credit facilities. By pooling their resources and establishing collective credibility, these groups become more eligible for loans, credit facilities, and financial assistance. They can negotiate better terms with financial institutions and avail themselves of credit for pre-harvest expenses, working capital, or investment in infrastructure and technology.
- **Capacity building and training:** Market groups provide training and capacity-building programs to farmers. They offer workshops, seminars, and skill development sessions on various aspects of farming, post-harvest handling, quality management, and market linkages. Such training enhances farmers' knowledge and skills, equipping them to navigate the complexities of the agricultural market more effectively.

- **Reduced post-harvest losses:** Agri-price commodity market groups help farmers reduce post-harvest losses. They assist in the implementation of improved storage facilities, transport infrastructure, and handling practices. By ensuring proper post-harvest management, including grading, sorting, and packaging, these groups help farmers maintain the quality and value of their produce, resulting in reduced losses and better marketability.
- Collective Marketing and Branding: Market groups enable farmers to collectively market their produce under a common brand or label. This can enhance the visibility and market presence of their agricultural commodities. By leveraging collective marketing and branding efforts, farmers can differentiate their products, establish brand recognition, and create a competitive edge in the market.

The marketing committee plays a crucial role in communicating the benefits of organic farming and knowledge about traditional seeds to farmers. Here's how they facilitate the dissemination of information:

Workshops and training programs: The marketing committee organizes workshops and training programs specifically focused on organic farming and traditional seeds. These sessions involve experts, agricultural scientists, and experienced farmers who share their knowledge and experiences with farmers. They provide information on the benefits of organic farming practices, such as reduced reliance on chemical inputs, improved soil health, biodiversity conservation, and better market opportunities for organic produce. The committee also educates farmers about the advantages of using traditional seeds, including their adaptability, nutritional value, and cultural significance.

Demonstrations and field visits: The marketing committee arranges demonstrations and field visits to showcase successful organic farming practices and the use of traditional seeds. Farmers are given the opportunity to witness firsthand the positive outcomes of organic farming methods and observe the growth and quality of crops cultivated using traditional seeds. These practical experiences help farmers understand the benefits and encourage them to adopt these practices.

Information materials and publications: The marketing committee develops and distributes information materials to farmers, including brochures, pamphlets, manuals, and guidelines. These materials highlight the advantages of organic farming and provide details about traditional seeds, their characteristics, and their role in preserving biodiversity and cultural heritage. The committee ensures that the information is easily accessible and available in local languages for better understanding.

Farmer field schools: The marketing committee may establish farmer field schools where farmers gather regularly to learn and exchange knowledge about organic farming and traditional seeds. Trained facilitators guide farmers through practical exercises, discussions, and hands-on learning activities. These schools create a platform for farmers to learn from each other, share experiences, and collectively improve their understanding and skills related to organic farming and traditional seeds.

Collaborations and partnerships: The marketing committee collaborates with agricultural research institutions, organic farming associations, seed banks, and non-governmental organizations (NGOs) working in the field of organic agriculture and traditional seed conservation. Through these partnerships, the committee gains access to updated information, expertise, and resources, which they can then pass on to farmers. Joint awareness campaigns, knowledge-sharing events, and collaborative projects are organized to maximize the reach and impact of the information.

Digital platforms and information channels: To enhance communication and outreach, the marketing committee leverages digital platforms and information channels. They establish websites, social media accounts, and mobile applications to share information about organic farming practices and traditional seeds. These platforms provide updates, success stories, case studies, and relevant resources to farmers. Additionally, the committee may utilize SMS alerts, voice messages, or interactive voice response (IVR) systems to disseminate information to farmers who have limited access to the internet.

Farmer Meetings and Farmer Producer Organizations (FPOs): The marketing committee organizes farmer meetings and encourages the formation of Farmer Producer Organizations (FPOs) focused on organic farming and traditional seeds. These platforms provide opportunities for farmers to interact with experts, exchange knowledge, and collectively work towards promoting organic farming practices and preserving traditional seeds. The marketing committee actively supports and facilitates the activities of FPOs in disseminating information and creating awareness among farmers.

By employing these communication strategies, the marketing committee ensures that farmers are well-informed about the benefits of organic farming and have access to knowledge about traditional seeds. This empowers farmers to make informed decisions and adopt sustainable agricultural practices that contribute to their overall well-being and the conservation of agro-biodiversity.

In India, agricultural produce market groups operate under certain regulatory rules and guidelines to ensure market discipline and transparency. These regulations aim to protect the interests of farmers and promote fair practices in agricultural marketing. Here are some key regulatory rules and guidelines governing market discipline and market transparency in agricultural produce market groups in India:

The Agricultural Produce Market Committee (APMC) Act: The APMC Act is a state-level legislation that governs the functioning of agricultural produce markets in India. It provides a legal framework for market operations and establishes rules to maintain discipline and transparency. The Act mandates the establishment of market committees, which are responsible for regulating and overseeing market activities.

Licensing and Registration: Agricultural produce market groups operate under a licensing and registration system. All participants involved in market activities, such as traders, commission agents, and market functionaries, are required to obtain licenses or registrations from the market committee. This ensures that only authorized and qualified individuals engage in agricultural trade and transactions.

Market Fee and Charges: The APMC Act specifies the market fee and charges applicable to various transactions in the market. Market committees collect these fees to cover administrative expenses and infrastructure development. The rates and modes of collection are prescribed by the respective state governments. Transparent and standardized fee structures contribute to market discipline and ensure fair and equitable cost-sharing among market participants.

Market Regulations and Bye-laws: Market committees formulate and enforce market regulations and bye-laws to govern the conduct of market participants. These regulations cover aspects such as the quality standards for agricultural produce, grading and sorting procedures, dispute resolution mechanisms, and penalties for non-compliance. Market committees monitor and enforce these regulations to maintain market discipline and prevent unfair practices.

Price Discovery Mechanisms: Agricultural produce market groups employ price discovery mechanisms to determine the prices of agricultural commodities. The APMC Act encourages transparent and competitive price discovery through auction systems, open outcry, or electronic platforms. These mechanisms ensure that prices are determined through fair and open processes, promoting market transparency and reducing information asymmetry.

Market Information Systems: Market committees are responsible for establishing and maintaining market information systems. These systems provide timely and accurate information on market prices, arrivals, demand-supply trends, and other relevant market data. Market committees disseminate this information to market participants, including farmers, traders, and buyers, through notice boards, websites, SMS alerts, or mobile applications. Access to reliable market information enhances market transparency and enables farmers to make informed decisions.

Market Inspections and Monitoring: Market committees conduct regular inspections and monitoring of market activities to ensure compliance with regulations and maintain market integrity. They monitor the quality of agricultural produce, enforce grading and quality standards, and conduct checks on weighing scales and measurement devices. Inspections help prevent malpractices, unauthorized transactions, and the use of unfair weights or measures.

Dispute Resolution Mechanisms: The APMC Act provides for dispute resolution mechanisms to address conflicts or grievances arising in agricultural markets. Market committees set up committees or boards to resolve disputes related to trade, payment defaults, quality disputes, or any other market-related issues. These mechanisms ensure that conflicts are resolved in a fair and timely manner, promoting market discipline and trust among market participants.

It's important to note that specific rules and guidelines may vary across states in India, as the APMC Act allows states to modify and adapt regulations to suit their local conditions. Farmers and market participants should refer to the respective state's APMC Act and market committee regulations for detailed and up-to-date information on market discipline and transparency guidelines applicable in their region.

Methods for determining prices of agricultural produce in market committees

The method used by the marketing committee to determine the price of agricultural produce may vary depending on the specific market committee and the prevailing regulations. However, I can provide you with some general insights into the different methods commonly employed:

- **Auction system:** Auctions are a widely used method to determine the price of agricultural produce. In this method, buyers compete with each other by submitting bids for the desired quantity and quality of produce. The marketing committee facilitates the auction process, ensuring transparency and fairness. The highest bidder at the end of the auction is awarded the produce at the corresponding price.

- **Open outcry:** Open outcry is another traditional method used in some agricultural markets. In this method, buyers physically gather in a designated area, such as a trading hall or a specific spot within the market yard. The buyers openly announce their bid prices, and the process continues until a mutually acceptable price is reached between the buyer and the seller.
- **Electronic trading platforms:** With advancements in technology, many market committees have adopted electronic trading platforms to determine prices. These platforms enable remote participation and allow buyers to submit bids electronically. The marketing committee manages the platform, ensuring transparency and efficient price discovery.
- **Price information systems:** Some market committees rely on price information systems to determine the price of agricultural produce. These systems aggregate data on prevailing market prices, including historical trends, demand-supply dynamics, and other relevant factors. The marketing committee analyzes this information and sets the price based on market conditions.
- **Negotiation-based pricing:** In certain cases, especially for specialized or niche agricultural produce, the marketing committee may allow negotiation-based pricing. In this method, buyers and sellers directly negotiate the price based on factors such as quality, quantity, and specific market requirements. The marketing committee may provide guidance or oversight to ensure fair negotiations.

It's important to note that the choice of the method for determining prices depends on factors such as the nature of the produce, market dynamics, geographical location, and the preferences of market participants. The marketing committee's primary goal is to ensure a transparent and efficient price discovery process that benefits both farmers and buyers, while also maintaining market discipline and fairness.

Conclusion:

Agricultural Market Committees (AMCs) in India hold significant importance in the marketing of agricultural produce, promoting sustainable growth and fostering strong connections between farmers and consumers. AMCs serve as platforms for fair trade practices, transparent transactions, and efficient price discovery mechanisms, ensuring that farmers receive fair prices for their produce while providing buyers with access to high-quality agricultural commodities. The establishment and maintenance of market infrastructure by AMCs create a conducive environment for agricultural trade, facilitating seamless transactions and enhancing market efficiency. By enforcing stringent quality standards and grading parameters, AMCs ensure that buyers receive agricultural commodities of the desired quality, thereby safeguarding consumer interests and upholding the reputation of Indian agricultural produce. The licensing and registration processes implemented by AMCs contribute to market regulation and participant credibility, promoting compliance with market regulations and enhancing transparency. Through these efforts, AMCs empower farmers to make informed decisions, strengthen their relationship with consumers, and establish a direct and equitable exchange of agricultural commodities. By eliminating intermediaries and facilitating direct farmer-consumer interactions, AMCs play a crucial role in mitigating exploitation and ensuring that farmers receive reasonable returns for their efforts. The transparent price discovery mechanisms facilitated by AMCs contribute to market fairness, balancing the interests of both farmers and consumers. Overall, the role of AMCs in marketing agricultural produce in Tamil Nadu is pivotal in driving sustainable growth, fostering trust, and strengthening the agricultural sector by promoting fair practices, quality assurance, and effective farmer-consumer connectivity.

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MECHANISMS OF SILICON-INDUCED FUNGAL DISEASE RESISTANCE IN PLANTS

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Abstract:

Silicon (Si) is a bioactive element associated with beneficial effects on mechanical and physiological properties of plants. Silicon alleviates abiotic and biotic stresses, and increases the resistance of plants to pathogenic fungi. Several studies have suggested that Si activates plant defence mechanisms, yet the exact nature of the interaction between the element and biochemical pathways leading to resistance remains unclear. Silicon possesses unique biochemical properties that may explain its bioactivity as a regulator of plant defence mechanisms. It can act as a modulator influencing the timing and extent of plant defence responses in a manner reminiscent of the role of secondary messengers in induced systemic resistance; it can also bind to hydroxyl groups of proteins strategically involved in signal transduction; or it can interfere with cationic co-factors of enzymes influencing pathogenesis-related events. Silicon may therefore interact with several key components of plant stress signalling systems leading to induced resistance.

Keywords: Silicon, biotic, abiotic, defence mechanism, resistance

Introduction:

Silicon is the second most abundant element after oxygen in the earth crust. It is readily taken up by plants and often present in relatively high concentration of plant tissues. Si was initially not recognized as an essential element for higher plants, although it was known to be beneficial for plant growth and production. Its accumulation among plant species differs greatly, due to differences in root Si uptake capacity. Si uptake takes place through plant roots as silicic acid [Si (OH)4], an uncharged molecule, and passes through the plasma membrane via two Si transporters, Lsi1 and Lsi2, which function as influx transporters and efflux transporters. (Ma *et al*., 2002, 2006,). The beneficial effect of adequate Si includes decreased susceptibility to fungal pathogen and insects. It helps in decreasing abiotic stresses and increase growth in some plants. Silicon is deposited in the form of silicone gel of biogenetic opal as amorphous $nSiO_2$, nH_2O in cell walls and intercellular spaces of root and leaf cells as well as in bracts. Silicon also can be found in the form of monosilicic acid, colloidal silicic acid, or organosilicone compounds in plant tissues. Numerous studies show that Si accumulates in plants and exerts various beneficial effects for many plant species, especially gramineous plants such as rice and sugarcane and some cyperaceous plants (Zavala *et. al*., 2017).

Silicon (Si) acts as a beneficial element for plant growth and provides protection against abiotic and biotic stresses. Despite numerous reports on the beneficial role of Si in enhancing plant resistance to fungal pathogens, the underlying mechanisms remain largely unclear. Silicon shows antifungal activity; however, Si-induced improved disease resistance is partly manifested by the formation of Si polymerized mechanical obstruction under the cuticle and in cell walls, which prevents fungal ingress. Moreover, rapid production of defense compounds through secondary metabolic pathways is thought to be a key mechanism of Si-induced chemical defense against fungal pathogens beyond the physical barrier. Besides, improved mineral nutrition assures the healthy status of Si-supplied plants and a healthy plant exhibits better photosynthetic potential, antioxidant capacity and disease resistance. Multiple plant hormones and their crosstalk mediate the Si-induced basal as well as induced resistance; nonetheless, how root uptake of Si systemically modulates resistance to foliar diseases in low Si accumulating plants, needs in-depth investigation. Despite a long history of Si in controlling fungal diseases in many plant-pathogen systems, the accurate biological mechanisms of potential interaction between this quasi-essential element and different biochemical pathways that lead to plant resistance to fungal pathogens still remain unclear. It is believed that the general mechanism of Si-induced enhanced defense may be common in most plant species, which involves the expression of downstream defense-related. Silicon-induced enhanced resistance to pathogens is manifested by a delayed incubation period, reduced colony size, decreased lesion size and number, and suppressed inoculum production of fungi. Initially, it was proposed that mechanical barriers due to insoluble silica deposition below the leaf cuticle inhibit penetration of pathogenic fungi (Debona *et al*., 2017). However, later it was revealed that the physical barrier is just a tiny facet of the Si-induced defense mechanism as this highly bioactive quasi element can rapidly and more extensively trigger plant natural defense responses. Moreover, Si-induced defense responses are mediated by participation and/or coordination of multiple hormones, especially three classical defense hormones, salicylic acid (SA), jasmonic acid (JA) and ethylene (ET) (Wang *et al*., 2017). Besides, balanced mineral nutrition in Si-supplied plants improves plant health status and enhances disease resistance (Etesami and Jeong, 2018).

History

- **Lsenosuke Onodera**, Japanese plant nutrient chemist the first researcher who suggested that Si was involved in rice resistance to blast.
- **Onodera**, published a milestone paper entitled ‘Chemical studies on rice blast disease. This is the first report on Si research published in a scientific journal of agronomy.
- **Hayashi, Miyake and lkeda** also showed that the application of Si increased resistance to blast as well as increased silica content of rice.
- **Kawashima** first demonstrated under controlled conditions that application of Si to rice plants increased resistance to blast as well as increased Si content in rice.

Hypotheses for silicon-enhanced resistance to fungal diseases

Two hypotheses-

1. The first one (physical defense) is associated with the higher deposit of silicon in the leaf so as to form physical barrier to impede pathogen penetration.
2. The second one (biochemical defense) is related to its biologically active role in the expression of natural defense mechanisms. (Francois *et al*., 2005).

Silicon and plants

1. **Absorption of silicon by plants**
2. **Agronomic importance of silicon in plant crops**
3. **Accumulation of silicon in plant species**

1. Absorption of silicon by plants

Silicon is taken up by plant roots as non-charged monosilicic acid, when pH of the soil solution is below 9. Monosilicic acid uptake is passive and largely determined by transpiration rate. It is deposited in cell walls, intercellular spaces and as a subcuticular layer outside the cells of leaves. Silicon accumulates in higher amounts in mature leaves than in young ones. Plants absorb a significant fraction of dissolved silicon that originates from litterfall decomposition i.e., phytolith dissolution. The concentration level of absorbed silicon in plants ranges from 0.1 to 10% dry weight, depending on the plant genotype.

2. Agronomic importance of silicon in plant crops

- Silicon is increase and enhance yield, growth and production of plants.
- Silicon reduces transpiration and enhances plant resistance to drought stress, salinity and metal toxicity, and increases enzyme activity.
- Most interesting, silicon protects plants against a multitude of stresses without the occurrence of resistance trade-off and growth and yield penalties.

3. Accumulation of silicon in plant species

Si accumulation in plants, mainly in the cell wall. Its upward movement, via apoplast, from the roots to the leaves, silicon polymerization occurs in the extracellular spaces, accumulating on the walls of the epidermal cells of leaves and xylem vessels. (Yaghoubi *et. al*., 2013). In the absence of abiotic and biotic stresses, silicon was believed to have a negligible effect on metabolism of healthy plants, which suggests its nonessential role. Agricultural point of view, silicon uptake in graminaceous plants, such as wheat, oat, rye, barley, sorghum, maize, and sugarcane, was much higher than its uptake in other plant species. One typical example was rice, which absorbed 150-300 kg Si/ha.

Silicon controls fungal plant pathogens

In plant species, the association between silicon and reduced severity of fungal diseases has been documented in several studies. Another interesting association is the seemingly stronger efficacy of silicon against biotrophic and hemi biotrophic pathogens (e.g., rice blast, powdery mildews) compared to necrotrophs**.** Adding silicon to plants as a fertilizer makes them more resistant to various pathogenic fungi (Mahlein *et. al*., 2012) Silicon has proved effective in controlling both soil- and air-borne fungal diseases in several plant crops.

Table 1: Some examples of fungal plant pathogens

Host plant	**Fungal pathogen**
Barley	*Alternaria spp.*
Wheat	*Septoria nodorum* *Erysiphe graminis* *Blumeria graminis* f. sp. *Tritici*
Rice	*Pyricularia oryzae* *Bipolaris oryza* *Magnaporthe grisea* *Rhizoctonia solani*
Corn	*Pythium aphanidermatum* *Fusarium graminearum* *Fusarium moniliforme*
Banana	*Mycospaerella fijiensis* *Fusarium oxysporum* f. sp. *cubense*
Pearl millet	*Sclerospora graminicola*
Arabidopsis	*Erysiphe cichoracearum*
Rose	*Diplocarpon rosae* *Podosphaera pannosa*
Common bean	*Colletotrichum lindemuthianum*

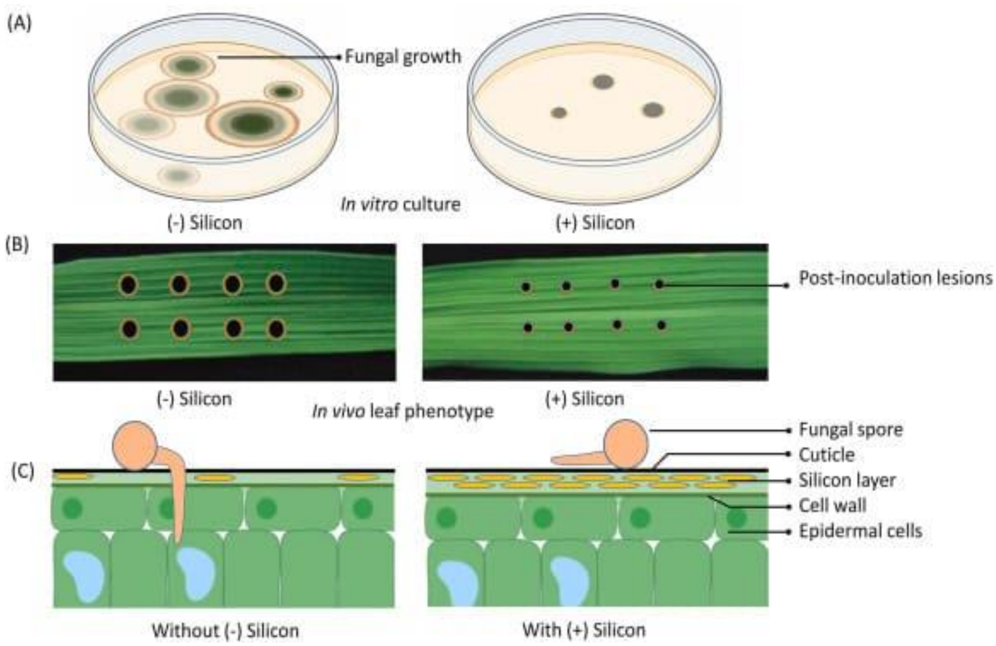

Fig. 1: Effect of silicon on fungal plant pathogen

Mechanisms of silicon-induced resistance

1. **Physical mechanism**

The physical barriers inhibit pathogen penetration and make plant cells less susceptible to enzymatic degradation caused by fungal pathogen invasion. Most Si is cross-linked with hemicellulose in cell walls, which improves mechanical properties and regeneration. Si contributes not only to cell-wall rigidity and reinforcement, it also increases cell-wall elasticity during extension growth (Marschner, 2012) e.g., Si application restricted hyphal entry to the first-invaded epidermal cell for wheat leaves infected with *Pyricularia oryzae*, while hyphae successfully invaded several neighboring leaf cells when there was no Si treatment. The increase of resistance has been associated with several factors, such as

(1) The density of the long and short silicified cells presents in the epidermis of the leaves,
(2) The thick silica layer below the cuticle,
(3) The double cuticular layer,
(4) The thickened silicon-cellulose membrane,
(5) The papilla formation (Francois *et al*., 2005).

The basic concept of physical barriers is the formation of a mechanical obstruction through Si accumulation below the cuticle and in cell walls that prevent or delay the penetration of infection pegs of fungal appressoria. In addition to the formation of the Si-enriched layer, the uniform distribution of Si aggregates is critical to effectively prevent fungal ingress (Debona *et al*., 2017; Wang *et al.*, 2017).

2. **Biochemical Mechanisms**

Biochemical and physiological mechanisms of resistance associated with Si include the increased production of phenolic compounds, phytoalexins and lignin, the activity of enzymes related to defense such as chitinases and b-1, 3 - glucanases, as well as increased expression of genes associated with plant resistance to diseases. Silicon-enhanced biochemical resistance is associated with increasing the activity of defence-related enzymes, such as polyphenol oxidase, glucanase, peroxidase, and phenylalanine ammonia-lyase (PAL). Increased production of antifungal compounds, such as phenolic, flavonoids, phytoalexins and pathogenesis-related (PR) proteins in plants. Regulating systemic signals, such as salicylic acid (SA), jasmonic acid (JA), and ethylene (Francois *et al*., 2005).

3. **Molecular Mechanisms**

Si may act in the primary response and modulate the activity of post-elicitation intracellular signalling systems which regulate the expression of defence genes related to structural modifications of cell walls, hypersensitivity responses, hormone synthesis, antimicrobial compound synthesis, and PR proteins (Francois *et al*., 2005). During the induction of SAR in cucumber mediated with Si, the expression of gene encoding a novel proline-rich protein (PRP1) was enhanced, which contributed to cell-wall reinforcement at the site of attempted penetration of fungi into epidermal cells. Si could induce tomato resistance to *Ralstonia solanacearum* via upregulating the expression of genes involved in defence and stress responses, such as WRKY1 transcription factor, disease resistance response protein, ferritin, late embryogenesis abundant protein, and trehalose phosphatase.

Local defense, induced resistance, and systemic acquired resistance as influenced by silicon. To survive pathogen attacks, plants deploy multiple layers of basal and induced defenses (El-Shetehy *et al*., 2021). These sophisticated mechanisms of immune responses are regulated by a complex signaling network involving multiple key defense hormones such as SA, JA and ET in precise combination in response to a specific pathogen (Ding *et al*., 2021).

Table 2: Defence-related enzymes regulated by silicon in plant–pathogen interactions

Hosts	Diseases	Pathogen	Defence-related enzymes
Bean	Anthracnose	*Colletotrichum lindemuthianum*	Superoxide dismutase, ascorbate peroxidase, glutathione reductase
Cucumber	Crown and root rot, Powdery mildew	*Pythium spp., Podosphaera xanthii*	Chitinase, peroxidases, polyphenoloxidases Peroxidases, polyphenoloxidases, chitinases
Melon	Pink rot, Powdery mildew	*Trichothecium roseum, Podosphaera xanthii*	Peroxidase Chitinases, superoxide dismutase, β-1,3-glucanase
Pea	Leaf spot	*Mycosphaerella pinodes*	Chitinase, β-1,3-glucanase
Rice	Blast, Brown spot, Sheath blight	*Magnaporthe oryzae, Pyricularia oryzae, Bipolaris oryzae, Rhizoctonia solani*	Glucanase, peroxidase, polyphenol oxidase, phenylalanine ammonia-lyase, superoxide dismutase, catalase, ascorbate peroxidase, glutathione reductase, lipoxygenase,Chitinase, peroxidase Phenylalanine ammonia-lyases, peroxidases, polyphenoloxidases, chitinases
Soybean	Target spot	*Corynespora cassiicola*	Chitinases, β-1-3-glucanases, phenylalanine ammonia-lyases, peroxidases, polyphenol oxidases
Wheat	Blast	*Pyricularia oryzae*	Chitinases, peroxidases

Conclusion:

Silicon can contribute to reduce the intensity of diseases in the field. Silicon is absorbed and translocated and can be found at the infection sites, especially in monocotyledons, forming both physical and biochemical resistance barriers. It can be included in disease management plans, not as the only method able to solve all disease problems, but as an important component of the integrated disease management, that is, it can contribute. Silicon application could be one of the most promising approaches for sustainable, environmentally sound and broad-spectrum control of fungal diseases in plants in various agricultural contexts. The understanding of silicon in plants will be helpful to effectively use silicon to increase crop yield and enhance resistance to fungal pathogen.

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EXTENSION INNOVATIONS AS A PATHWAYS FOR CLIMATE SMART AGRICULTURE IN INDIA

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Introduction:

The biggest threat to development in the twenty-first century is climate change. It is one of the main challenges to humanity and has an impact on a variety of areas, including forestry, agriculture, the environment, and human lives. The geological, biological, and ecologicalsystems of our world have undergone significant and potentially permanent changes as a result ofclimate change. The 60 per cent of the earth's surface that is made up of croplands, pastures, and woodsis gradually becoming more vulnerable to risks from rising climate variability. The distribution of agro-ecological zones, habitats, patterns of plant diseases and pests, fish populations, and ocean circulation patterns all alter in response to climate patterns, and these changes can have a big impact on agriculture and food production. The difficulty of quickly increasing productivity is made more difficult by the current and anticipated effects of climate change. A more widespread adoption of a "Climate Smart Agriculture" (CSA) strategy is one suggested strategy to accomplish this. CSA is composed of three main pillars: sustainably increasing agricultural productivity and incomes; adapting to and fostering resilience to climate change; and reducing and/or removing greenhouse gas emissions in comparison to conventional practices. CSA is defined by its intended outcomes rather than by specific farming practices. Despite the fact that socioeconomic research on the effects of these CSA activities is notably limited, much research has been done on the biophysical side of climate change. Therefore, a robust extension network is required in climate-smart agriculture to alter farmer behavior or to equip them with various site-specific adaptation and mitigation techniques.

The majority of nations' economies are based on agriculture. Agriculture also offers a huge population employment option in addition to food and raw materials. Agricultural production is directly impacted by climate change because it is one of the industry’s most susceptible to its effects and is naturally climate-sensitive. Agriculture and economic development have long been intertwined. Temperature, carbon dioxide, glacier runoff, precipitation, and the interactions between these factors are all predicted to be significantly impacted by climate change. These factors determine the biosphere's ability to sustainably generate food for both people and domesticated animals. The many strategies used to counteract these problems will determine how much of an impact climate change has on agriculture overall.

Generally speaking, climate change could have an impact on agriculture in a number of ways, including productivity, which refers to the quantity and quality of crops, agricultural practices, which involve changes to irrigation and agricultural inputs like herbicides, insecticides, and fertilizers, environmental effects, which are particularly related to frequency and intensity of soil drainage (which results in nitrogen leaching), soil erosion, and a decrease in crop diversity, and rural space.

General affects of climate change on agriculture:

- Productivity in terms of crop production, including quantity and quality
- Altering agricultural methods by using different irrigation techniques and agricultural inputsincluding herbicides, insecticides, and fertilizers
- Environmental consequences, particularly in regard to soil drainage frequency and severity(which results in nitrogen leaching), soil erosion, and decreased crop diversity
- Rural space, as a result of cultivated land loss and gain, land speculation, renunciation of land,and hydraulic amenities.
- As a result of adaptation, organisms may become more or less competitive, and people may feelpressure to create creatures that are more competitive, such as rice that is salt- or flood-resistant.

Agriculture and climate change scenario in India

India is a country whose economy is heavily reliant on agriculture, and more than two-thirds of its people live off the land. In India, agriculture accounts for about 14 per cent of GDP. India is a sizable nation with a varied climate. Different seasons call for different crops and farming practices. Agriculture depends heavily on monsoon rains, and there is a direct connection betweenclimate and water availability. The effects of climate change are widespread, but because so manypeople depend on agriculture, nations like India are especially vulnerable. According to estimates, yields in India will decline by 4.5 to 9 per cent as a result of medium-term (2010–2039) climate change,depending on the intensity and distribution of warming.

Climate change has a direct or indirect impact on people and their way of life. Millions of people in India face a direct threat from climate change that is becoming worse. Poor rural households will be disproportionately affected by the negative effects of climate change since their livelihoods depend mostly on agriculture and natural resources (Kates, 2000; Mendelsohn *et al.*, 2007; Satapathy *et al.,* 2011).

Due to the temperature increase in the major growing zones, decreased yields of wheat and rice are anticipated. India experienced its warmest year (+0.93C) since 1901 in 2010. Most cereals would produce less as a result of rising temperatures, CO_2 levels, and reduced water availability. By 2100, it is anticipated that crop production will decline by 10–40 percent.

Rao *et al.* (2011) observed that whereas Rabi (spring) crops will be more impacted by a rise in minimum temperature, kharif (autumn) crops will be more impacted by rainfall unpredictability. Rabi's extreme heat stress has a severe influence on wheat. Both the temperature and the availability of water will have an impact on rice. If water supply is not restricted, legume crops like soybean and peanuts are anticipated to benefit from the rising warmth and CO_2. Heat waves had an impact on the milk production of livestock. A change in seasonal catches has an impact on the marine fisheries' breeding season. Commercial poultry suffered as a result of the heat stress.

Climate-smart approach of agriculture in India

As we all know, CSA is a requirement to help farms become more and more climate wise, not an option. Like the rest of the globe, the Indian government has taken some actions to address the complex problem of climate change. With eight missions, the National Action Plan on Climate Change (NAPCC) was introduced in 2008. The National Mission for Sustainable Agriculture (NMSA), which aims to make agriculture productive, sustainable, and financially rewarding as well as climate resilient, was one of them. It also aims to build the capacity of farmers and stakeholders in the area of climate change adaptation and mitigation measures. Programs for climate smart villages (CSV) were started in 2011 in Haryana, Punjab, Bihar, Karnataka, and Odisha. CSVs were implemented in Haryana through a variety of creative partnerships, tight coordination with NICRA.

Climate smart agriculture and extension advisory services

The global climate change agenda gives agriculture a prominent place since it is both a human activity that is at danger from climate change and a factor in environmental and climate change. Agriculture (including forestry and fisheries) must become "climate smart," which means it must sustainably enhance agricultural output and incomes, adapt to climate change and create resilience to it, and cut and eliminate greenhouse gas emissions when it is practical to do so (FAO, 2013a). A technique for reforming and reorienting agricultural growth in light of the new realities of climate change is known as "climate-smart agriculture" (Lipper *et al.,* 2014). "Agriculture that sustainably increases productivity, develops resilience (adaptation), reduces Green House Gases (GHGs) where practicable, and boosts attainment of national food security and development goals" is how it is characterized (FAO, 2013b).

In this case, productivity, adaptability, and mitigation are three interconnected pillars that must be met to achieve the CSA's goal of food security and development.

CSA is an integrative strategy that specifically tries to achieve three goals to solve the interconnected concerns of food security and climate change:

1. Sustainably increasing agricultural productivity, to support equitable increases in farm incomes, food security and development;
2. Adapting and building resilience of agricultural and food security systems to climate change at multiple levels;
3. Reducing greenhouse gas emissions from agriculture (including crops, livestock and fisheries).

Rural Advisory Services (RAS) promote climate-smart agriculture (CSA) through the use of cutting-edge techniques like plant clinics and participatory video, which they use to disseminate climate knowledge, technologies, and information on production practices for climate adaptation (Digital Green, case from India). By boosting farmers' capacity, enhancing technology and information transmission, facilitating and brokering, advocating for policies, and more, extension providers can significantly contribute to CSA. Although RAS have a comparative advantage in these activities and are already actively involved in them more generally, institutional reform at the systems level, as well as capacity development at the person and organizational levels, are necessary to increase their efficacy with regard to CSA.

Sustainability increasing productivity through information dissemination

There is a reform in extension services from transferring skills, technologies and knowledge related to the production of crops, livestock and forestry products from research to farmers, to developing technologies with farmers and catalyzing and facilitating innovation processes. This shift in focus is in alignment with the need for site-specific assessments to identify suitable agricultural technologies and practices needed for CSA. RAS disseminate technologies, information and practices with a range of approaches including traditional extension modes (e.g., interpersonal interaction, demonstrations, field days, printed materials, etc.), Information and Communication Technology (ICTs) (radio, mobile phones, video, social media), rural resource centres, farmer-to-farmer extension and farmer field school among others. Extension services are being reformed from just disseminating knowledge, skills, and technologies about how to produce crops, livestock, and forestry products to farmers to now working with them to develop new technologies while also accelerating and enabling innovation processes. This change in emphasis is consistent with the requirement for site-specific analyses to determine the appropriate agricultural technology and practices required for CSA. RAS spread technologies, knowledge, and practices using a variety of strategies, such as conventional extension methods (such as face-to-face interaction, demonstrations, field days, printed materials, etc.), Information and Communication Technologies (ICTs) (radio, mobile phones, video, social media), rural resource centres, farmer-to-farmer extension, and farmer field schools, among others.

For instance, specialists in climate change can get knowledge from RAS's experience with ICTs. Experts in climate change, for instance, can benefit from RAS' experience using ICTs for information distribution. Although distributing technology and knowledge has traditionally been the responsibility of extension workers, RAS providers confront difficulties in developing and promoting climate-resilient technologies and practices. According to Simpson and Burpee (2014), two major interrelated challenges for RAS providers are figuring out what kinds of adaptive changes farmers need to make and when to make them, as well as making sure that pertinent technologies and modes of dissemination keep up with the need for constantly changing climate change adjustments. Rural advisers will need new capacities and skills, and rural service providers will have to go through institutional changes in order to discover technical solutions for sustainably increasing agricultural productivity. Because there is such a strong need for researchers to draw on local knowledge, have a clear understanding of farmers' needs and problems, as well as obtain feedback on how technological interventions are working, closer links between agricultural researchers and extension providers than currently exist are essential.

Extension approaches used in CSA

Because of its ability to meet the pressing demands of climate mitigation, adaptation and resilience, and food security, climate-smart agriculture (CSA) has quickly gained acceptance in the international community. While there are several recognized and accessible climate-smart technologies and practices, their application is hampered by a lack of location-specific tools, long-term experiences, and a supportive enabling environment. Extension services have historically been seen as a way to apply information based on research, with a heavy emphasis on raising agricultural output. According to GFRAS (2012), the function of extension systems today has significantly changed as a result of new global concerns like decreasing water supply, increased soil degradation, and changing and unstable climate and markets. As a result, the job of the modern extensionist has changed from being production-focused to becoming an integrated, cross-sectoral component of the extension ecosystem. The distinction between extension approaches as such (such as participatory training approach, training and visit approach), or the primary underlying principles of the advice (such as organic production, integrated production), is not absolute today because extension comes "in many sizes and shapes." But the issue of how-to best address climate change is one that all extension systems face. The fact that CSA considerations in extension techniques might still be viewed as novel only serves to emphasize this.

Extension systems can contribute to CSA in a number of ways. However, the philosophy employed (for example, demand- vs. supply-led, one-to-one interaction vs. mass extension) and specific methodologies suit various types of communications to farmers and offer various opportunities to gather data from farmers' fields. Additionally, the importance of reach and effect potential, two characteristics that are negatively connected and vary amongst extension tactics, is significant. In general, the larger the reach, the smaller the impact, and vice versa. While intensive interactions through farmer field schools can be more effective for complicated knowledge, mass media frequently suits simpler messages. The choice of strategy combinations can affect how much extension services can help with income and food security, resilience and adaptation, and climate change mitigation. Some of these strategies are follows:

- Climate Awareness programmes/Campaigns, Exhibitions
- Climate Trainings
- Climate workshops
- Plant health Rallies
- Climate Farmers field schools (FFS)
- Field visits to progressive farmers
- Demonstration on different adaptation or mitigation practices
- Dissemination of appropriate climate resilient technology
- ICT-supported networks
- Participatory crop planning
- Appointment of climate manager at the village level
- Appointment of monsoon manager at the district level
- Use of indigenous technical knowledge (ITKs)
- Establishment of plant clinics
- Climate-smart villages

Climate awareness mass media campaigns: Mass extension campaign tactics are particularly alluring due to their wide reach. As is well known, the main challenges facing national extension systems are a lack of field extension workers and a lack of funding to serve numerous farmers dispersed over a wide geographic area. Mass media can be used to perform extension more effectively and overcome these limitations. For the purpose of spreading awareness or providing straightforward information, extension with mass media can also be managed by non-extension players (such as radio or television) with technical inputs coming from extension workers via SMS.

Climate training: It is crucial to refresh the knowledge of intermediaries and extension staff regarding climate change, its effects and consequences or regarding various adaptation and mitigation techniques. As a new and developing topic, climate-smart agriculture, extension service providers must to be educated on it. Agro-meteorology is one of the many areas in which training can be provided; extension service providers should be conversant with the terminologies used locally in meteorology and should be able to read and analyses scientific data. Farmers should be the focus of extension intermediaries, who only work at the field level.

Plant clinics: Similar to human health clinics, plant clinics serve as the first point of contact for the national extension system and provide farmers with direct access to extension personnel for "any problem and any crop"-related information. Plant clinics serve as a conduit for the two-way exchange of knowledge and information between extension agents and farmers and connect to other elements of a plant health system (Boa *et al.*, 2015). Abiotic causes (such as lack of nutrients, standing water, improper use of chemicals, etc.) or biotic ones can both contribute to the different crop issues that are brought to plant clinics (e.g., pathogens, insects, rats, etc.). Plant physicians should be familiar with farmers and farming practices, speak the local language, and be aware of the available inputs.

Climate Farmers Field Schools (FFS): The Farmer Field School (FFS) is a non-formal, participatory extension strategy based on experiential learning that prioritizes farmers and their needs (FAO, 2002). It gives farmers a low-risk environment to test novel agricultural management techniques, talk about and learn from their findings, which enables them to gain new practical knowledge and skills and enhance their ability to make decisions both individually and as a group (Settle *et al.*, 2014)

Plant health rally approach: It is a rapid extension approach for bringing major agricultural dangers or threats to important crops to the public's attention, encouraging the use of better agricultural practices, and gathering farmer comment on important production-related concerns. The plant clinic strategy and the plant health rally approach are complementary to one another since they have different levels of reach, impact, and message complexity. The plant health rally approach was first introduced by Bentley *et al.* in 2003.

Contingency crop planning: It is a handbook with advice on all major facets of crop management and cultural practices. For farmers, this type of calendar is highly helpful for scheduling irrigation, sowing crops, and taking plant protection measures. The local meteorological conditions for the regional crops grown in that area are taken into consideration. It is participative in nature since scientists' scientific knowledge and farmers' local knowledge of the crops or different agricultural techniques both play crucial roles in crop planning. The department of agrometeorology aids in its preparation.

ICT supported network: Information and communication technologies (ICTs) were crucial as a channel for information and communication during the awareness-raising, adaptation, and mitigation phases of the fight against climate change. ICT adoption and accessibility varies between developed and developing nations, urban and rural areas, and even within rural areas themselves. A crucial prerequisite for farmers' decision to adapt is their capacity to perceive climate change. By educating farmers on the variety of available adaptation and mitigation techniques, the subject of climate change was addressed using mobile phones, movies, radios, and other media.

Farmer-to-Farmer Extension (F2FE): F2FE refers to the practice of farmers training farmers, frequently through setting up a system of farmer-trainers and farmer-promoters (Scarborough *et al.*, 1997). F2FE has significant potential for scaling up climate-smart agriculture in an efficient manner (CSA). Farmers are more ready to learn from their peers than from extension personnel, thus the strategy encourages them to be change agents and increases adoption (Franzel *et al.,* 2015). F2FE programmes help with all aspects of CSA, i.e., they increase production, foster resilience, and lower greenhouse gas emissions.

Climate-Smart Villages (CSVs): CSVs are built-up settlements or examples of regional initiatives that guarantee food security, encourage adaptation, and increase resistance to climate pressures. Climate-smart technology, local knowledge and institutions, village development plans, and climate information services make up the four main parts of CSV. A CSV's location is chosen based on the climate risk profile of the area and the interest of local governments and farmers in the project. There is no set list of interventions or one method that works for everyone. The focus is on creating a portfolio of treatments that are tailored to the local circumstances and that work well together.

Climate information services

Because sensitive farmers experience climate change primarily as changes in the frequency and intensity of extreme events, reducing sensitivity to climate risks in the present is essential for adapting to climate change in the future (Cooper *et al.,* 2008). Extreme occurrences undermine livelihoods through the destruction of infrastructure, the loss of productive assets, and health problems while also impeding the adoption of climate-resilient practices and the radical change needed to adapt to climate change (Hansen *et al.,* 2014). Therefore, initiatives to promote the shift to more productive and resilient agricultural livelihoods in risky locations must be supported by methods, programmes, and policies that help vulnerable populations get over the hurdle of climate risk. Because sensitive farmers experience climate change primarily as changes in the frequency and intensity of extreme events, reducing sensitivity to climate risks in the present is essential for adapting to climate change in the future (Cooper *et al.,* 2008). Extreme occurrences undermine livelihoods through the destruction of infrastructure, the loss of productive assets, and health problems while also impeding the adoption of climate-resilient practices and the radical change needed to adapt to climate change (Hansen *et al.,* 2014). Therefore, initiatives to promote the shift to more productive and resilient agricultural livelihoods in risky locations must be supported by methods, programmes, and policies that help vulnerable populations get over the hurdle of climate risk. So here extension plays a major role in the changing climate scenario by providing them climate-smart information at the right time.

Extension methods for transfer of climate knowledge

Only if farmers have sufficient understanding and knowledge of climate change concerns, such as what is climate change, how it affects agriculture, what are the repercussions and impact, and so on, can effective adaption of the CSA advisories issued by various projects be accomplished. Therefore, based on their clients, locations, and objectives, various projects adopted a variety of strategies, some of which are detailed below.

Short Messaging Services or SMS: To registered mobile numbers of farmers, brief text messages of 160–164 characters in the local language (Marathi) were delivered. The farmers received a maximum of two SMS every week based on weather advisories and backup preparations.

Climate wallpapers: In order to assist farmers with advice, one-page warnings in the shape of tables or posters about weather forecasts for agricultural operations that needed to be undertaken were put on communal notice boards in villages. These recommendations were known as Krishi Salah in the CCA programme.

Climate voice messages: SMS was converted into voice messages in the areas with low literacy rate and disseminated to the farmers.

Folk media: Under the CCA initiative, a few nukkad natak (street plays) about how climate change affects agriculture were created so that farmers may learn more about the shifting climatic circumstances.

Use of Public Addressing System (PAS): It was a useful tool for communicating urgent information to the villagers, such as informing farmers about dangerous weather conditions or providing agro-advisory services in communities where SMS could not be provided because of network and electrical issues. Farmers, for instance, would be quickly told if rain was forecast for the following day so they could schedule their farming activities accordingly.

Climate group meetings: Farmers were grouped together since it is simple to communicate with them or provide them with climate-related information while they are together. In the village, many committees were established to manage various aspects, such as the village development committee (VDC) established for the CCA project. A committee consisted of 10 to 15 people, and women made up 40 to 50 percent of the entire committee.

To encourage the farmers to adopt these mitigating methods, exposure tours were organized to the fields of progressive farmers who cultivate pomegranates, use organic slurry for their crops, employ drip or sprinkle irrigation, etc.

Climate workshops: To educate farmers, a number of seminars covering a range of subjects were held, such as building water ponds, growing pomegranates, using organic fertilizer, and running a custom hiring centre.

Field demonstration- A field demonstration was conducted to control a bacterial pomegranate disease. The farmers were urged to use suitable management techniques, such as using vermicompost, neem cake, organic manures, and bio-fertilizers. Similar to this, the value of mulching to lower soil temperature has been made more well known.

Recommendations:

- Promoting ICT use is necessary to combat climate change.
- Retraining or retraining of extension employees to gain new skills in managing climate change.
- Recognizing and confirming Indigenous Technical Knowledge (ITKs)
- Encourage farmer-to-farmer extension linkage for the dissemination of climate-smart knowledge.
- The projects must include a larger number of farmers.
- It is necessary to increase the awareness of the burgeoning problem of climate change.
- More working extension workers are required in the working area.
- It is necessary to hire a female extension worker to concentrate more on the involvement of women in various activities.
- It is important to encourage more climate-smart extension strategies, such as the creation of CSVs, plant clinics, and the hiring of "monsoon managers" at the village level.

Conclusion:

Because they help farmers transfer knowledge to their fields, extension services are essential to the CSA. The best combination of various extension strategies to be used in CSA will largely depend on the complexity of extension messages, the target population and its geographic spread, the technology available, the type and variety of data to be collected from farmers, and lastly, the financial resources available for extension. In order to make extension more climate-responsive and help with the triple issue of addressing food security, adaptation, and mitigation, extension must work hand in hand with advocacy and raise decision makers' awareness of the impending threat of climate change for agriculture. Consequently, CSA policies should support both procedures and products, such as financial services (crop insurance, subsidies, credits, etc.) and methods for knowledge management and exchange (strengthening of extension services, early warning system, etc.).

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