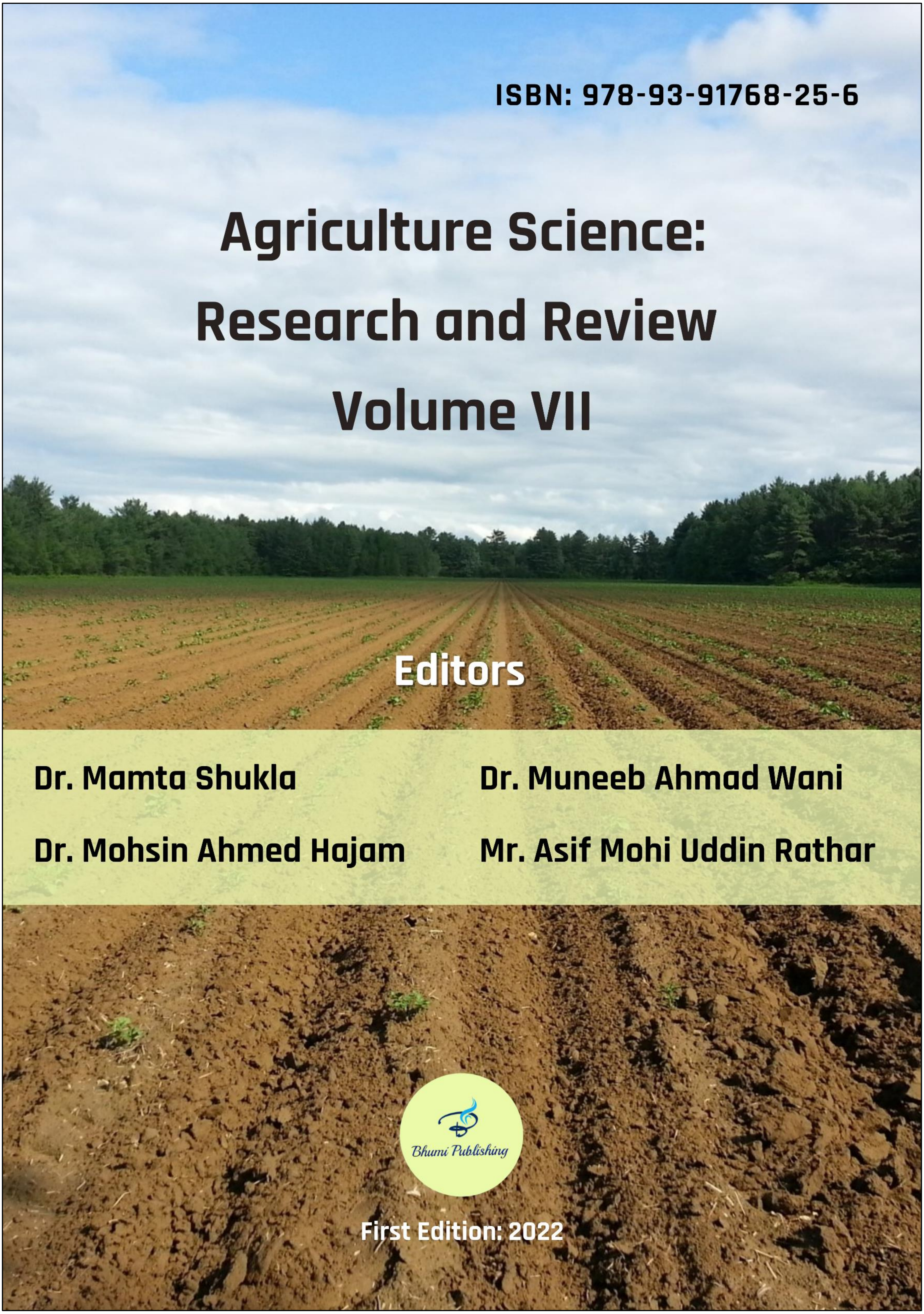

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Agriculture Science: Research and Review Volume VII

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PREFACE

We are delighted to publish our book entitled ***"Agricultural Science: Research and Reviews Volume VII".*** *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

SOIL MANAGEMENT FOR SUSTAINABLE AGRICULTURE

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Introduction:

The need for agriculture to generate more food has increased due to the exponential growth of the world's population. In the past 12 years, the world's population has increased by one billion, surpassing 6 billion in 2000, and is expected to reach 9 billion by 2050 (Brown, 2004). The technologies used to change agriculture since the 1960s may be boosting production to fulfil the world's food need, but they may also be endangering agricultural ecosystems. For instance, herbicides and insecticides based on chemicals initially assisted farmers to lower their losses due to hazardous insects and illness. However, when pests became more resilient and the chemicals left hazardous residues in our water, land, and food, they started to fail. (Nierenberg and Halweil, 2005). Additionally, soil managers over-relied on chemical fertilizers to replace or supplement soil nutrients, which decreased the quality of the soil and water (Stamatiadis *et al.*, 1999).

A vital human activity, agriculture is both inextricably linked to nature and a threat to it. As a result, sustainability has become essential to agricultural policy and practice going forward. The term "sustainability agriculture" which is defined as "actions to protect, sustainability manage and restore natural or modified ecosystems, which address societal challenges (such as climate change, food and water security, or natural disasters) effectively and adaptively, while simultaneously providing human well- being and biodiversity benefits" acknowledges the significant impact of agriculture concurrent with the environmental crises we face (Cohen-Shacham *et al.*, 2016).

First and foremost, sustainable agriculture must take into account two mutually exclusive, intertwined societal imperatives: protecting the environment and ensuring access to nutritious food for all. One of the most crucial natural resources for the production of agriculture is soil. The majority of living things are supported by soil because it is their primary sources of mineral nutrients. A healthy soil management programme ensures that the right minerals enter the food chain and that they don't become toxic or deficient for plants. Both directly and indirectly, soil management affects crop yield, environmental sustainability, and human health. The management of soils will be more crucial than ever in the upcoming years due to the anticipated rise in global population and the resulting need to intensify food production. The difficulty will be managing soils in a sustainable way through correct nutrient management and appropriate soil conservation methods in order to attain future food security.

Research will be needed to produce enough safe and nutrient-rich food for healthy diets and to prevent additional soil degradation due to erosion or contamination.

Sustainable soil management

Sustainable soil management refers to agronomic and soil management techniques that maximise agricultural productivity over the long term while preserving the environment and the health of the soil. The use of organic manures, nutrient cycling, increased nitrogen fixation, conservation tillage and irrigation practises to reduce soil and nutrient losses, the use of crop varieties, and crop production techniques that are based on local knowledge of sustainable soil management are all highlights of the sustainable approach to soil fertility management (Tripathi, 2019).

Table 1: Evaluation of soil management practices to increase carbon stocks

Treatment	Effect on OM input (changes to primary production and / or supplied to the soil)	Effect on OM output (rate of mineralization)	Other positive Effects	Negative secondary environmental effects	Additional carbon stock (Mg C ha^{-1} $year^{-1}$)
No-till	Slightly low production, slightly low level of OM conversion into humus	Low rate (increased protection of OM due to improve soil aggregate)	Erosion control, reduced fuel consumption	Slightly low production use of pesticide, emission of N_2O to be confirmed	0.07–0.33
Crop Rotation	Increase OM input	Increases soil respiration	Breaks the insect and pest cycle	None	0.05–0.25
Cover Cropping	Annual production and increase OM returned (crop not harvested)	Increases soil respiration	Scavenging residual nutrients, erosion control, reduces fertilizer consumption	Possible emission of N_2O	0.15–0.25
Manure application	Exogenous OM input increases production by the addition of nutrients	Increases soil respiration	Improves soil Productivity	N leaching and N_2O emission if excessive inputs occur	0.05–0.15

Source: Komatsuzaki and Ohta, 2007

The effective management of soil can greatly aid in the sequestration of carbon. In order to prevent quick-reemission, carbon sequestration entails converting atmospheric CO_2 into long-lasting pools and safely storing it. By introducing significant volumes of biomass into the soil, soil organic carbon (SOC) stocks minimise soil disturbance, save soil and water, promote soil structure, increase the activity and species diversity of soil fauna, and reinforce the mechanism of elemental cycling (Lal, 2004).

For agricultural production and environmental quality to be sustained for future generation s, cropland's soil quality must be maintained and improved. Since soil management affects the level of food production and, to a large part, the state of the global environment, and since there is currently tremendous demand on the world's land resources, soil management strategies that enhance SOC stock and hence improve soil quality will become more apparent.

Approaches to sustainable agriculture

Use of organic matter

The main source of nitrogen and other nutrients is organic matter. It improves the soil's ability to absorb shocks, aids in preserving a stable soil texture and erosion resistance, and upholds a thriving colony of soil microbes (Cho *et al.*, 1986). While maintaining a high soil organic matter content is always preferred and proper management of the soil organic matter is essential in attaining profitable, sustainable, and environmentally friendly agriculture, organic matter should not be viewed as a panacea in modern agriculture (Hoeft and Nafziger, 1988; Darst and Murphy, 1989). The soil where the crop is cut should receive crop remains, potentially after composting. The level of soil organic matter will rise while nutrients losses are reduced by choosing the right crops and cropping techniques.

Reduced tillage

Conservation tillage is a type of low-input agriculture since it causes the least amount of soil disturbance and less energy and labour. While no-tillage keeps organic materials undisturbed and stratified in the topsoil, tilling the soil quickly absorbs organic elements into the soil matrix. Different factors will have an impact on the soil's characteristics and soil microorganisms, including runoff water, drying and wetting, freezing and thawing (Stinner and House, 1989).

Use of livestock wastes

It is desirable to utilize animal waste from livestock farming. Efficient waste management will reduce pollution while also giving of crops a useful supply of low-cost organic fertilizer.

Protection of non-cultivated land

Rural areas are seeing an increase in the amount of marginal land left uncultivated. If these uncultivated areas are not adequately covered with vegetation, they are quite vulnerable to erosion. In these places, appropriate controls for soil erosion should be created and implemented.

Crop rotation

One of the most effective methods of sustainable agriculture is crop rotation. It goal is to prevent the negative effects associated with repeatedly growing the same crops in the same soil. Since many pests like certain crops, it aids in the fight against pest issues. The population of the pests can grow significantly if there is a consistent supply of food.

Permaculture

A food production system using permaculture reduces resources waste and smart farming. Techniques used in permaculture design include growing grains without tillage, spiralling plants and herbs, sheet mulching, and using each plant for a variety of tasks. It focus on using perennial plants including fruit trees, nut trees, and bushes in a system that is supposed to replicate how plants in a natural ecosystem would behave.

Cover crops

Many farmers decide to always plant crops in a field and never leave it bare, this decision may have unforeseen repercussions. The farmer can accomplish his objectives of minimizing soil erosion, limiting the growth of weeds, and improving soil quality by planting cover crops like clover or oats and ultimately enhancing the quality of the soil.

Soil enrichment

The foundation of agricultural ecosystems is the soil. Both yields and the strength of a crop can be improved by having healthy soil. There are numerous techniques to preserve and improve soil quality. Examples include using composted plant waster or animal manure, as well as leaving crop leftovers in the field after a harvest.

Natural pest predators

It's crucial to consider the farm as an ecosystem rather than a factory if you want to keep pests under control. For instance, many birds and other animal are in fact pests that affect agriculture. Managing your farm to support populations of these pest predators is a smart strategy that is also successful.

Bio intensive Integrated Pest Management

IPM, or integrated pest management, is a strategy that mostly uses biological methods. Crop rotation is emphasized in IPM as a key component of pest management. Chemical remedies will only be required as last option. IPM instead. Using sterile males and biological pest control agents like ladybugs would be the proper responses. Instead, using sterile males and biological pest control agents like ladybugs would be the proper responses.

Polyculture farming

This method is comparable to crop rotation, which seeks to imitate natural principles for the highest yields. In one location, several crop species are grown. These species frequently work well together, producing a wider range of goods on a single plot and making the best use of the available resources. High biodiversity strengthens the system's resistance to weather changes, encourages a healthy diet, and uses built-in mechanisms to preserve soil fertility.

Agroforestry

In dry areas with soils vulnerable to desertification, agroforestry has emerged as one of the most effective tools for farmers. When addressed sustainably, it entails the development of trees and shrubs alongside agricultural and grazing land for long-lasting, fruitful, and diverse land use.

Biodynamic farming

Based on the "anthroposophical" idea, biodynamic farming integrates ecological and holistic growth approaches. It focuses on putting principles into effect, such as composting, applying animal manure from farm animals, rotating complementing crops, or using cover crops, to create the soil fertility and health required for food production.

Better water management

The selection of native crops that are better suited to the local climate is the first step in water management. For arid places, it is necessary to select crops that do not require a lot of water. When drought conditions are present, rainfall harvesting technologies that store rainwater can be utilized. In addition, recycled municipal wastewater can be used for irrigation.

Mulching

Mulching may be a crucial component of sustainable agriculture. The main objective of sustainable agriculture, including improving soil health and biodiversity, conserving water, using fewer pesticides and fertilizer, and lowering input costs, are directly related to mulching pasture.

Biofertilizers

One of the key elements of integrated nutrient management is the use of biofertilizers, which are a cost-efficient and renewable source of plant nutrients that can be used in place of or as addition to chemical fertilizers in sustainable agriculture. When given through seed or soil, these preparations, which contain living cells or dormant cells of effective microorganism strains, aid in the uptake of nutrients by agricultural plants through their interactions in the rhizosphere. They quicken several microbial processes in the soil that increase the amount of nutrients available in an easy-to-assimilate state for plants.

Green manuring

The importance of green manuring technology is rising as soil health, reducing environmental pollution, and using less chemicals in agriculture become more important goals. As a result, it I s a low-cost-eco-friendly technology that helps to sustainably preserve environmental quality while also conserving natural resources.

Benefits of sustainable agriculture

Contributes to environmental conservation

Natural resources including water and air, as well as land, are replenished through sustainable agriculture. Farmers who apply sustainable practices will use less chemical input, less non-renewable energy, and conserve limited resources. Give the growing population and increased need for food, this replenishment assures that these natural resources will be able to support life for future generations.

Saves energy for future

Petroleum in particular is major source of non-renewable energy for modern agriculture. Insofar as it is economically practical, sustainable farming systems have decreased the need for fossil fuels or non-renewable energy sources and replaced them with renewable resources or labour.

Public health safety

Pesticides and fertilizers that are harmful are avoided in sustainable agriculture. Farmers are able to grow fruits, vegetables, and other crops that are safer for customers, employees, and local communities as a result. Sustainable farmers can prevent human exposure to infectious, poisons, and other dangerous substances by managing livestock waste carefully and correctly.

Prevents pollution

Sustainable agriculture entails that all waste generated on a farm is absorbed by its ecosystem. Waste cannot produce pollution in this way.

Prevents air pollution

Air quality is impacted by agriculture in a number of ways, including smoke from burning crops, dust from tillage, traffic, and harvesting pesticide drift from spraying, and nitrous oxide emissions from nitrogen fertilizer use. By mixing crop residue into the soil, using the proper amount of tillage, and planting windbreaks, cover crops, or strips of native perennial grasses to prevent dust, sustainable agriculture has choices to enhance air quality.

Prevents soil erosion

Soil erosion has been seriously hampered by our ability to produce enough food on a consistent basis. As a result, many techniques have been created to maintain soil, such as decreasing or eliminating tillage, controlling irrigations to decrease runoff, and keeping the soil covered with plants or mulch.

Reduction in cost

Cost associated with farming are reduced overall by sustainable agriculture.

Biodiversity

Biodiversity is a result of the diversity of plants and animals produced by sustainable farms.

Sustainable livestock management

Sustainable livestock production is a component of sustainable agriculture and involves the long-term growth of livestock overall through the selection of appropriate animal species, animal nutrition, reproduction, herd health, and grazing management.

Beneficial to animals

Animals are handled more humanely and with respect as a result of sustainable agriculture. Sustainable ranchers and farmers employ livestock management techniques that safeguard the welfare of their livestock.

Economically beneficial for farmers

Farmers are paid fairly for their produce in return for using sustainable farming practices. Rural communities are immensely strengthened by this.

Social equality

The use of sustainable agricultural methods also helps the workforce, who are given more competitive pay and benefits. In addition, they are subjected to humane and equitable working conditions, which include a healthy diet, a secure working environment, and decent housing.

Beneficial for environment

Sustainable agriculture aids the environment by reducing the need to use non-renewable energy sources.

Factors contributing to soil fertility decline

Depletion of nutrients in soils has a negative impact on soil quality, lowers crop output, and could endanger global food security and sustainable agriculture. The following major reasons for the overall loss in soil fertility are examined, along with the contributing variables for the overall loss in soil fertility are examined, along with the contributing variables for each of these reasons:

Soil erosion

The causes of soil erosion are both innate in nature and brought on by human activity. The negative effects of soil erosion include the loss of rich top soil, including soil organic matter (SOM) and plant nutrients, at the source as well as flooding, sedimentation, and damage to rich land, physical infrastructures, and contamination of water sources at the destination.

Nutrient mining

The removal of plant nutrients from soil through harvested crop yields and/or crop waste is known as nutrient mining. When the amount of nutrients removed exceeds the total nutrients present in the soil, nutrient depletion occurs.

Depletion of soil organic matter

One of the biggest obstacle to sustainable soil management has been identified as reduced SOM as a result of inadequate OM input into soil. SOM loss can happen for a number of causes.

Crop wastes are rarely, if ever, returned to the land because they are widely used as animal feed. As a result, each crop cycle results in a negative balances in SOM. Intensive tillage techniques used in multiple cropping are also responsible for long-term losses of SOM. Dung has also been used as fuel and the burning of organic waste has added to the harmful impacts of SOM. Poor biological, chemical, physical qualities of soil are caused by low SOM levels.

Imbalance use of agro-chemical

More nutrients are required in the cropping system due to increased cropping intensity and the introduction of better crops and their variants. There have also been reports of instances of soil pollution brought on by the excessive and careless use of agrochemicals. Continuous and unbalanced use of agro-chemicals in the absence of sufficient organic manure has led to soil degradation, including decreased soil organic matter (SOM), hardness (difficult to cultivate), acidification, micronutrient deficiencies, deterioration of soil and water qualities, and loss of agro-biodiversity.

Soil compaction

A decrease in soil porosity results in an increase in bulk density and the production of platy aggregates, which causes soil compaction. One of the key elements that affects a soil's susceptibility to compaction is its texture. The amount of biomass produced and the rate at which water and nutrients may permeate the soil are both significantly reduced by soil compaction (e.g. impeding root penetration). A plough pan, which is characterized by a hard layer due to excessive vehicle passing and high mechanisation and is frequently seen in arable soil, is one example of how inappropriate agricultural methods can cause compaction.

Soil contamination

In agriculture, the usage of pesticides comprising pharmaceuticals, PCBs, and PAHs is frequently linked to soil pollutants. Additionally, human activities like fertilization and amendment techniques, which are frequently used to boost soil productivity, are the cause of heavy metal input in agriculture (for example phosphate fertilizers usually contains cadmium. It is advised to use pesticides, herbicides, and fertilizers sparingly, in conjunction with accurate field monitoring of conditions (such as soil moisture), weather forecast (such as avoiding treatments before rain), and application method, as well as a variety of dynamic and interconnected physical, chemical, and biological processes. To assess the risk to groundwater and surface water, these processes and their interactions must be carefully taken into account (Bradbury and Kirby, 2006). Morschel *et al.* (2004), for example, demonstrated that grass strips significantly reduce pollution in water bodies and soil, also preserving natural biodiversity.

Biodiversity loss

Orgiazzi *et al.* (2016) described soil biodiversity in many ways including:

- ❖ Ecosystem diversity, which includes the range of soil habitats.

- The variety and quantity of many sorts of organisms that live in soil constitute species diversity.
- The mix of several genes found in a population of a single species is known as genetic diversity.
- Phenotypic diversity is determined by genes and environmental conditions and is based on any and/or all of the morphological, biochemical, or physiological features of the organisms in the soil.

Conclusion:

The majority of living things are supported by soil because it is their primary supply of mineral nutrients. A healthy soil management programme guarantees that the right minerals enter the food chain and that they don't become toxic or insufficient for plants. Both directly and indirectly, soil management affects crop yield, environmental sustain ability, and human health. The management of soils will be more crucial than ever in the upcoming years due to the anticipated rise in global population and the resulting need to intensify food production. The difficulty will be managing soil in a sustainable way through correct nutrient management and appropriate soil conservation methods in order to attain future food security.

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SOIL TESTING: A SUSTAINABLE APPROACH FOR SOIL HEALTH

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Abstract:

The basic environment for plant growth, the production of crops and fodder, and the facilitation of a number of ecosystem services, such as nutrient cycling, water management, and biodiversity support, are all provided by soil. High nutrient availability from organic and mineral soil components, good soil structure, high accessible water content, and microbial or animal communities that promote healthy root and shoot growth all contribute to soil fertility. Although soil testing is an art of crop production, similar to how a thermometer is in medicine, it is not a panacea for all of the issues that crop production is prone to. Low nutrient usage efficiency, productivity, and profitability are caused by widespread nutrient shortages and declining soil health. Primary and secondary production are reliant on ecosystem services that take place in the soil, like biotic population control, nutrient cycling, and soil health. A useful method for determining the current nutritional status and issues with a farmer's fields is soil testing. An intelligent or balanced use of integrated nutrient management, including major and macro nutrients, organic manures, and amendments for a particular site, is made possible by suggestions from soil tests. Effective soil testing services support precise fertiliser application. Finally, soil testing and its suggestions can be a practical way to ensure that living things and future generations have access to enough food, feed, fibre, and other necessities without endangering the health of the soil. For the purpose of determining the overall physical, chemical, and biological behaviour of soil.

Introduction:

The basis of agriculture and our food chain is soil. A robust crop production and a sustainable future for farming depend on healthy and vital soil. The "ability of crop production methods to continuously provide food without deteriorating the environment" is referred to as agricultural sustainability (Sharma and Mandal, 2009). It shows how food production has changed over time. The future of global food security hinges on our ability to maintain healthy soil, conserve fertiliser, and use it effectively (Swaminathan, 2005). Agriculture is the cornerstone of economic growth in every nation, developed or emerging. Our first insight in the context of agricultural development is the issue of inescapable population growth while the amount of arable land is decreasing owing to its alternative usage (Parewa, 2014).

Therefore, increasing production per unit area in a planned, sustainable way is essential to meeting the needs of both the present and future generations. A real solution for self-sufficeincy in food, feed, fodder, and fibre to meet the daily demands of living things in a sustainable mnner can be found through soil testing and its suggestions (Parewa *et al.*, 2016).

On the surface of the earth, life is supported by the heterogeneous natural resource known as soil. In order to feed the world's expanding population, soil serves as an essential component of all terrestrial ecosystem activities (Paustian *et al.*, 2016). The foundation of biodiversity preservation, climate change mitigation, water security, and food security is soil (McBratney *et al.*, 2014). It is described as being four-dimensional, unconsolidated, and dynamic in nature, providing agricultural plants with water, nutrients, and mechanical support (Lal, 2016). A critical component of successful agriculture is soil testing. It increases yields, check erosion, and conserves natural resources for farmers and the environment. Because healthy soil contributes to both a healthy environment and a healthy human population, soil testing become a win-win situation, following the famous quote “we are what we eat”, and perhaps, what we breathe.

The important role of soil in sustaining the food security and other ecosystem services can be explained by Fig.-1.

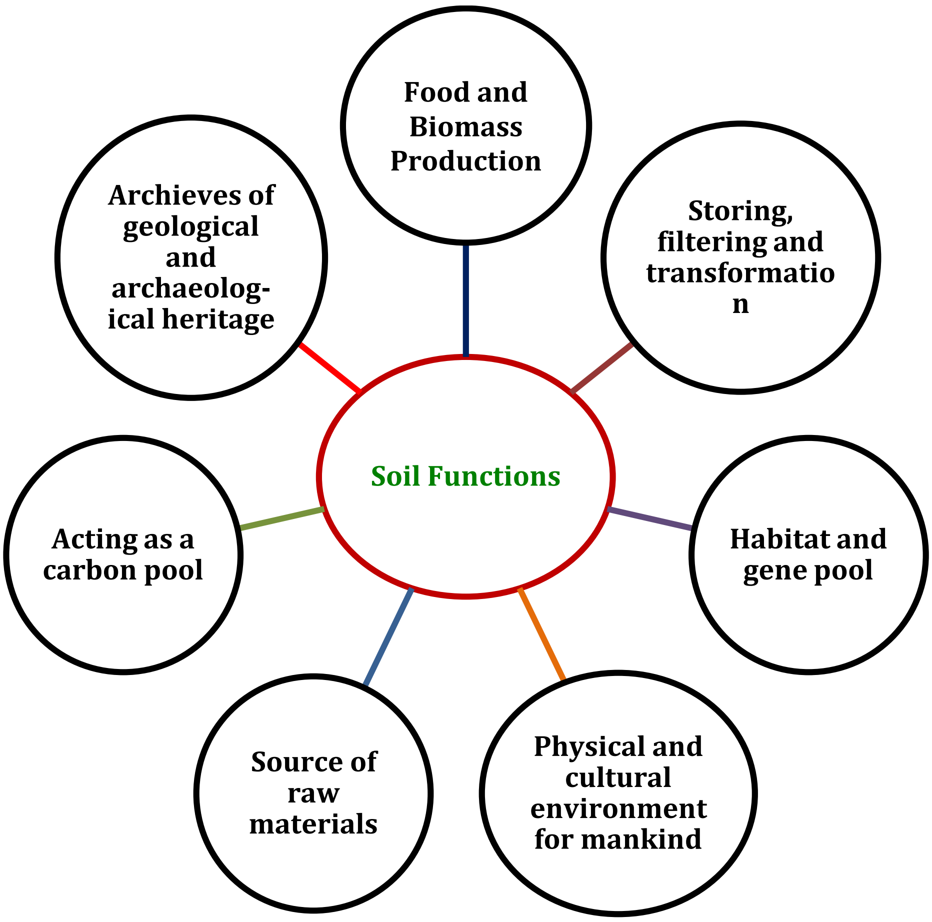

Figure 1: Functions of soil (adapted from European Commission, 2006).

Soil testing:

In most cases, the word "soil testing" refers to the analysis of a soil sample to ascertain its composition, nutrient content, and other properties like its acidity/alkalinity or pH level. A soil test can identify the soil's fertility, or the predicted growth potential, which can reveal nutrient deficiencies, toxicities from an abundance of fertility, and inhibitions from the presence of trace minerals that are not absolutely necessary for plant growth. Collecting soil samples, preparing them for analysis, doing chemical and physical analysis, interpreting the results, and then advising on fertiliser applications for the crops are all steps in the soil testing process (Claire *et al.*, 2019). It is widely accepted that soil testing is a reliable scientific method for determining the soil's innate capacity to provide plant nutrients. Scientific studies, thorough field tests, and suggestions for fertiliser use based on the results of soil tests have all helped to demonstrate the advantages of soil testing.

The intrinsic ability of soil to provide plant nutrients and the productivity of the soils can be evaluated using a reliable scientific tool called soil testing. To ensure national food and nutritional security, to maintain soil health, to increase soil fertility, and to leave a positive legacy for future generations, it becomes essential (RCFL, 2008). A soil test is crucial for a number of reasons, including maximising crop production, protecting the environment from runoff and excess fertiliser leaching, assisting in the diagnosis of plant culture issues, enhancing the nutritional balance of the growing medium, and saving money and energy by using only the necessary amount of fertiliser.

Soil testing is usually carried out as part of a programme, consisting of four phases: **(1)** Soil sampling, **(2)** Sample analysis, **(3)** Data interpretation and **(4)** Soil management recommendations.

History and development of soil testing:

As part of the Indo-US Operational Agreement for "Determination of Soil Fertility and Fertilizer Use," 16 soil testing laboratories were established in the country at the start of the planning era. To support the Intensive Agricultural District Programme (IADP) in certain districts, nine further soil testing laboratories were built in 1965, and 25 additional soil testing laboratories were added in 1970. The Government of India has supported this programme over many plan periods to strengthen the nation's capability for soil analysis. Dr. N.P. Datta and his colleagues at IARI owe a lot of early work on soil testing (Datta and Kamath, 1959).

Objective of soil testing:

The primary goal of the soil testing programme is to provide farmers with a service that will result in better and more efficient fertiliser use as well as better soil management techniques for raising agricultural output. Without enough fertiliser to make up for any shortages, high crop yields cannot be achieved (Das *et al.*, 2014).

- To evaluate the fertility and nutrient status of soil for providing an index of nutrient availability or supply in a given soil.
- Determination of acidity, salinity and alkalinity problems.
- To provide a recommendation on the amount of manure and fertilizer based on soil test value and according to crop.
- To avoid excess use of fertilizer and to ensure environmental safety.
- When crops are harvested, a considerable amount of nutrients are removed from the soil and causes loss of fertility in soil over a long period of time. So, the soil should be tested.
- Evaluation of the suitability of the soil for the crop.
- Restoration of soil fertility is a key factor for crop productivity, profitability and sustainability.
- Fertilization programme must consider crop needs, soil supply, fertilizer use efficiency, the contribution from manures etc.
- Time to time evaluation of the inherent soil fertility status is essential for arriving at the crop and site-specific balanced fertilization program to sustain productivity.
- To predict the probability of obtaining a profitable response to and fertilizers.

Importance of soil testing:

(i) Learn about the soil condition and how to improve it

Healthy crops require fertile soils to grow. It must first be quantified in order to increase soil fertility. The physical, chemical and biological properties of the soil govern its fertility. It is possible to see the texture, colour, and structure of the soil. The chemical makeup of soil, however, cannot be seen. The importance of soil sampling can be attributed to the requirement to measure this. To ascertain a soil's pH level and nutrient content, soil tests are utilised. With this knowledge, the precise kind and amount of fertiliser that must be used to increase soil fertility may be determined.

(ii) First step into soil fertility management

Farmers can maximise the effectiveness of nutrients and water utilisation and enhance their agricultural productivity by using an appropriate soil fertility management approach. The first step in effective soil fertility management is soil testing. You may improve the health of your soil by using the information that comes from soil testing.

(iii) Minimise fertiliser expenditures

If you are aware of the precise type and quantity of fertilisers your soil and crops require, you won't squander money on unnecessary purchases. Additionally, resources for inorganic fertilizers in general and minerals like phosphorus and potassium are few. Since their prices have been rising over time and this tendency is expected to continue, it is wise to prepare for the upcoming adjustment now.

(iv) Avoid over-fertilisation

Over-fertilization may result from fertilizer application without knowledge of your soil's real nutritional requirements. You may prevent using too much fertilizer by evaluating your soils and getting fertilizer advice. This is beneficial for the environment and your crops. Over-fertilizing crops results in fertilizer burn and yellowing foliage. Additionally, it can cause nutrient leaching, water contamination, and permanent harm to the aquatic species in the area.

(v) Prevent soil degradation

Every farmer faces a risk from soil erosion. According to estimates, improper soil management causes 24 billion tonnes of fertile soil to be lost annually owing to erosion. Testing the soil first, then applying the necessary fertilizers when they are needed ensures proper soil management. It is a more effective and lucrative approach in addition to reducing the concerns of soil deterioration. Additionally, soil restoration is an expensive, time consuming and challenging operation.

(vi) Identifies contaminated soils

The techniques used for soil testing assist the environment as well as farmers' concerns. Numerous businesses, factories, and even residential and commercial sites release dangerous chemicals into the ground or water (which ultimately gets mixed with nearby soil). In these situation, the land loses its fertility and becomes a problem for the ecosystem. Soil testing can be a big help in preventing these situation. Additionally, plastic and litter are dumped in large, open spaces without proper garbage disposal. Soil testing can be useful in preventing such lands. The process aids in not only determining what contaminants are present in the soil but also in determining the appropriate course of action.

(vii) Helps in construction

The carrying capability of the soil and its structural stabilisation are both determined through soil testing. Soil testing is done at the start of construction projects to prevent exposure to unidentified risks.

Soil Health:

The ability of soil to continue to serve as a vibrant living ecosystem that supports humans, animals, and plants is known as soil health. Clean air and water, abundant crops and for ests, productive grazing pastures, a variety of wildlife, and stunning landscapes all result from healthy soil. Soil does all this by performing five essential functions:

- Regulating water
- Sustaining plant and animal life
- Filtering and buffering potential pollutants
- Cycling nutrients
- Providing physical stability and support

Soil Health management:

The main principles to manage soil health that improves soil function are:

- Maximize Living Roots
- Minimize Disturbance
- Maximize Soil Cover
- Maximize Biodiversity

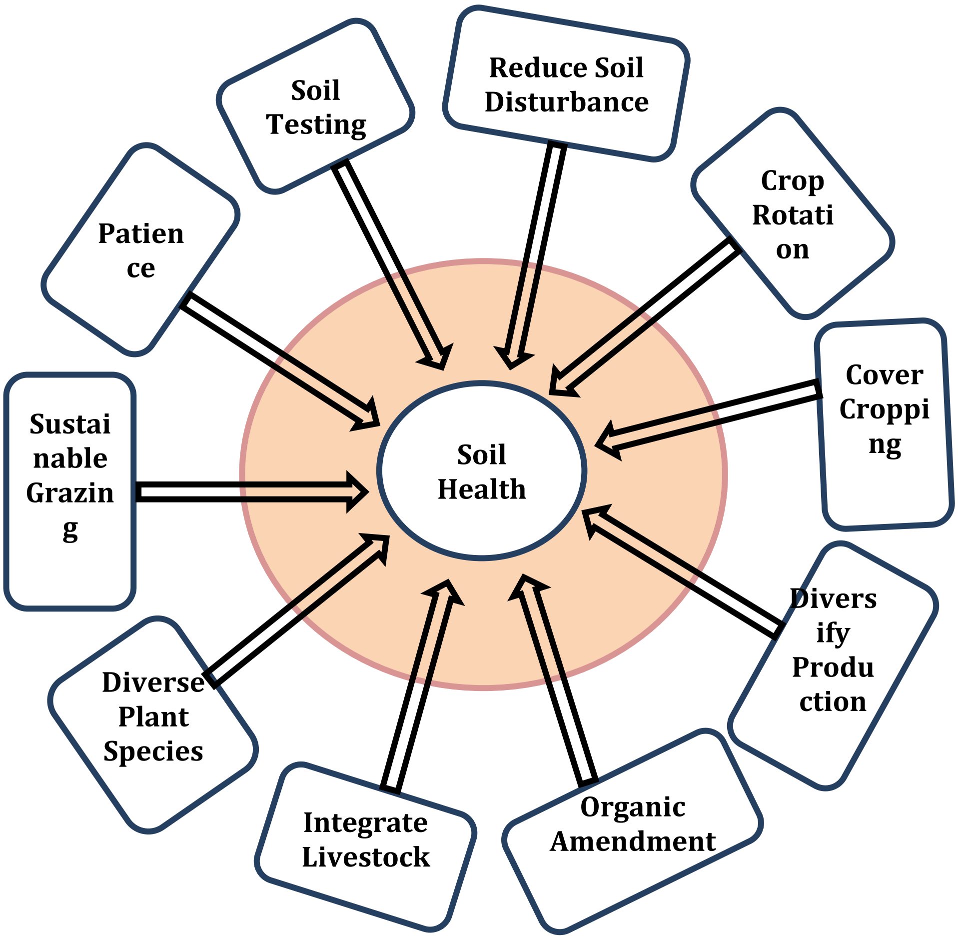

Figure 2: Strategies of soil health management for sustainable productivity (John, 2019)

Soil health indicator:

Indicators of soil health are a collection of quantifiable physical, chemical, and biological c haracteristics that are related to the functioning of soil processes and can be used to assessthe stat e of soil health as it is impacted by management and climate change factors. The main connection between agricultural conservation management systems and the accomplishment of the main objectives of sustainable agriculture is thought to be soil quality or health (Parr *et at.*, 1992 and Gregorich and Carter, 1997). In essence, the primary indicator of sustainable land management is the evaluation of soil quality or health and the direction of change over time (Karlen *et al.*, 1997). Research and governmental groups are promoting soil health "tests" that prescribe a minimum data set of soil health indicators for agricultural management (Nelson *et al.*,

2009) and to assist monitoring efforts and policy development (Ritz *et al.*, 2009 and Schindelbeck *et al.*, 2008).

Table 1: Soil health and relation to processes and functions

Soil health indicator	Soil processes affected	Landscape Scale
Physical indicators		
Soil structure	Aggregate stability, organic matter turnover	Aggregation, surface seal, indication of water and chemical retention and transportation
Porosity	Air capacity, available water capacity, relative water capacity	Soil crusting, reduced seed germination, aeration, water entry
Infiltration	Soil water availability and movement	Potential for leaching, productivity, erosion
Bulk density	Soil structural condition, compaction	Volumetric basis for soil reporting
Soil depth and rooting	Available water capacity, Sub soil salinity	Productivity potential, uncertain weather trends can be discerned over longer periods
Soil-plant available water and distribution	Field capacity, permanent wilting point, macro pore flow, texture	Water and chemical retention and transportation, yield
Soil protective cover	Soil water and nutrient movement, soil stabilization, C and N fixation	Soil physical movement, organic matter input and movement
Chemical indicators		
pH	Biological and chemical activity thresholds	Soil acidification, salinization, electrical conductivity, soil structural stability
Electrical Conductivity	Plant and microbial activity thresholds,	Leachable salts, soil structural decline
Plant available N, P and K	Plant available nutrients and potential for loss	Capacity for crop growth and yield environmental hazard (e.g. algal bloom)
Soil Organic Matter (light fraction, macro-organic matter, mineralizable N and P	Plant residue decomposition, organic matter storage and quality macro aggregate formation, metabolic activity of organisms, Inorganic N flux from mineralisation and immobilization	Loss of soil organic matter, soil aggregate formation, Total organic C, soil respiration rate, nutrient supply, microbial activity, nutrient supply

Biological indicators		
Soil total carbon and nitrogen	Carbon and nitrogen mass and balance	Soil structure, nutrient supply
Soil respiration	Microbial activity	Microbial activity
Microbial biomass carbon and nitrogen	Microbial activity	Soil structure, nutrient supply, pesticide degradation
Microbial diversity	Substrate use efficiency	Substrate quality
Enzyme activity	Nutrient cycling and availability, Labile carbon	Biochemical activity, nutrient supply

Source: Allen *et al*., 2011

Table 2: Suggested management strategies for addressing soil health constraints

Suggested management practices		
	Short term or intermittent	**Long-term measures**
Physical concerns		
Low aggregate stability	Fresh organic materials (shallow-rooted cover/rotation crops, manure, green clippings)	Reduced tillage, surface mulch, rotation with sod crops
Low available water capacity	Stable organic materials (compost, crop residue high in lignin, biochar)	Reduced tillage, rotation with sod crops
High surface density	Limited mechanical soil loosening (e.g. strip tillage, aerators); shallow rooted cover crops, bio-drilling, fresh organic matter	Shallow rooted cover/rotation crops; avoid traffic on wet soils; controlled traffic
Chemical concerns		
Unfavourable pH	Liming material or acidifier	Repeated application based on soil tests
Low P, K and minor elements	Fertilizer, manure, compost, P-mining cover crops	Application of P, K materials based on soil tests; increased application of sources of organic matter, reduced tillage
High salinity	Subsurface drainage and leaching	Reduced irrigation rates, low salinity water source, water table management
High sodium content	Gypsum, subsurface drainage and leaching	Reduced irrigation rates, water table management

Biological concerns		
Low organic matter content	Stable organic matter (compost, crop residue high in lignin, biochar), cover and rotation crops	Reduced tillage, rotation with sod crops
Low active carbon	Fresh organic matter (shallow rooted cover/ rotation crops, manure, green clippings)	Reduced tillage, rotation
Low mineralizable N (low PMN)	N-rich organic matter (leguminous cover crops, manure, green clippings	Cover crops, manure, rotation with forage legume sod crop, reduced tillage

Source: Cornell Soil Health Manual, 2009

Impact of soil testing

(a) Agronomical:

The most typical method for determining whether crop yields will respond favourably to fertilizer and lime treatments is soil testing. This is not only denotes an inefficient use of fertilizers, but in some situations an inefficient use of fertilizers may actually impair crop output (Ministry of Agriculture, 2012). The results of soil testing have an indirect impact on crop output and growth. These impact can help the farmers are:

- ❖ Increasing consistency of nutrient availability across a field.
- ❖ More uniform crop growth. This also helps individual plants stronger against weeds and simplify other processes like cultivation and spraying.
- ❖ More uniform plant maturity. This can help simplify crop harvesting and drying along with improving market quality.
- ❖ Improving yields and profitability because providing necessary nutrients to crops.
- ❖ Allowing fine-tuning of which nutrients are most needed.

(b) Environmental and Social:

Soil testing can also impact on environmental and social. Regular usage can wear out the land on which you grow your crops. The biggest impact of soil testing has on environmental and social are:

- ❖ Providing the right level of nutrients helps increase yields and may help reduce the need for intensively farming marginal land
- ❖ Poorly nourished crops leave less plant residue to hold soil in place. Plant residue helps build soil and saves it from wind and water erosion.
- ❖ More efficient use of plant nutrients means fewer losses from leaching or runoff into water layer.

If soils are in good condition, they may be able to offer society a variety of "ecosystem ser vices," which are resources or functions that come from the natural environment and are beneficial to people (Haygarth and Ritz, 2009). Supporting services such nutrient cycling, water release and storage, soil formation, habitat for biodiversity, greenhouse gas exchange with the atmosphere, and the breakdown of complex materials. Regulatory services, such as the control of flooding, the storage of carbon and other greenhouse gases, the retention of infections, pollutants, and agrochemicals. Providing a foundation for the production of food and fibre as well as recharging water sources are example of provisioning services. For example, soils maintain habitats, provide for leisure activities, and preserve archaeological artefacts as cultural services (Sharma and Sharma, 2016).

Constraints for soil testing programme

- The main obstacle is that farmers lack a scientific method for taking soil samples from a particular field.
- It may be another constraints that a large number of soil testing laboratories have shortage of qualified technical personnel along with man power is the most important limitation in successfully running the programme on sound scientific ground.
- Sometimes the farmers may not get the results of the soil tests and fertiliser recommendations in time to make fertilizer purchases. The period of time between collecting the sample and receiving the soil test report is considerable.
- Capacity of the soil testing labs to analyse the soil samples are inadequate and lack of insufficient soil testing laboratory and mobile soil testing van in the country.
- A lack of new technology and laboratory automation.
- Weak and insufficient links between STLs and SAUs and other research institutions.
- The level of training assistance provided to STL staff by research groups is inadequate.

Present scenario:

Without technical officers and extension officers, popularising soil sampling and testing would be an impossible endeavour in India. Farmers need robust extension support to help them adopt scientific soil sampling procedures for effective soil sampling and soil testing. About 5000 testing laboratories have been established by the Indian government, state governments, and agricultural colleges, but this number is insufficient to analyse the massive soil samples taken from each block and tehsil.

Suggestion:

- Opening additional, transportable soil testing labs at the block/tehsil level in each district throughout the state and equipping them with expertise, technical support, and materials would be helpful in overcoming the limitations.

- ❖ Each soil testing laboratory may be provided with the necessary staff and headed by a technical person with an M. Sc. (Soil Science and Agricultural Chemistry/ Agronomy) as an essential qualification.
- ❖ Since inadequate technical knowledge on proper soil sampling is a barrier to increasing crop production, progressive farmers and other extension personnel involved in the process should receive training and capacity building on the specifics of soil sampling and testing. This will remove the misgivings of farmers about true soil test results.
- ❖ Follow the steps in the scientific soil sample procedure.
- ❖ Extension initiatives to spread awareness of soil sampling and testing as a way to generate cash by avoiding the extra expense of fertilisers.
- ❖ The results of the soil test allow farmers the chance to choose crops based on soil quality and fertilizer application in the proper amounts and methods, which not only saves money on fertilizer costs and time but also effectively protects the environment.

Conclusion:

Soil testing for agronomic crop production is a reliable, scientifically based method for predicting crop responses to nutrient applications. It need a robust research programme and supporting data base to establish levels and nutrient recommendations. Despite the fact that environmental soil testing is still in its early stages, some generalizations may be made about it. Due to the numerous variables that affect how quickly nutrients are released from soil into the environment, a soil test value alone will not be able to reveal the influence of a field on water quality, and determining essential levels will necessitate additional research. However, a soil test value may identify fields that require additional evaluation of landscape and management factors to assess the risk particular fields may pose on water quality.

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SOIL EROSION: EXTENT, CAUSES, CONSEQUENCES AND MANAGEMENT IN INDIA

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What is soil erosion?

India has a widespread problem of soil erosion, which poses a major risk to human life and wellbeing. The process by which soil particles are detached from their initial location and moved by geomorphic processes is known as soil erosion. Transportation is the movement of detached soil particles (sediment) from the soil bulk. Although soil erosion is a naturally occurring phenomenon, human activity usually causes soil detachment and transport.

It can be found in regions that have experienced natural or geologic disturbances, such as forests, arid and semi-arid lands and agricultural fields, building sites, degraded lands, mineral mines, glaciated and coastal areas. In the worst case scenario, the soil could completely disappear and the bed rock could become visible. Given how slowly soil forms, after it has been fully removed, it will take hundreds or perhaps millions of years for the soil to regenerate, rendering the area unusable and unproductive throughout that time. The emphasis of this chapter is on this accelerated or human-induced erosion.

Causative agents of erosion: water, wind and tillage

In some parts of the world, all three forms of erosion operate simultaneously in the landscape. Though in India, water is responsible for nearly 90% of all erosion and affects the greatest land area. The identification of the processes taking place at a location is an important component of erosion control (Lal and Elliot, 1994).

Two forces—those exerted by water flowing across the surface and those caused by raindrop splashing on the soil surface—cause soil to separate from the soil mass (runoff). Thin sheets of runoff that are moving over the surface are the first to carry the separated dirt by flowing water (sheet erosion). The erosive power of the river is substantially amplified in both of these types of channels where the surface runoff frequently concentrates in small channels (rill erosion) or deeper incisions (gully erosion). One of the most obvious evidence of erosion occurring in the landscape are the rills and gullies caused by water. Sometimes, when the depth or velocity of runoff is lowered instance, when the running water encounters a vegetative barrier—the soil in the flowing water (sediment) settles out of the water. As a result, eroded soil is deposited. However, in a lot of other situations, the runoff and sediment are transported to a stream system and are completely eliminated from the landscape.

Soil Erodibility: Is a measure of the soil's susceptibility to detachment and transport by the agents of erosion. Based on each soil's unique physical properties erodibility is primarily influenced by texture, but structure, organic matter, and permeability also play a role. In general, soils with quick infiltration rates, more organic matter, and better soil structure resist erosion better. Silt, very fine sand, and clayey soils are more susceptibe to erosion than sand, sandy loam, and loam-textured soils.

Forms of water erosion

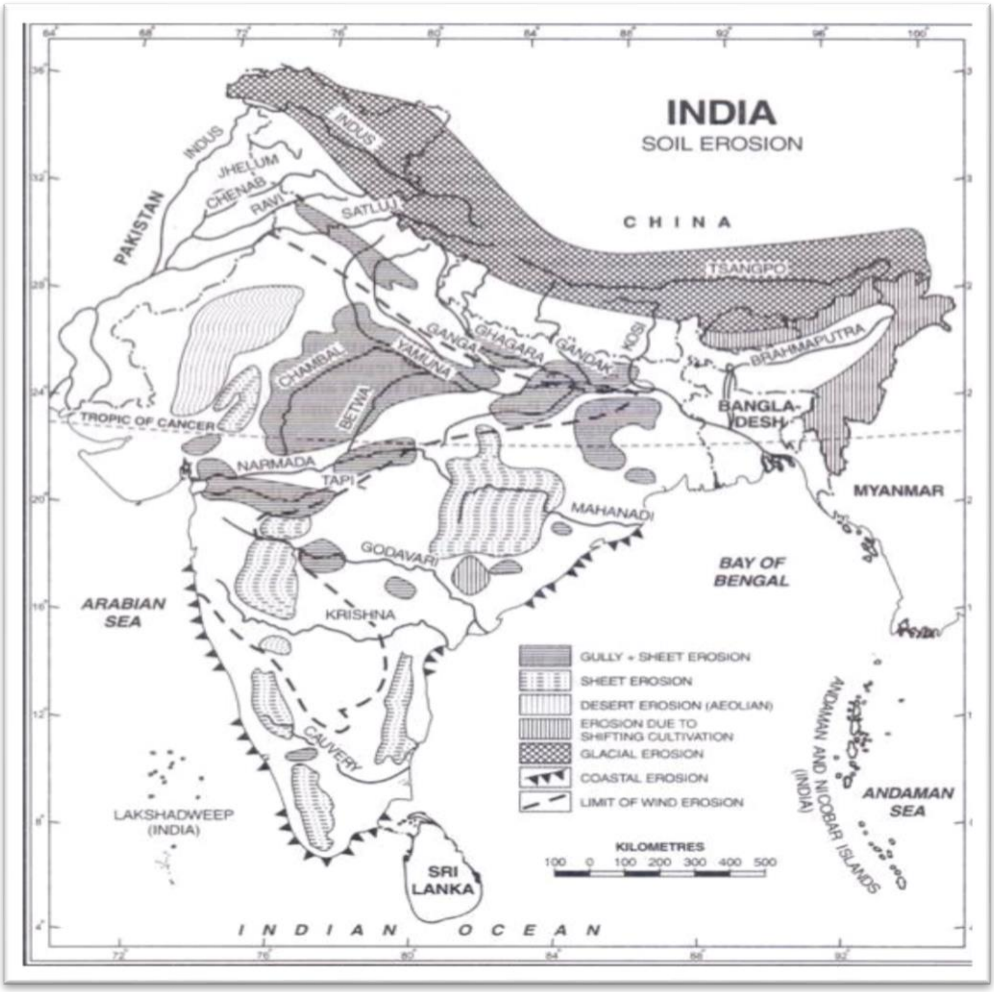
i. Splash erosion: Water during heavy rains removes a lot of top soil. When rain drops strike the surface, sand and silt particles are detached from the soil body.
ii. Sheet erosion: As rainfall continues, a large amount of water flows in the form of surface run-off in thin sheets which removes the visible top soil from a large area.
iii. Rill erosion: Numerous small channels may develop throughout the area as a result of higher run off velocities along areas of higher gradient and soft parent material. Where water rushes quickly, like around the borders of highways and levees, such grooves or channels appear on the surface.
iv. Gully erosion: Gully erosion is an advanced stage of rill erosion. These rills could deepen and grow into gullies. Gully formation may influence large regions, turning the entire region into badlands. The lateral and vertical erosion of rills causes gully erosion. Gully formation is more likely to occur in sandy soils. Ravines of Yamuna and Chambal are formed similarly.
v. Littoral erosion: Sea waves, tidal waves, and tsunamis crash against the coast in coastal regions and severely harm the land. Littoral erosion is what this is, and it is most severe along the Kerala coast.

Wind erosion is the main type of erosion, most common in dry and semi-arid regions. The three routes of transportation for wind-detachable particles are creep, saltation, and suspension. The majority of creep particles, which are typically medium to coarse sand-sized soil aggregates, roll around the surface before being trapped and deposited. Small hops are made by saltating particles, which are typically fine to medium sized sand particles or aggregates, as they move across the surface. Usually in the clay- to extremely fine sand-size range, suspended particles or aggregates go into the upper atmosphere where they can travel enormous distances.The wind stream is used to carry soil, and the distance travelled depends greatly on the size of the grains being moved.

Tillage tools like the MB plough are used in tillage erosion for both soil detachment and soil movement. Contrary to water and wind erosion, tillage erosion is more difficult to visually detect when it is happening, which results in the net downslope movement of soil as a result of these tillage operations. Upper slope areas' soils thin out as a result of tillage erosion, and lower slope positions' depositional soils may get over-thickened.

Each entails unique methods for separating and moving soil, so each calls for unique measures to lower the associated rates of erosion. Variations in rainfall, runoff, soil properties, topography, and cover conditions affect the pace of detachment. Therefore, the interactions between climate, hydrological, morphology, topography, topsoil conditions, and all these significant aspects impact the rates of erosion.

What is the extent of soil erosion in India?



Soil erosion in India (Reference: http://www.agrilearner.com/)

According to the National Bureau of Soil Survey & Land Use Planning (NBSS & LUP), soil erosion affects an area in India of roughly 119.2 million hectares. 16.35 tonnes per hectare, or 5000 million tonnes annually, is the average rate of soil erosion in the nation. About 1600 m tonnes, or 30% of the entire degraded region, are being lost to the sea forever (Dhruvanarayana and Ram Babu, 1983), 10% is deposited in reservoirs, which reduces the storage capacity of those reservoirs by 2 % annually, and the remaining 61 percent is still being moved around.

Out of the 305.9 million hectares of reported land, it is thought that 145 million hectares in the nation require conservation measures.

Where does erosion commonly occur in India?

In states like Assam, Meghalaya, Tripura, Manipur, Mizoram, and the Western Ghats, soil erosion is a major issue on the hillslopes with heavy rainfall. Additionally, it can be found in some areas of Madhya Pradesh, Karnataka, Tamil Nadu, and Maharashtra, Andhra Pradesh.

Table 1: Levels of erosion in India

Severity of Erosion	Annual Soil Loss Range (tonnes per hectare)	The Share of Total Affected Area (%)	Annual Loss of Soil (million tonnes)
Slight	<5	24	401
Moderate	5-10	43	1406
High	10-20	24	1610
Very high	20-30	5	640
Severe	30-40	3	666
Very severe	40-80	1	255
Total	>80		4978

Source: Singh, G (1990).

According to Sehgal and Abrol (1994 and 1997), water and wind erosion cover approximately 162.4 (1994) and 167.0 (1997) million hectares of land in India, with water erosion accounting for nearly 91% of this total.

The main causes of rapid water and wind erosion were found to be deforestation, overgrazing, and the expansion of agriculture into marginal areas, road development, land use changes, and illogical agricultural practices. In India's arid and semi-arid regions, sandy soils with little organic matter and moisture are particularly vulnerable to strong winds. The scorching desert of India and its surrounding areas, the frigid deserts of Leh, and coastal landscapes are all characterized by wind erosion. Wind erosion occurs across a surface area of almost 13.5 million hectares.

According to the National Bureau of Soil Survey & Land Use Planning (NBSS & LUP, 2005), approximately 119.2 million hectares of India's land are eroding due to soil. According to the most recent study by NRSA (2014), investigations done in the past without the use of satellite imageries show a striking similarity to the pattern of soil erosion in India as determined by the interpretation of satellite imageries. The most widespread erosional zones are those caused by water. The country's most western regions contain the severely wind-eroded region.

Effects of erosion on crop production and soil productivity

The disappearance of the rich surface soil horizon, the absorption of denser subsoil into the surface layer, and a potential reduction in the soil's rooting zone are the three main consequences of erosion on crop growth and yield (Van Oost and Bakker, 2012).

i. Each erosional occurrence destroys a small portion of the top organic soil layer. In some soils, a clay-enriched layer forms under the A horizon, and when this clayey material is incorporated into the surface layer, it results in a denser, cloddier layer that is less conducive to crop seed germination. The loss of surface material causes the soil's capacity to hold and supply nutrients to decline, with the latter effect being more severe in sandy soils. This nutrient removal can be managed by applying fertilizers which in return pollute the surface water.

ii. The thickness of soil between the surface and the growth-restricting layer diminishes when erosion eliminates the top layer of soil, which may restrict the development of crop roots. Significant yield decreases may occur once the plough layer incorporates the growth-limiting layer into the plough layer. The impacts of subsurface integration on yields are largely irreversible on human timeframes, in contrast to the situation when nutrients are replaced by fertilizer.

iii. Sehgal and Abrol (1994) claim that water-induced soil erosion affects soil productivity by between 12% in deep soil and 73% in shallow soil, with the loss being greater in red and black soils compared to alluvial soils.

iv. Crop yields for food, fibre, and fuel are the principal impact of these erosion-induced changes to soil productivity.

v. The amount of soil organic carbon (SOC) that is stored in the landscape is significantly impacted by erosion. Every time with an occurrence of erosion, a small amount of soil is removed off the surface, which contains more soil organic matter (including SOC) than the horizons beneath it.

vi. High sediment inputs into the stream channels and increased sedimentation into wetlands nearby are results of human-caused water erosion. Multiple impacts result from increased sedimentation and sediment amount (Owens *et al.*, 2005).

vii. The contamination of water bodies by fertilizers and other agrochemicals, such as pesticides, is also a result of soil erosion. Due to this pollution, streams become eutrophic, which affects aquatic life and has direct deleterious consequences on species. Phosphorus is a particular concern for eutrophication. Phosphorus is firmly held by the solid phase and is carried as disintegrated solid particles, as well as along with of manure and human waste (Yuan *et al.*, 2018)

viii. According to Derpsch *et al.* (2010), natural sources account for 75% of worldwide dust emissions whereas anthropogenic or human-caused sources account for 25%. The intake of tiny particulate matter by people during dust storms directly affects human health.Due to decreased sight, dust deposition causes power loss from solar panels, which lowers the photovoltaic performance of the panels, dust storms also have an influence on ground and air transportation.

ix. Landscapes are clearly harmed by erosion when the subsoil is exposed, rills and gullies are present, or dust storms occur. The impact of this degradation on a community's sociological, spiritual, and cultural values can be severe and go well beyond just economics.

Sustainable management of soil erosion:

i. Approach to control soil erosion involves minimizing deforestation or faulty conversions of grassland to crops that expose the soil to erosion. Increased mineralization (caused by aggregate breakdown and microclimate changes) and higher erosion losses are two effects of land use change on soil organic carbon (SOC) loss.

ii. Preventing soil surface erosive processes as well as reducing runoff depth and speed on hill slopes. While some strategies, like no-till/reduced tillage, maintain the surface while also reducing runoff, others, like terrace development and upkeep, are primarily concerned with the latter.

iii. Keep the surface soil covered by growing plants, organic and/or inorganic leftovers, to prevent erosion. Mulching, no-till by direct sowing (with an emphasis on reducing pesticide usage), cover crops, and agro-ecological methods such as crop rotation, agroforestry, shelterbelts, strip farming, and maintaining the right grazing intensity rates.

iv. Physical barriers across the slope, particularly in areas with concave slope where runoff converges across slope. The most well-known of these physical solutions are terraces, but other options include strip cropping, contour planting, cross-slope slope barriers including grass strips, contour bunds, and stone lines, grassed rivers, and vegetative buffer strips.

v. Reducing or eliminating the quantity of tillage of the soil surface is the most often used strategy (Derpsch *et al.,* 2010) to reduce soil erosion. Depending on how much mechanical disturbance there is and how much residue is still present, the method is referred to as no-till, zero till, reduced tillage, or conservation tillage. Remainders are kept on the soil's surface when tillage is reduced.

vi. Using vegetative techniques like grass strips and shrub and tree barriers, one can reduce runoff and capture sediment both on- and off-site (Mekonnen *et al.*, 2015). These actions have the huge benefit of being easily done utilising native grass and shrub species.

vii. Terraces physically change the slope's gradient by segmenting it into a series of horizontal steps. Terraces effectively cut down on soil erosion. For instance, Montgomery (2007) demonstrated that erosion rates for terraces used to grow rice were lowered to almost geological rates.

viii. With the advent of planned development, the Indian government recognised the need of conserving soil and water. A network of centres for soil conservation, research, demonstration, and training was built during the first and second five-year plans. The Central Soil and Water Conservation Research and Training Institute (CSWCRTI), with its headquarters in Dehradun, was founded in 1974 after these centres were later handed to ICAR in 1967.

ix. Launched in 1982–1983, the programme "Integrated Watershed Management in the Catchments of Flood Prone Rivers" (FPR) is currently being conducted in 291 watersheds in 8 catchments located in 8 States. By reducing soil erosion in the catchments of rivers that are prone to flooding, the goal is to decrease flood frequency and extent. With an emphasis on soil and water conservation, the Fifth Drought Prone Area Programme (DPAP) and Desert Development Programme (DDP) were also put into practise. The Integrated Wasteland Development Project (IWDP, 1995) and the National Watershed Development Programme for Rainfed Areas (NWDPRAs) both focused on sustainable use of soil and other resources in 1990–1991.

x. The River Valley Projects (RVP) for Soil Conservation in the Catchments was initiated in 1962. By integrating watershed scheduling with appropriate measures like vegetative trees and bushes, contour/graded bunding, agroforestry, horticulture plantation, silvi-pastoral development, pasture development, afforestation, etc., the scheme aims to reduce the premature silting of reservoirs and increase the productivity of catchment areas.

Conclusion:

India's soil erosion is a result of both natural and man-made forces. The rates of erosion are influenced by a number of important elements, including climate, hydrology, structure, terrain, soil surface conditions, changes in land use and land cover, and interactions among these primary components. All sections of the country experience water erosion, but wind erosion is more prevalent in the west. The entire economy is negatively impacted by soil erosion both locally and outside. Siltation in reservoirs, tanks, and rivers is caused by soil erosion. Reduced agricultural yield and productivity are a direct result of the depletion and deterioration of soil base caused by erosive processes. More regular and consistent data bases are needed in order to evaluate the degree of soil erosion throughout time and area. The strategy for watershed management is India's most popular method of preventing and controlling soil erosion. Soil conservation and management are necessary to attain the goal of sustainable development (Saroha, 2017).

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RENEWABLE ENERGY FOCUS IN AGRICULTURE

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Inroduction:

In India, renewable energy sources including wind, solar, biomass, small hydropower, etc. account for roughly 16 percent of energy generation, while coal continues to be the primary source, accounting for about 60 percent of overall generation (Ali *et al.*, 2012). Interest in the scientific exploitation of renewable sources of energy has increased due to the growing threat of an acute lack of commercial energy sources paired with major environmental contamination issues (NAAS, 2018). India is ranked 10th globally for solar Photovoltaic system but 5th globally for the installation of all wind energy. The amount of solar energy that is blocked by the earth is roughly 1.8 x $l0^{11}$ MW. One of the most promising unconventional energy sources as a result. The majority of our nation's land is covered in solar energy throughout the year. India's yearly average daily solar radiation is about 1800 J/cm^2/day across the whole nation. It has long been customary to dry many agricultural products in direct sunshine.

Scope of renewable energy in farming sector

India has a potential for 900 GW of commercially viable renewable energy, according to estimates. The potential for solar power is about 800 MW, the potential for wind power is roughly 104 GW at 80 metre tower height, the potential for bioenergy is 25 GW, and the remaining potential is for other renewables.

In India, the average daily sun radiation on horizontal surfaces is 5.6 kWh m^{-2}, and It is 6 to 6.5 kWh m^{-2} day^{-1} in west India. However, Leh and Ladakh, receives the most approximately 7–7.5 kWh m^{-2} day^{-1} of solar irradiation. The greatest concentration of April receives the most radiation per year (6.5–7.5 kWh m^{-2} day^{-1}), while December is the month with the lowest minimum (4.5-5.5 kWh m^{-2} day^{-1}).

The country has a 50 m height wind potential of roughly 104 GW. This has a 49,130 MW coastal potential. With projected potentials of 35.07, 14.49, 14.15, and 13.59 GW, respectively, the majority of the wind energy potential is located in the states of Gujarat, Andhra Pradesh, Tamil Nadu, and Karnataka. The wind energy potential is roughly 5.05 GW in the Indian deserts that surround western Rajasthan.

Accessible renewable energy technologies in agriculture

I. Solar thermal technology

1. Solar cooker

Directly and indirectly focusing solar cookers are of two main sorts. For residential cooking, the indirect type solar cookers, which consist of an insulated box with a transparent window that lets sunlight in, have been successfully designed and commercially used. Solar cookers can be used to cook a variety of foods, including rice, lentils, vegetables, and dal, as well as to roast nuts, boil potatoes, bake vegetables, make bati, and prepare regional dishes. The solar cooker has a 24.6 percent total efficiency. Through State Energy Development Corporations or other nodal organisations, such solar cookers are being commercialized in the majority of the states.

2. Solar dryer

The most typical use of solar energy is to dry various agricultural products in the open sun. Fruit, vegetables, and cereals can be efficiently dried using a solar dryer, which also solves the issues associated with open-air drying, such as dust contamination of dried goods, insect infestation, and product degradation from unexpected downpours. Different forced and natural circulation sun dryer designs have been created in various regions of India. For a variety of commodities, natural convection and forced convection type solar dryers have been created with the goals of speeding up the drying process and enhancing the quality of the produce. In contrast to the forced convection solar drier, which uses a power blower to move the air. Natural heat gradient causes the product to be dried by natural convection as it passes through. The dryer's effectiveness is 17.57 %. Depending on how damp the product was when it was first harvested, a 1 m^2 glass collector dryer may dry 10–12 kg of fruits and vegetables in 12–24 hours. The price of an inclined solar dryer is roughly Rs 9000 per m^2 of collection area.

3. Solar water heaters

Traditional methods for producing hot water include heating with conventional energy sources like firewood, cow dung, electricity from thermal power plants, and fossil fuels including kerosene, LPG and coal. Every time these traditional energy sources are used to heat water, a sizable amount of CO_2 gas is released into the environment and causes air pollution.

As an alternative, hot water can be generated using solar water heaters, which use renewable solar energy. Natural circulation and collector-cu-storage solar water heaters are the two types that are most frequently utilized for home purposes. Both of these water heaters use flat glass collectors to gather solar radiation.

4. Solar cooker for animal feed

Solar cooker for animal feed, which is typically used to boil feed. Materials that are readily available locally, such as clay, pearl millet husk, and animal dung, can be used to construct the animal feed solar cooker. Farmers have used the animal feed solar cooker to effectively boil feed materials including cotton seed and khal. The solar cooker for animal feed has a thermal efficiency of about 21.8%. The solar cooker for animal feed saves roughly 1059 kg of fuel wood annually, or 3611 MJ of energy. Additionally, using the solar cooker to cook animal feed would save CO2 emissions by 1442.64 kg annually.

5. Solar distillation unit

People rely on either surface water, which is a basic requirement for life, or groundwater resources like wells, tube wells, or groundwater resources like ponds, lakes, rivers, etc. Recent years have seen a decline in both the amount and quality of freshwater due to improper water use, salt pollution, heavy metal contamination, etc. Drinking water supply in such circumstances is a serious issue, especially in arid regions where water is extremely rare. In such urgent circumstances, a solar distillation device can transform brackish water into distilled water using solar energy. Solar distillate production still needs to be blended with the proper standard minerals in the right amounts before it is fit for consumption. It was discovered that these stills' thermal efficiency varied from 20 to 34 percent from winter to summer, and their productivity ranged from 1.0 to 3.3 litres m^{-2} day^{-1}.

6. Agri- voltaic system

As the sun moved across the sky with the current AV system, the PV modules shaded the ground on the leeward side. A separation gap between two arrays is kept in place to prevent one PV array from shading the next array. Suitable crops were grown in the interspaces between two PV arrays. Furthermore, as PV modules are installed over mounting structures at a specific height from the ground surface, the area below the PV module was also used to grow crops. However, choosing crops that can tolerate some shade and are shorter in height is necessary when planting crops between PV module arrays in order to prevent shading of the PV panels. Plant development is governed by the amount of solar radiation that is available under both direct (open sun) and diffused situations since the amount of photosynthetically active radiation (PAR) varies under each. Crop height is an important factor to consider when choosing crops for AVS because tall crops may shade PV modules, lowering PV generation. Therefore, the most suited crops for AVS in arid ecosystems are those with low heights (preferably less than 50 cm), which can withstand some shade, and require little water.

In an agri-voltaic system, the following crops are chosen to grow. While isabgol (Plantago ovata), cumin (Cuminum cyminum), and chickpea (Cicer arietinum) have been chosen for irrigated situations during the Rabi season, moong bean (Vigna radiata), moth bean (Vigna aconitifolia), and cluster bean (Cyamopsis tetragonoloba) were chosen as arable crops for rainfed situations. In addition to these arable crops, annual components include Spinacia oleracea (spinach), snapdragon, and medicinal plants such Aloe vera, brinjal, and aloe vera. lemon grass and palmarosa, two scented grasses, are chosen for growing in areas beneath PV modules (Poonia *et al.,* 2021). These plants should alter the microclimates beneath the PV modules, enabling the dry ecosystem to produce the maximum amount of PV. These plants are anticipated to alter the microclimates beneath PV modules, assisting with the best PV generation possible in arid ecosystems. Additionally, planting crops on the soil surface between PV arrays will prevent soil erosion caused by wind, lowering the amount of dust that accumulates on PV modules.

Through the use of a net metering system, the electricity produced by PV modules in an agri-voltaic system may be provided directly to the local grid. Agri-voltaic systems typically generate between 4-5 kWh kWp per day (Patrick, 2008). The sale of the electricity produced can bring upto Rs. 8.0 lakh per acre.

7. Photovoltaic solar pumping system

Solar energy is converted into electrical energy via photovoltaic water pumping systems, which then drive the water pump. Due to their low cost and environmental friendliness, solar water pumping technology might be seen as a possible replacement for electricity, diesel, or gasoline-based pumping systems. Even in the absence of an energy supply, solar pumping systems can collect water from a source (a river, basin, well, etc.). These systems enable access to water in the most remote regions and are frequently used to supply drinking water, agriculture, or to fill reservoirs.

PV systems can be utilised for drinking water delivery, water filtration, and desalination in addition to irrigation. It is imperative to have access to clean water, but in some parts of the world's developing nations, this benefit is not always available. In addition, a lot of rural areas lack access to a centralised system for supplying drinking water. Solar PV water pumping technology may be a good choice in these circumstances (www.trace-software.com).

Advantages:

- When compared to diesel- or gasoline-powered pumping systems, PV water pumping systems are more affordable over the long term.
- Since they don't need an attendant present while in use, they are dependable and low maintenance.
- Since the water can store itself, there is no requirement for energy storage.
- Photovoltaic water pumping systems with high flexibility may adjust to future growth requirements.
- A solar PV pumping system's PV panels reduce CO_2 emissions in the atmosphere at a rate of about 1360 kg CO_2 per square metre per year
- an assured power supply allows the farmer to increase crop yield
- During off-peak hours, energy generated from the solar PV pumping system could be used for domestic purposes and to power small farm equipment.

- PV water pumping technology is environmentally clean and does not pollute the air, water, or noise.

II. Wind energy

1. Wind turbine of Horizontal axis

In order to produce power from wind energy, a horizontal axis wind turbine (HAWT) with three blades mounted at the top of a tower between 60 and 80 metres high is typically employed. Wind turbines have a maximum kinetic energy capture rate of 59 percent.

Wind turbine installation efficiency in the field has been shown to range between 40 and 44 percent at an altitude of 80 metres. Turbines installed in fields in various regions of India range in capacity from 250 kW to 2 MW.

The amount of land needed to put a wind turbine in a field depends on the turbine's capacity and blade length.

2. Wind turbine of Vertical axis

By mounting a tiny vertical axis wind turbine (VAWT) that serves as a dual-purpose wind barrier. The barrier will be able to prevent wind erosion and turn wind energy into electricity. The barrier offers a sheltered distance of 15 H, where H is the height of the barrier. Using the designed wind barrier in the field, 6–10 kWh of power can be produced per hectare per day when the available wind speed is greater than 10 km/h during the summer months. Therefore, a small irrigation pump can be operated in an agricultural area using a dual-purpose wind barrier and VAWT.

III. Energy production using agriculture wastes

After deducting the country's many traditional utilities, India has an excess of or access to about 114 million tonnes of crop waste. These agricultural residues can be anaerobically digested to produce.

Agricultural concerns related to pollution, climate change, and other issues will be reduced by anaerobic digestion of crop leftovers. Renewable energy can be produced from biomass and agricultural waste in three primary ways:

- Gaseous fuels like biogas (methane),
- Liquid fuels like methanol, ethanol, butanol, or pyrolysis oil, and
- Electricity.

Biochemical and thermochemical processes are the two basic ways that biomass is converted into energy. Thermo-chemical processes such as heating, pyrolysis, combustion, and gasification are used to transform biomass into usable products. The procedures used in bio-chemical conversion involve both biological and chemical agents for degradation and are best suited for green biomass with higher moisture content and lower lignin levels. Biochemical processes are often slower than thermochemical processes in terms of speed. Both procedures are significant and make use of various feedstocks. In the context of Indian agriculture, woody type crop leftovers that are lignocellulosic and their biological disintegration is slow are amenable to thermo-chemical procedures. The steam turbine's exhaust can either be totally condensed to generate electricity or used partially or entirely for another practical heating activity.

IV. Hydroelectric form of energy

The natural flow of water is the source of hydroelectric electricity. The energy is created when water falls and turns a turbine's blades. The generator that turns the energy from the turbine into electricity is attached to it. The volume of water flowing through a turbine (also known as the water flow) and the height at which the water "falls" determine how much energy a system can generate (head). More electricity is produced the higher the flow and head.

The global sector that uses the most water is agriculture. 70% of the water used globally was for irrigation of agricultural land. Up to 95% of all water usage in some developing nations are for irrigation, which is crucial for both food production and food security. The ability to preserve, enhance, and grow irrigated agriculture is crucial to the future agricultural development.

A clean, domestic, and renewable energy source is hydropower. It generates no pollutants and offers cheap electricity. Hydropower, in contrast to fossil fuels, does not pollute water while generating energy. The only form of energy that can replace the electricity produced from fossil fuels is hydropower. The only renewable energy source that can both meet rising energy demands and replace the electricity generated by fossil fuels is hydropower.

Water is a resource that could lead to conflict between upstream and downstream nations. Since irrigated agriculture uses 70 to 90 percent of the water in many of these locations, it is the primary force behind much of the rivalry. Natural or other sources provide the water utilized in agriculture. Rainwater and surface water are examples of natural sources (lakes and rivers). Use of these resources must be sustainable.

V. Future of agriculture in India using renewable energy

Despite the recent considerable advancements in the production and application of renewable energy in agriculture, there are still numerous potential to significantly contribute to the 175 GW renewable energy target by 2022. Although there are many benefits to using or producing renewable energy in agricultural fields, farmers' fields and rural periphery acceptance of these technologies is far from satisfactory.

Due to the high installation costs, solar PV pumping systems are being installed all over the nation with 70–80% government funding. For instance, installing a 3 HP and a 5 HP solar PV pumping system in a farmer's field costs approximately Rs 3 lakhs and Rs 5 lakhs, respectively. Beneficiary farmers are successfully irrigating primarily horticulture crops using these pumps. Farmers have a strong desire to put the system on their fields, but fewer people than anticipated have been allocated benefits under a government subsidy programme. Bi - directional power metres or net metres can be connected to solar PV pumping systems to maximize their benefits.

Finally, when the depth of ground water rises, the size of solar PV modules in a solar PV pumping unit expands. Since PV modules make up the majority of the cost of a solar PV pumping system, the overall cost of pumping groundwater increases when the groundwater is deep.

Agri-voltaic systems give farmers the chance to generate electricity from their fields, which can boost their revenue. However, installing it is rather expensive. For instance, installing an agri-voltaic system on a single acre of land requires an investment of Rs 50–60 lakhs. Public-Private Partnership (PPP) models may be created to address this issue. A private entity will be in charge of PV installation and generating under the PPP model, while the landowner or farmers will be in charge of farming. KUSUM (Kisan Urja Suraksha Evam Utthaan Mahaabhiyan), a programme newly introduced, aims to install 10,000 MW worth of solar farming systems around the nation. Additionally, it is necessary to examine the performance of suitable crops for agri-voltaic systems in various agro-ecological zones of the nation.

Conclusion:

Finding sources of renewable energy to supplement today's diminishing quantities of readily available, reasonably priced fossil fuels is the only practical answer to the challenge of non-renewable energy. The only fully renewable energy source, at least for the foreseeable future, is solar energy. Renewable solar energy comes from a variety of sources, including windmills, falling water, solar collectors, and photovoltaic cells. Green plants are the most typical solar energy collectors. After all, plants were the first to capture the fossil fuels that we use today. Therefore, it makes sense to consider agriculture as a potential source of renewable energy.

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RUST: A MAJOR FUNGAL DISEASE IN WHEAT CROP

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Abstract:

Bread wheat (*Triticum aestivum* L.) belongs to family *Poaceae*, allo-polyploid (hexaploid) natue, with AABBDD type genome and is one of the world's primary staple food grain crops. Wheat is the leading source of basic calories (85 %) and plant-derived protein (82 %) in human food worldwide. Wheat production is constrained by various biotic and abiotic factors due to change in various environmental conditions. Biotic factors included fungal, bacterial, nematode and viral pathogens, which causes diseases to wheat crop. Among these pathogens, diseases caused by the rust fungi have since long been a major concern and problem for breeders, farmers and commercial seed producers. Wheat rust is the oldest well-known diseases and is important worldwide. Stem rust poses the greatest threat because it severely damages susceptible crops. Despite being under control in the majority of the world major production regions, serious genetic vulnerability still exists and active measures are being taken to incorporate new effective resistance in the majority of wheat-growing zones. In order to create resistant cultivars and understand disease epidemiology, plant pathologists and plant breeders have gradually decreased epidemic intensity and frequency of epidemics. In context of climatic change, the breeding programme for disease resistance still needs to be strengthened. So, integrated disease management (IDM) is an effective way to control the spread of wheat rust.

Keywords: Climatic change, disease resistance, genetic vulnerability and plant breeders

Introduction:

Bread wheat (*Triticum aestivum* L.) belongs to family *Poaceae*, allo-polyploid (hexaploid) natue, with AABBDD type genome and is one of the world's primary staple food grain crops. Wheat is the leading source of basic calories (85 %) and plant-derived protein (82 %) in human food worldwide (Sharma *et al*, 2019). In 2020, 735.3 million tonnes of wheat were produced from 223.67 million hectares globally (DESA, 2021). Future production of food crops must be increase as theworld`s population is estimated to raised 9.1 billion by 2050. For itself, it is predicted that the annual cereal production must be increased by 1 billion tones (Shewry *et al*., 2016). Wheat production is constrained by various biotic and abiotic factors due to change in various environmental conditions. Biotic factors included fungal, bacterial, nematode and viral pathogens, which causes diseases to wheat crop. Among these pathogens, diseases caused by the rust fungi have since long been a major concern and problem for breeders, farmers and commercial seed producers**.**

Wheat rust is the oldest well-known diseases and is important worldwide (Singh *et al.*, 2005). It is one of the most destructive diseases of wheat in numerous wheat-growing regions globally and can cause yield loss up to 100% if susceptible varieties are grown and the environmental conditions are favorable (Hodson, 2014). Rust diseases generally caused by fungi pathogens of phylum Basidiomycota, class Urediniomycetes, order Uredinales, family Pucciniaceae, genus *Puccinia* (Bolton *et al*, 2008). Rust fungi mainly attack on leaves and stems of the plants.The first stem (black) rust epidemic record in central India date goes back to 1786 A.D. (Nagarajan *et al*, 1975). The black rust epidemic losses were significant during pre-independence period (Vasudeva and Prasada, 1948) while widespread occurrence of leaf rust (yellow) was recorded during 1971-73 in popular varitey Kalyan Sona in northern plains of India (Joshi *et al*, 1975). Yellow rust is more distressing in West Asia, southern Africa, East China, South America and northern Europe. Brown rust is more severe in South Asia, North Africa, South East Asia and South America, while black rust leads more harm to North America, Australasia, northern Africa, south Africa and, to some extent, Europe (McIntosh, 1995). The aim of current chapter is to consider on, causal pathogenic fungi, geographical distribution, their life cycle, harmful impacts and disease management strategies of the different rusts affecting wheat production.

Stripe Rust:

The stripe rust (yellow rust) is caused by *Puccinia striiformis* f. sp. *tritici* is one of the mosthazardous diseases of wheat crop globally. Yellow rust of wheat is thought to be prevalent even before human beings started cultivation of wheat as a staple food. It occurs regularly in Northern Europe, the Mediterranean region, Middle East, Western United States, Australia, East African highlands, China, the Indian subcontinent, New Zealand and South America due to areas with cool and wet ecological conditions (Danial, 1994; Mamluk *et al*., 1996).

Yellow rust is more common in tropical areas of higher altitudes of North Africa, Mexico, Himalayan foothills of India and Pakistan because of more constructive environmental conditions and mega-varieties cultivation (McIntosh, 1980). However, the recent investigations regarding stripe rust point out that the highest levels of genetic diversity and recombinant population structure from Himalayan and near-Himalayan regions, which propose that this may be the center of origin and diversity as well (Ali *et al*., 2014; Thach *et al*., 2016). In India, rust epidemics have occurred during 1843 in Delhi and in 1884 and 1895 at Allahabad, Banaras and Jhansi. Afterward, in 1905 the rust epidemic was recorded from Punjab and sub-mountainous zones of Gorakhpur (Gupta *et al*., 2017). Stripe rust appears very early in the growing season, which results in the weak and stunted growth of the wheat plants and causing severe grain yield losses (up to 70%) (Khanfri *et al*., 2018).

Due to stripe rust grain yield losses depends on various factors such as variety susceptibility, infection time, growth stage, rate of disease development, period of the disease and environmental conditions (Chen, 2005). In Asia subcontinent, nearly 46% of yield losses are accredited to the epidemics of stripe rust (Singh *et al*., 2004). Severe reduction in the yield due to stripe rust was observed during 2008-09 due to widely cultivated wheat variety PBW-343, in the sub-mountainous districts of Punjab (Jindal *et al.*, 2012).

Life Cycle of Stripe Rust:

Stripe rust is extraordinarily diverse with respect to host desire and quantity of spore stages within the life cycle (Liu *et al*., 2010). It requires two hosts, gramineous host (wheat) for asexual and *Berberis spp*., as the alternate host for sexual reproduction (Berlin *et al*., 2017) and includes five types of different spores (Schwessinger, 2017). Dikaryotic nature of spores are urediniospores and teliospores, while, basidiospores are haploid and produced by teliospores (Chen, 2005). The dikaryotic stage of fungus is restricted to wheat crop, which is called as the primary host. Urediniospores, teliospores and basidiospores are produced on the primary host (wheat).

Urediniospores of *P. striiformis* infects the primary host, which after gains entry throug stomata under optimum temperature and humidity condition. Later on, the germ tube develops an appressorium and the fungus develops a chain of infection structures, such as the sub-stomatal vesicle, primary infection hypha, haustoria mother cell and finally a haustorium.

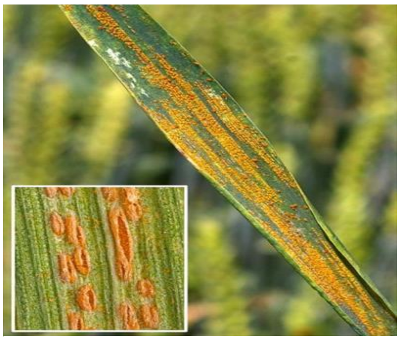
In the secondary infection, a complex network of mycelium is developed inside the mesophyll tissue of host. The haustoria is a nutrient- absorbing structures, taking up nutrients from the host plants. After that the fungus produces sporogenic tissue, called uredinium, close to the leaf surface and develops urediniospores, completing the asexual life cycle (Jiao *et al*., 2017). After the 7 days of infection, development of chlorotic spots on the leaf surface and initiating sporulation which end results in the formation of characteristic yellow streaks on leaf surface of host (Sorensen, 2012). For spore germination 10-12°C temperature is optimum and the high temperature hinders sporulation, which may also lead the fungus to undergo a dormancy phase. Under favorable weather conditions, the time period between inoculation and sporulation is 12-13 days while rapid germination of spores occurs in presence of moisture along with temperature range of 7 to 12 °C (Waqar *et al*., 2018).

Relative humidity is an important factor and has direct effect on the germination of spore, infection, dispersion and survival of the fungus. A continuous moisture for three hours is required for germination of urediniospores and subsequent infection to host (Rapilly, 1979).

Temperature also influences the survival of spores and a range of 2.8-21.7 °C is favorable for the germination of stripe rust spores (Line, 2002).

Symptoms:

After one week of first infection, the first symptoms of stripe rust appear on the leaf sheaths. In the beginning spores look like small, yellow points or flecks. Later on, these points develop into long and narrow stripes of rust pustules on the leaf sheaths, glumes and awns. At maturity time these pustules abrupt and release in yellow-orange masses of urediniospores (Gupta *et al*., 2017) and the infected parts become brownish and ultimately dries up. Fungus consumes the plant nutrients and water by haustoria, which results in reduction of plant vigor and causing dehydration of infected parts. Under severe early infection, plants can even result in the stunted growth (Singh *et al.,* 2017).



After one week of first infection, the first symptoms of stripe rust appear on the leaf sheaths. In the beginning spores look like small, yellow points or flecks. Later on, these points develop into long and narrow stripes of rust pustules on the leaf sheaths, glumes and awns. At maturity time these pustules abrupt and release in yellow-orange masses of urediniospores (Gupta *et al*., 2017) and the infected parts become brownish and ultimately dries up. Fungus consumes the plant nutrients and water by haustoria, which results in reduction of plant vigor and causing dehydration of infected parts. Under severe early infection, plants can even result in the stunted growth (Singh *et al.,* 2017). Under late sown conditions of the host or due to the raise in temperature, the development of urediniospore is followed by the development of teliospores. Teliospores are bi-celled, dark brown colored, thick-walled black spores which infect barberry *(Berberis* spp.) leaves, which is an alternate host, producing pycnia and aecia on the upper and lower surfaces, respectively (Khanfri *et al*., 2018). During the end of growing season, great amount of urediniospores can be developed and blown away from contaminated fields and deposited near their source.

Brown Rust:

Brown rust (leaf rust) in wheat is caused by the fungal pathogen *Puccinia triticina* Eriks., which causes serious losses in all wheat growing areas of the world including North America, South America, Africa, Europe, New Zealand, Asia and Australia (Bolton *et al*, 2008). It mostly targets leaf blades, though under more favorable circumstances it may also target leaf sheaths and glumes. Being an obligate parasite, *P. triticina* can only produce contagious urediniospores on living leaf tissues. To complete its whole life cycle, it needs both primary (telial or uredinal) and secondary (pycnial or aecial) hosts. The principal hosts are bread wheat, durum wheat, cultivated and wild emmer wheat, *Ae. speltoides*, *Ae. cylindrica* and *triticale*. *Thalictrum speciosissimum* and *Isopyrum fumaroides* are the secondary or alternate hosts. Once generated, the urediniospores can be widely dispersed by wind and contaminate host plants found several miles away, leading to rust outbreaks that spread across entire continents (Kolmer, 2013).

Life Cycle of Wheat Leaf Rust:

Puccinia triticina, the pathogen that causes leaf rust, is a macrocyclic heteroecious fungal species with five unique spore phases that affect diverse host species that are genetically remote from one another (Carver, 2009). The wheat plant develops dark brown, two-celled teliospores when the surrounding environment is favorable (between 10 -25 °C and the presence of free water on the leaf surface) (Bolton *et al*, 2008). On the tissue of the wheat leaf, the teliospores sprout to produce haploid basidiospores. The alternate host is then infected by the basidiospores, which are then carried by the wind and produce haploid pycnia in the pycnial structures as a result, insects spread pycniospores to other pycnial infections where sexual reproduction between two genetically distinct cell types (opposite mating types) occurs, leading to the development of plasmogamy (Kolmer, 2013). Finally, the aecial cups discharge aeciospores that the wind will disperse to infect wheat. Although *P. triticina's* sexual phase facilitates genetic material exchange between physiological races and perhaps populations, it contributes little to *P. triticina's* direct inoculum source for wheat species (FAO, 2002) because alternate hosts are rare in the majority of the world's wheat-growing regions.

Symptoms:

Upper leaf blades are where symptoms are most frequently found, however sheaths, glumes and awns can also occasionally become infected and show symptoms. On the leaf blades,

little brown pustules appear in an erratic scatter pattern. The pustules are circular or slightly elliptical, smaller than those of stem rust and contain masses of orange to orange-brown urediospores. In severe cases, they may form patches.

The disease affects mature grain plants in the summer and typically develops too late to cause considerable harm in temperate regions since its onset is delayed but quickens in temperatures exceeding 15 °C. Losses of between 5% and 20% are typical, but in extreme circumstances they can exceed 50% (Jin *et al*, 2010). The severity of the symptoms might range from hardly perceptible to entirely overrun on the leaf surface. The disease manifests on Thalictrum leaf as powdery yellow patches with aecia spreading from the bottom of the leaf.

Stem Rust:

Fungi *Puccinia graminis f. sp. tritici* is the causal organism of stem (black) rust of wheat, is generally distributed around the world, known to cause famines, while less prevalent than the other two wheat (yellow & brown) rusts (Leonard and Szabo, 2005). Stem rust is the most destructive disease of wheat in several wheat-growing regions globally and can leads yield loss up to 100%, if susceptible genotypes and the environment conditions are favorable (Hodson, 2014). Losses due to black rust are generally maximum in wheat when the pathogen becomes severe before the grain get completely developed. It parasitizes mostly on the leaf surface and stem and can also be attack on the leaf sheath, spike, glume, awns and grains in susceptible genotypes (Roelfs *et al*, 1992). Stem rust generally causes damage to above the ground parts of the plant and infected plants often produces lower number of tillers and fewer grains per spike and the grains become shriveled, usually shrunken and lead to reduced milling and food quality parameters (Agrios, 2005).

However, the detection of the Ug99 race in Kalengyere Research station, Uganda in 1998, its subsequent geographical distribution to many wheat-growing countries in the eastern Africa, to the Middle East, Zimbabwe, South Africa, Sudan and Iran. The appearance of Ug99 strains indicated the imminent threat to wheat production and estimates suggested that about 90% of wheat cultivars in the world are susceptible to Ug99 strain (Singh *et al.*, 2011). The "Digalu" race caused a destructive epidemic in Ethiopia during 2014 and a similar race has also been reported in Germany (Olivera *et al.*, 2017). Likewise, other non Ug99 races also appeared in various regions of the world that reducing the worth of the newly identified sources of resistance.

Life Cycle of Stem Rust:

The inoculum source is different under different environmental conditions, in warm climates, but without barbery, the volunteer plants bear the spores of rust over summer and the infected volunteer plants are the source of endogenous urediospores, that is the initial inoculum for wheat plants in the next growing season to initiate a disease cycle (Leonard and Szabo, 2005), where as in the cold climates and barbery, aeciospores are the main source of initial inoculum. Stem rust is macrocyclic and heteroecious (have two unrelated hosts) in nature. The primary hosts are wheat and triticale, where the pathogen spends most of the time and the secondary host is barberry (*Berberis vulgaris)*. Pathogen has total five types of spores at different developmental stages: pycniospores, aeciospores, uredospores, teliospores and basidiospores (Leonard, 2001).

Sexual reproduction completes on the alternate host (barbery) and asexual reproduction takes place on the primary host (wheat) (Leonard and Szabo, 2005). Teliospores overwintering on infected straw germinate annually in conjunction with the development of new growth of leaves of the barberry host (Roelfs *et al*, 1992). Teliospores are dikaryotic cells that undergo karyogamy early in teliospore development. After karyogamy, meiosis begins and that gives rise to single celled, hyaline haploid basidiospores. Later on, the basidiospores carried by wind, land on the upper leaf surface of alternate host plants species and causes infection.

Accordingly, haploid single celled pycniospores (on adaxial leaf surface) and receptive hyphae are produced by the flask shaped pycnia that function as two opposite gametes. Fusion of the pycniospores (male parent) and receptive hyphae (female parent) results in the formation of dikaryotic hyphae, which finally develop into aecia on the abaxial leaf area. Aecia produces aeciospores that will spread by wind to infect only the telial hosts (primary) to develop uredinia that ultimately start to develop urediniospores after the infection. Lastly, the teliospores are produced when the crop gets to maturity stage (Carver, 2009).

Symptoms:

Puccinia graminis f. sp. tritici infection primarily stems and leaf sheaths in wheat. After two weeks of infection, a brick-red structure appers, called a rust pustule also known as a uredium containing urediospores appears at the point of infection. Later on, another type of spore called teliospore, which is a black colored, is produced in telia to end the disease cycle of stem rust in wheat and to start a new life cycle in barberry (Cummins and Hiratsuka, 2003).

Onset of the disease is spotted by explosion of elongated, brown pustules on the stalk, leaf sheath and leaves, while the stem is oftenly most severely attacked. These spores burst, exposing a brown powder (urediospores) and are enclosed by prominent epidermal frings (Singh, 2005). Grain yield losses caused by stem rust are due to decrease in grain size and the lodging of plants (Leonard and Szabo, 2005).

The stem rust in wheat is found in warm temperature (18-30 ^{0}C) and high relative humid climate. The minimum, optimum and maximum temperatures required for spore germination are 2°, 15° to 24° and 30 °C, respectively and for sporulation, 5°, 30° and 40 °C, respectively (Roelfs *et al*., 1992).

Management strategies of wheat rust

Management strategies to mitigate the hazards of three wheat rust include cultural control practices, biochemical control, in addition to chemical and genetic control.

1. Some cultural methods to assist manage wheat rust illnesses include the elimination of alternative hosts and the removal of intercrop "green bridges" with tillage (Kolmer *et al.*, 2007). Crop rotation also lessens the season's production and accumulation of urediospores and helps to control the genetic diversity of the pathogen population. The survival of primary inoculum would be drastically decreased and the losses brought on by severe epidemics would be decreased if all volunteer plants were destroyed. (Bariana, 2007). Utilizing cultivars that grow quickly enables plants to reach maturity before major rust infections can develop. Eliminating the secondary host is a highly effective way to reduce wheat rust effects.
2. The bacterial strain *P. putida* is capable of generating a variety of antibiotics, siderophores and a negligible amount of hydrogen cyanide (HCN), all of which inhibit Puccinia growth. In both field and laboratory settings, bioagents such as *V. lecanii*, *B. bassiana*, *P. fumosoroseus*, *M. anisopliae* and *C. cladosporiodes* were utilized to combat Puccinia. According to the findings, *P. fumosoroseus* and *V. lecanii* were the most effective at reducing pustule size.
3. International monitoring programs that are coordinated are essential for directing management tactics. A notable example and a blueprint for monitoring other significant infections is the global cereal rust monitoring system that was established in response to the appearance of Ug99. This methodology has offered knowledge and methods for plant breeding and rust pathogen research. (Huerta-Espino *et al*, 2011).
4. Genetic resistance is the most efficient, cost-efficient, environmentally friendly and long-term method of controlling leaf rust disease and minimizing crop losses. Additionally, it is the optimal course of action, especially for resource-strapped farmers in developing countries (Hodson *et al*, 2009).
5. Chemical controls as a second line of defense against wheat rusts. The primary goal of applying fungicides is to prevent infection of the flag leaf until the kernels have fully developed. With new and more effective fungicides as Picoxystrobin, Fluoxastrobin, Pyraclostrobin, Propiconazole, Prothioconazole, Tebuconazole, Prothioconazole, Metconazole, *etc*., rust can be controlled chemically. (De Vallavieille-Pope *et al*, 2018).

Conclusion:

From the past decade, the three rust diseases in wheat are challenge for grain production. Stem rust poses the greatest threat because it severely damages susceptible crops. Despite being under control in the majority of the world major production regions, serious genetic vulnerability still exists and active measures are being taken to incorporate new effective resistance in the majority of wheat-growing zones. In order to create resistant cultivars and understand disease epidemiology, plant pathologists and plant breeders have gradually decreased epidemic intensity and frequency of epidemics.

In context of climatic change, the breeding programme for disease resistance still needs to be strengthened. The majority of the wheat rusts have been successfully controlled because improved germplasm is exchanged, which a crucial source of genetic diversity. GM (Genetic modification) technology and additional genetic analysis will provide the tools for understanding and developing durable rust resistance. Various practices like cultural control, biological control, host plant resistance (HPR), surveillance etc. should be used to control the wheat rust, chemical control is a second line control. So, integrated disease management (IDM) is an effective way to control the spread of wheat rust.

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PGPR: ROLE IN DISEASE MANAGEMENT

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Introduction:

One sort of beneficial microorganism is bacteria that infiltrate the roots or rhizosphere of crop plants. Rhizobacteria are bacteria that aid in the growth of plants (PGPR). The rhizosphere is the thin layer of soil surrounding crop roots (about 1 to 2 mm thick) and the volume of soil occupied by term PGPR roots. The phrase was coined by Joe Kloepper. PGPR promotes plant growth while simultaneously acting as a suppressor of soil-borne plant diseases. Two of the most studied PGPR genera are *Bacillus* and *Pseudomonas.* Pseudomonas rhizobacteria, such as *Pseudomonas fluorescens, Pseudomonas putida*, *Pseudomonas cepacia*, and *Pseudomonas aureofaciens*, not only reduce disease caused by soil-borne pathogens, but also increase plant growth and productivity. *Azospirillum, Herbaspirillum*, *Enterobacter*, *Acetobacter*, *Azotobater*, and *Pseudomonas*, as well as many unidentified rhizosphere isolates, are some of the PGPRs that have a direct growth promotion effect.

Plant growth in agricultural soils is influenced by a myriad of abiotic and biotic factors (Nelson, 2004). The global necessity to increase agricultural/horticultural production from a steadily decreasing and degrading land resource base has placed considerable strain on agro ecosystems (Tilak *et al.*, 2005).Technologies and strategies not in favor of the sustainability of soil health are today being used at an unprecedented rate to maximize the crop productivity (Fox *et al.*, 2007, Kumar *et al.*, 2010). Use of chemical fertilizers is credited with nearly fifty per cent increase in agricultural production but they are closely associated with environmental pollution and health hazards.

A few decades ago, growers routinely used physical and chemical approaches to manage the soil environment to improve crop yields and the application of microbial products for this purpose was less common. However, organic growers have actually been promoting the presence of beneficial bacteria without actually knowing it. Addition of compost and the absence of pesticides and more complex organic rotations are likely to promote existing population of beneficial bacteria. During the last couple of decades, the recent biotechnological advancements specifically in agriculture have unlocked new avenues for the augmentation of the agricultural productivity in a sustainable mode and have made possible exploitation of soil microorganisms for improving the crop health (Tank and Saraf, 2010).

The region around the root, the rhizosphere is relatively rich in nutrients, dye to loss of as much as 40 per cent of plant photosynthates from the roots. Due to availability of organic nutrients in root exudates, actively growing microbial population forms an important component of the rhizosphere. The microorganisms that colonize the rhizosphere profoundly affect root and plant biology in relation to nutrition, development and health (Ryan *et al.*, 2009) consequently, the rhizosphere supports large and active microbial populations capable of exerting beneficial, neutral, or detrimental effects on plant growth.

Kloepper and Schroth (1978) introduced the term 'rhizobacteria' to the soil bacterial community that competitively colonized plant roots and stimulated growth and thereby reducing the incidence of plant diseases. Kloepper and Schroth (1981) termed these beneficial rhizobacteria as plant growth – promoting rhizobacteria (PGPR). These encompass all bacteria that inhabit the plant roots and exert a positive effect by various mechanisms, ranging from a direct influence (e.g. increased solubilization and uptake of nutrients or production of plant growth regulators), to an indirect effect (e.g. suppression of pathogen by producing siderophore or antibiosis) Some of these PGPR can also enter root interior and establish as entophytic populations (Kloepper *et al.*, 1989; Glick *et al.*, 1994; Bashan and de-Bashan 2010).

PGPR considered as the significant component in the management of agricultural practices with innate genetic potential. The concept of PGPR has now been confined to the bacterial strains that can fulfill at least two of the three criteria such as aggressive colonization, plant growth stimulation and bio control (Weller *et al.*, 2002; Vessey 2003). PGPR have received prominent attention primarily because of their dual role in plant growth promotion and disease management (Tomcyzak and Lenteren, 1999; Parnwar *et al.*, 2004) and thus are being considered as an alternative or a supplemental way of reducing the use of chemicals in agriculture/ horticulture. The use of PGPR as bio fertilizers is one of the most promising biotechnologies to improve primary production with low inputs in fertilizers ,through any of the many mechanisms possible :increased solubility of immobile nutrients such as P and Fe (Hayat *et al.,* 2010); fixation of atmospheric nitrogen, with previous reports having strongly suggested the positive impacts of microbes on nitrogen uptake involving non legume biological nitrogen fixation (Woo *et al.,* 2006; Ardakani *et al.,* 2010); phytohormone production (auxins) and eliminating the deleterious effects of plant pathogens on plant growth (Jalili *et al.*, 2009).

Use of PGPR bas also emerged as a promising component of integrated plant nutrient management because of its manifold role in soil plant system. PGPR inoculants can fulfill diverse beneficial interactions in plants leading to promising solutions for sustainable and environment-friendly agriculture. (Mishra *et al.,* 2014) worked on the role of bio fertilizer on availability and uptake of nutrient supply mechanisms in plant system .Also inoculation with some PGPR have resulted in P solubilization or enhanced plant uptake of fixed soil P and applied phosphate resulting in higher crop yield (Vessey, 2003; Glick *et al.*, 2007).

Our understanding on PGPR is now advancing at cellular, genomic and proteomic level. Large numbers of PGPR strains of different bacterial classes and genera with multifunctional traits have, therefore, been described for their potent application in boosting plant activities in modern agriculture. However, it is equally important to study in detail the potentiality of this group of rhizospheric micro biota along with their mechanism of action involved in sustainable crop production. We also need to improve our knowledge for the sclection of potent microbial strains colonizing rhizosphere of growing plants for specific restoration programmes. It is important to consider the host plant specificity or adaptation to a particular soil, climatic conditions or pathogens in selecting the isolation conditions and screening assays (Chanway *et al.*, 1989, Bowen and Rovira 1999). Other approaches involve selection based on traits known to be associated with PGPR such as root colonization, antibiotic production and siderophore production (Giacomodonato *et al.*, 2001; El-Tarabily and Sivasithamparam, 2006).

PGPR and host interactions

PGPR in Rhizosphere:

PGPR can be defined as the indispensable part of rhizosphere biota that when grown in association with the host plants can stimulate the growth of the host. PGPR seemed as successful rhizobacteria in getting established in soil ecosystem due to their high adaptability in a wide variety of environments, faster growth rate and biochemical versatility to metabolize a wide range of natural and xenobiotic compounds (Bhattacharyya and Jha, 2012). The degree of intimacy between the PGPR and the host plant can vary depending on where and how the PGPR colonizes the host plant i.e. .either rhizospheric colonization or endophytic colonization.

Rhizosphere can be defined as any volume of soil specifically influenced by plant roots and/or in association with roots and hair and plant-produced material. This space includes soil bound by plant roots, often extending a few mm from the root surface and can include the plant root epidermal layer. This region of soil is much richer in bacteria than the surrounding bulk soil (Hiltner, 1904) Studies based on molecular techniques have estimated more than 4,000 microbial species per gram of soil (Montesinos, 2003). Plant exudates such as amino acids and sugars provide a rich source of energy and nutrients for the bacteria in rhizosphere, resulting in more microbial populations in the region than outside the region (Haas and Defago, 2005).

Root colonization is the process whereby bacteria survive inoculation onto seed or into soil, multiply in the spermosphere (region surrounding the seed) in response to seed exudates rich in carbohydrates and amino acids (Kloepper *et al.*, 1985, 1993), attach to root surface (Weller, 1983; Suslow, 1982), and colonize the developing root system in soils containing indigenous microorganisms (Weller, 1984; Suslow and Schroth, 1982; Kloepper *et al.*, 1980).

Successful root colonization and persistence of PGPRs in plant rhizosphere are required in order to exert their beneficial effect on the plant. The intimacy between the plants and the environment in rhizosphere is thus essential for better acquisition of water and nutrients by plants as well beneficial interactions of plants with soil-borne microorganisms.

For inoculants that are added in granular form instead of seed coatings spermosphere colonization would not apply. Therefore, in the root zone, rhizobacteria are efficient microbial competitors that could displace native root colonizing microorganisms (Cook and Baker, 1983; Kloepper *et al.*, 1999).The nutrient status of rhizosphere determines the nature of root exudates and it can have a direct effect on the composition of the rhizosphere microbial community. Therefore, available nutrients can also probably affect the ability of introduced PGPR to colonize roots and perform their beneficial activity

Extracellular PGPR (ePGPR) living in the rhizosphere increases plant growth through variety of mechanisms and include genera such as *Bacillus, Pseudomonas, Chromobacterium, Agrobacterium, Azotobacter* and *Azospirillum* (Gray and Smith, 2005). Most rhizosphcre microorganisms occur within 50mm of root surface and populations within 10mm of root surface may reach 1.2× 10^8 cells/g soil, despite large numbers of bacteria in rhizosphere, only 7-15 per cent of the total root surface is generally occupied by microbial cells (Gray and Smith, 2005).

Selected PGPR must be an aggressive root colonizer and have rapid growth rate. Maize growth promotion and root colonization by strain of *Rhizobium leguminosarum biovar phaseoli* and two isolates of fluorescent *pseudomonas* were found to be the most potential root colonizers. The most predomirant rhizosphere colonizing bacteria belong to the genus *Pseadomonas* and *Bacillus* because of their association with soil organic matter, nutritional diversity and rapid growth rate. Recently it has been reported that soil microorganisms, including free-living as well as associative and symbiotic rhizobacteria belonging to the genera like *Acinetobacter, Alcaligenes, Arthrobacter, Azospriillum Azotobacter Bacillus Brrkholderia. Enterobacter. Ervinia Flavobacterion Proleus. Pseudomonas.Rhzobitum, Serratia Xanthomonas* in particular are the integral parts of rhizosphere biota exhibiting successful rhizosphere colonization (Kaymak 2014) A variety of bacterial traits and specific genes are known to contribute to the process of root colonization, but only a few have been identified (Lugtenberg *et al.*, 2001) These include motility, chemotaxis to seed and root exudates, production of pili or fimbriae, production of specific cell surface components. Ability to use specific components of root exudates, protein secretion and quorum sensing (Lugtenberg *et al.*, 2002; Oldroyd and Downie, 2004).

PGPR in Endosphere:

Certain plant growth promoting rhizobacteria, not only colonize rhizosphere and rhizoplane, but are also reported to be as entophytes. They are localized in the intercellular spaces of the root epidermal cells and vascular tissue, Endophytic bacteria live in the plant tissues without causing harm to the host or gaining any benefit other than a non-competitive environment inside the host (Schulz and Boyle 2006) and of the nearly 300000 plant species that exist on the earth, each individual plant is host to one or more entophytes. An increasing number of observations suggest that root hairs can also play a decisive role in plant root colonization by beneficial bacteria other than rhizobacteria with entophytic lifestyle.

Reinhold-Hurek and Hurek (1998) reported that many microorganisms enter into plant roots by three putative pathways i.e. root tips, point of emergence of lateral root and the axils of emerging or developing lateral roots. The endophytes become localized at the point of entry or are able to spread throughout the plant. Root cracks are amply recognized as the main 'hot spots' for bacterial colonization (Hardoim et. al 2008). These cracks or wounds may be located at the emergence points of lateral roots or may be caused by microbial or nematode activities. Root differentiation and elongation zones and the intercellular spaces in both epidermis and cortex are also proposed to be major sites for bacterial colonization (Reinhold- Hurek and Hurek, 2011) have provided evidence of a new site through which some endophytic bacteria enter into the plant roots - the root hairs. Lugtenberg and Kamilova (2009) reported that some plant growth promoting rhizobacteria may stimulate cellular division in roots and increase root hair numbers under soil drought conditions. This then leads to improved water and nutrient uptake, particularly from deeper soil layers.

Bacterial endophytes have been isolated from surface-sterilized plant tissue or extracted from the internal plant tissue (James and Olivares, 1998). Endophytic bacteria have been found in numerous plant species, with most members of common soil bacterial genera such as *Pseudomonas, Bacillus,* and *Azospirillum* (Chanway, 1998).

It is believed that certain endophyte bacteria trigger a phenomenon known as induced systemic resistance (ISR), which is phenotypically similar to systemic- acquired resistance (SAR). SAR develops when plants successfully activate their defense mechanism in response to primary infection by a pathogen, notably when the latter induces a hypersensitive reaction through which it becomes limited in a local necrotic lesion of brown desiccated tissue .Bacterial endophytes and their role in ISR have been reviewed by Kloepper and Ryu (2006).

Mechanisms of biocontrol by PGPR

Plant Growth Producing Bacteria (PGPB) produce allelochemicals including iron-chelating siderophores antibiotics, biocidal volatiles, lytic enzymes and detoxification enzymes.

Competition for iron

Under iron-limiting conditions PGPB produce low molecular weight compounds called siderophores to competitively acquire ferric ion. Although siderophores various bacterial differ in their abilities to sequester iron in general they deprive pathogenic fungi of this essential element since the fungal siderophores has lower affinity.

Antibiosis

Various antibiotics have been reported, inchuding compounds such as amphisin, 2.4-diacetylphloroglucinol (DAPG), hydrogen cyanide, oomycin A, phenazine, pyoluteorin, pyrrolnitrin [3-chloro-4-(2-nitro-3chlorophenyl)-pyrrole], tensin, tropolone and cyclic lipopcptides produced by pseudomonads and oligomycin A, kanosamine zwittermicin A and xanthobaccin produced by *Bacillus*, *Streptomyces* and *Stenotrophomonas spp*.

Lytic enzyme production

PGPR produce variety of hydrolases including β-1,3-glucanase,chitinase and laminarinase to attack the pathogenic microorganisms

Detoxification and degradation of virulence factors

Another mechanism of biological control is the detoxification of pathogen virulence factors. Detoxification of albicidin toxin produced by *Xanthomonas albilineans* and Fusaric acid of Fusarium species have been reported.

Quenching quorum sensing

Bacterial plant pathogens rely upon autoinducer-mediated quorum-sensing to turn on gene cascades for their key virulence factors (e.g. cell-degrading enzymes and phytotoxins).It was found that some PGPB quench pathogen quorum-sensing capacity by degrading autoinducer signals thereby blocking expression of numerous virulence genes.

Induced systemic resistance

Resistance induced by PGPR in host plants is termed as induced systemic resistance (ISR). Induced Systemic Resistance has been reported to be one of the mechanisms by which PGPR control plant disease through the manipulation of host plant's physical and biochemical properties. ISR is a simple and chemical free method that enables the plant to defend itself against attack from multiple pathogens.

Pseudomonas

Pseudomonas are gram-negative, strictly aerobic, polarly flagellated rods. They are aggressive colonizers of the rhizosphere of various crop plants and have a broad spectrum anatagonistic activity against various plant pathogens. *Pseudomonas fluorescens* strain 7-14, whose ability to suppress both blast and sheath blight of rice has been well established. Various diseases have been reported to be controlled by *P. fluorescens* like stalk rot of maize.caused by *Pythium aphanidermatum* and *Fusarium graminearum* ,banana Fusarium will caused by *Fusarium oxysporum* f. sp. *Cubense*, root rot and wilt of various pulse crops caused by *Rhizoctonia* and *Fusarium* spp. *Psendomonas cepacia* was reported to be effective in controlling *Aspergillus flavus*- induced cotton boll decay (Misaghi, 1995) and *R. Solani* induced cotton seedling damping-off in the field (Zaki *et al.*, 1998). In other report it was found *Pseudomonas syringae* reduced the *Penicillium expansum* induced that decay in mechanically harvested apple fruits (Janisiewicz, 2004). *Pseudomonas putida* effcctively reduced the population of *P. citrophthora,* the causal agents of Phytophthora roor rot of citrus under field conditions (Turney, 1993). McManus *et al.* (1993) reported that some strains of *Pseudomonas fluorescens* inhibited the germination of *Tilletia laevis* teliospores and inoculated reduced bunt incidence by 65% when wheat seeds were with these strains *P.fuorescens* has also been reported to produce auxins, gibberellins and solubilises phosphorus in the soil which also promotes plant growth and this could be the reason for the higher vigor and percentage germination.

Bacillus

The Bacillus genus has mare genetic biodiversity. Bacilli are present in sea water, soil and are even found in extreme environments like hot springs. This bacterium could be one of the major sources of potential microbial bio pesticides because it retains several valuable traits. Bacilli have the capacity to produce spores which are extremely resistant to high temperatures, unfavorable pH, and lack of nutrients or water. Shelf life of bio pesticides based on sporulated bacteria is generally longer and require less storage precaution compared to other products containing living organisms. Another reason for the high interest in Bacilli is the diversity of their modes of action. Among the Bacillus genus *Bacillus subtilis, Bacillus mycoides, Bacillus pumilus, Bacillus amyloliquefaciens* are reportedly having bio control potential. *Bacillus subtilis* is a motile bacterium that readily moves towards and on the root surface which facilitates colonization of new ecological niches. Bacillus subtilis is widely used for the control of several soil-borne pathogens including *Macrophamina phaseolina, Rhizoctonia solani, Fusarium spp. Pethium spp. and Phytophthora spp* etc. in several crops. It is also effective in controlling grey mold in various fruit and vegetable crops. *Bacillus subtilis* was also reported to be effective in controlling rust (*Uromyces phaseoli*) on beans (Baker *et al.,* 1983). *Bacillus mycoides* controlled *Pythium mamiltatum* damping-off in cucumber seedlings (Paul *et al.,* 1995). *Bacillus pumilu*s is effective in controlling various powdery mildews. Downy mildews, late blight, early blight and root rot in soya bean caused by Rhizoctonia and Fusarim. *Bacillus amyloliquefaciens* is used in managing various soil borne pathogens in potato, corn, strawberry ,tomato ,cucumber and other ornamental plants, Three PGPR strains *Bacillus pumilus* strain INR7, *Curtobacterium flaccurfaciens* strain MEl and *Bacillus subtilis* strain GB03 significantly reduced severity of angular leaf spot caused by *Pseudomonas syringae* pv.*lachrymans* and anthracnose of cucumber caused by *Cailletotrichum orbiculare* (Raupach and Kloepper, 2000). Raj *et al.* (2003) also reported that treatments with rhizobacterial formulations LS256 (*B. sabtilis* strain GBO3 + *B. pamilus* strain INR7), LS257 (*B. subrilis* strain GBO3+ *B. pamius* strain T4) significantly enhanced the growth of pearl millet plants and also reduced the percentage of downv mildew incidence caused by *Sclerospora graminicola*.

Actinomycetes:

Actinomycetes are group of gram positive bacteria and produces many antibiotics. Actinomycete isolate, *Streptomyces* sp. strain Di-944 has been shown to suppress Rhizoctonia damping-off of tomato seedlings by 90% under controlled environmental conditions (Sabaratnam and Traquair, 1997). *Streptomyces* sp. Strain 3 reduced disease severity of Fusarium head blight (FHB) 21 days after inoculation in wheat. Streptomyces strain MYO2 showed significant antagonism against 14 plant pathogen including *Fusarium oxysporum* f. sp. *cucumerianum* (LN *et al.*, 2009), Hitunen *et al.* (2009) reported that antibiotic producing *Streptomyces* spp.reduced severity of potato scab when added to disease conducive soil.

Advantages

- PGPR increase nitrogen fixation in leguminous crops thereby enhancing Nitrogen availability to the plants.
- Promotes growth of beneficial bacteria for soil biota and for crop growth like Nitrogen fixing bacteria.
- Supply of other important nutrients like phosphorous, copper, sulphur and iron is enhanced using PGPR.
- PGPRs have been known to produce plant hormones useful for the plant growth and other metabolic processes.
- Useful in controlling diseases and number of insect pests.

Limitations (Rai, 2006)

- Packaging of PGPR is a problem because it has to be produced, formulated and sold in such a way the biological activity and viability of the organism is not harmed.
- These formulations have to compete with the other inorganic/synthetic chemicals which are easily available and known to the farmers.
- Activities of the PGPRs are weather dependent so its activity may not be useful in some marginal or extreme climatic conditions.

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SHRIMP CULTURE (*LITOPENAEUS VANNAMEI*) AND ITS MANAGEMENT

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Introduction:

India has a vast coastline, which allows for extensive exploitation of marine resource. Fishermen in India used to engage in traditional sea fishing till a few years ago. Fishermen became focused on catching shrimps in the 1970s due to the significant profit margins associated with their export value. During 1991-94, brackish water prawn farming took off in a large manner, particularly in the coastal regions of Andhra Pradesh and Tamil Nadu (Subramanian, 1994). Brackish water is most frequent in estuaries where a freshwater river meets the sea. These waters sustain only a certain type of flora and fauna that can live exclusively in these waters, making them ideal for brackish water aquaculture. Shrimp fry caught in salt beds, coastal paddy fields, or brackish water fishponds were once permitted to develop to marketable size and collected as a supplemental crop. However, in recent years, since the harvest of shrimp generates better revenue than the main crop, many farmers have transformed their rice fields, salt beds, and fishponds into shrimp farms.

Shrimp farming is one of the most rapidly expanding aquaculture sectors in Asia, Latin America, and, more recently, Africa. Until 2009, shrimp farming in India was linked with the monoculture of tiger shrimp, *Penaeus monodon* (Ramaswamy *et al.*, 2013). Because of the availability of Specific Pathogen Free (SPF) and Specific Pathogen Resistant (SPR) brood stock, most South East Asian nations, including Thailand, Vietnam, and Indonesia, have moved to culture of exotic White leg shrimp, *Litopenaeus vannamei*, since 2001-02. In 2003, the entire global output of farmed shrimp exceeded 1.6 million tonnes, with a value of approximately 9,000 million US dollars (Tourtip et al., 2009). Around 75% of farmed shrimp is produced in Asia, mostly in China and Thailand. The remaining 25% is produced mostly in Latin America, with Brazil being the leading producer. Thailand is the world's greatest exporter (Giap *et al.*, 2009).
In India, a pilot-scale introduction of *L. vannamei* began in 2003, and following a risk assessment study, a large-scale introduction was approved in 2009 (Khushbu *et al.*, 2022a).

The idea of a limitless market demand, high export prices, job creation, and increased foreign exchange profits have pushed several countries in the region rich in aquatic resources to prioritize the development of the shrimp farming business.

Types of culture:

a) Extensive culture:

Extensive shrimp farming is a traditional farming practice which requires water to be exchanged under tidal influences with the inflow bringing natural seed and feed to the culture ponds (Rosenberry, 1998). Harvesting is undertaken on a bi-monthly basis during low spring tide events, when the ponds can be completely drained (Hung *et al.,* 2013). Supplemental feeding is not used in extensive culture systems, and the shrimp rely completely on natural feed (Reis *et al.,* 2021). There are three types of culturing practices employed in India.

Extensive farming employs very low stocking densities, usually in the range of about 3,000–5,000 fry per hectare (Valenti *et al.,* 2021). The dramatic increase in area utilization for extensive prawn production in recent years can be attributed to high market demand, increased hatchery-bred fry production, minimum technical requirements, and lower production cost and risks (Kabir *et al.,* 2020). In Philippines shrimp production has been mainly characterized by the extensive system. Out of the 200,000 ha of brackish water about 25% (50,000 ha) are stocked with shrimps in monoculture or in polyculture with milkfish (Ghoshal *et al.,* 2019).

Until 10 to 15 years ago, natural seed abundance of banana prawn (*Penaeus merguiensis*) and Indian white prawn (*P. indicus*) was sufficiently high to supply the ponds with juveniles and due to a decline in naturally produced post larvae (PL), farmers have to stock black tiger shrimp (*Penaeus monodon*) PL to improve their yields (Ahmad *et al.,* 2019). The practice of stocking PL in this manner is known as the 'improved extensive system'. These two systems occupy a large proportion of the shrimp culture area globally (Hung and Huy, 2007). In 2004, extensive and improved extensive systems accounted for 68 percent and 27 percent of the shrimp farming surface area (Thunjai *et al.,* 2004).

b) Semi- intensive culture:

Food is supplemented in semi-intensive production systems with garbage fish, tiny shrimp, Jawla paste shrimp (*Acetes indicus*), and inexpensive shrimp pellets (about US$0.8/kg).

- The stocking density is between 5 and 10 shrimp/m^2.
- The age of the pond, the farmer's expertise, feed, extraneous costs, the amount of seed supplied, and skilled labor all contributed favorably to the yield.
- The average predicted production was 3937 kg/ha (Raju, 2002). The research suggested that, in order to maximize profit, stocking density and feed consumption should be reduced from current levels.
- Aeration is not employed. The farms might be run as rotating shrimp/rice farms or incorporated into mangrove regions (McGraw and Scarpa, 2003).

c) Intensive Culture:

Shrimp are stocked at 20 to 50 shrimp per m^2 in intensive production systems. Ponds are often built near the top of the tidal prism and have a surface size of 2,000 to 3,000 m^2.

- The system necessitates a high level of upkeep and care in terms of feeding, water quality monitoring, and aeration.
- Formulated feeds as well as farm-made feeds are used (McGraw and Scarpa, 2004).

Table 1: Comparison of different type of culture

	Extensive	**Semi- intensive**	**Intensive**	**Super-intensive**
Stocking density	0.2-5/m²	5-20/m²	15-50/m²	50-200/m²
Nutrition	Natural food	Supplement + Natural food	Commercial Feed	Commercial Feed
Aeration	None	Sometime	Continuous	Continuous
Water exchange Rate / day	Tidal	1-20%	5-30%	50-200 %

d) Super-intensive Culture: Aquaculture systems with low land requirements and high stocking densities. Some farmers in the Brazil's northeast are implementing super-intensive agricultural technology. Ponds have square or rectangular surfaces ranging from 2,500 to 4,000 square meters, depths ranging from 1.8 to 3.0 meters, bottoms coated with high density polyethylene (HDPE) geo membranes, and central drains (Felix *et al.,* 2020). Shrimp are fed multiple times per day through human broadcasting or feeding trays, there is a high mechanical aeration rate (20 to 30 hp/ha), initial stocking densities vary between 120 and 300 shrimp per square meter, and yields can exceed 25,000 kg/ha/crop (Hou *et al.*, 2018). The shrimp may also survive considerably greater stocking volume.

Prestocking, stocking and post stocking management in shrimp culture: The success of any shrimp culture is dependent on improved management procedures in pond preparation and pre-stocking management activities.

Pond preparation: It is one of the most significant pre-stocking management techniques required for optimal shrimp development in grow out farming systems. Several considerations must be made during the pond preparation for shrimp production (Rajendran *et al.*, 2016).

Pond Renovation: The majority of remaining traditional shrimp ponds are large (1.5–0.9 ha), irregular in shape, and somewhat shallow (70–80 cm), resulting in significant variance in water temperature and salinity (Minardi *et al.*, 2019).

These ponds might be readily enhanced via rehabilitation by making them more regular in shape, uniform in size, and deep enough to accommodate the construction of adequate inlet and outlet gates to promote water exchange through supply and drainage canals (Hasan *et al.*, 2020). Farmers are urged to carry out the following processes while renovating a pond (Rajendran *et al.*, 2016)

1. Adjust the pond's size and form for better management at a reasonable cost. The pond should be rectangular in shape and occupy an area of 0.5–1 hectares. Dig up the pond to a depth of 150–180 cm to contain more water and minimize rapid changes in water temperature during the day.
2. When installed and used properly, the paddle wheels will not stir up dregs at the pond bottom, causing the water to become murky.
3. When the water depth is high, the pond dike should be built broader and stronger by compressing the soil to prevent water leakage and dike breach. If there are any tree root fragments at the pond's bottom, remove them completely.
4. Furthermore, decaying roots can quickly degrade water quality. Farmers should smoothen the pond bottom after cleaning the roots to create a slope toward the discharge gate.
5. When we alter a pond, we must construct two independent water gates, one for allowing water in and the other for discharging and harvesting water.
6. The size of the water gates should be proportional to the size of the pond to allow for enough water exchange for shrimp harvesting in a timely manner.
7. For a 1 hectare pond, its breadth should be roughly 1 m. Farmers should build water pumps capable of pumping water into the pond at any time.
8. There must be reservoir ponds where water may be stored and treated before being pumped into the raising pond.
9. To keep shrimp predators out, the water must be filtered with a sieve or a cloth filter (Soundarapandian and Gunalan, 2008).

Figure 1: Show shrimp pond a) With Lining b) Without lining

Top soil removal: The top black soil and bottom sludge must be removed to avoid anaerobic conditions from developing during the culture phase.

The sludge must be disposed of distant from the pond site so that it does not contaminate the water. Grow out ponds with high stocking density remove the whole pond top soil, whereas modified extensive ponds remove sections of the pond where there is a large buildup of organic matter from past crops, such as the feeding zone (Roy *et al.*, 2007).

Pond Preparation: It is critical to prepare the pond before adding the seed to promote maximum output. Unwanted species are eradicated by emptying the water and drying the pond until the soil splits in the pond bottom, killing predator fishes and other competing organisms in the pond (Jayaprakashvel *et al.*, 2020). Aside from permitting the escape of harmful gases from the pond bottom, drying the pond bottom is the cheapest technique of eradicating undesirable organisms. Allow the pond bottom to dry in the sun for a length of time until the dark color and foul odor in the soil have faded. This drying process can aid in the loosening of hard bottom and mineralization of pond bottom (Zadeh *et al.*, 2010).

Liming: After the pond becomes completely dried then remove 2–4 cm of top soil from the bottom. To eradicate illness caused by the collection of dead algae, lime must be distributed throughout the pond bottom, which is moist and stinky. Lime can also aid in the decomposition of organic materials and the killing of predators and other unpleasant aquatic animals that live on the pond bottom (Qiu *et al.*, 2021**).** Plough the pond bottom horizontally and vertically to a depth of 30 cm to remove noxious gases, oxygenate the bottom soil, discolor the black soil to eliminate the hydrogen sulfide odor and boost fertility, smoothen it, and produce a slope toward the outflow gate. Repair leaks at the water gates and on the earthen dike.

Bloom Development and Probiotic Application: Fill the pond to a depth of 40–50 cm, then sprinkle tea seed cake at a rate of 150–200 kg/ha to kill common fish or other aquatic creatures that may escape into the pond when water enters (Chang *et al.*, 2018). The pond is then supplemented with organic fertilizer (dry cow dung, rice bran, and groundnut cake) at a rate of 50–100 kg/ha and inorganic fertilizer (urea, DAP, and super phosphate) at a rate of 10–15 kg/ha. The pond is left for 3–4 days to allow for natural food (plankton) development, with water mixed by paddle wheel aerators (Khushbu *et al.*, 2022). When the pond's water turns green or brown, add more fresh seawater until the necessary depth is reached.

Figure 2: Show bloom development

Figure 3: Show shrimp

Seed Selection and Stocking: Aquaculture success is largely determined by the quality of seed and feed. Shrimp maturation and reproductive performance are critical for the successful propagation of captive penaeid broodstock. The global expansion of *L.vannamei* cultivation can be attributed to fast growing and disease resistant strains created through selective breeding operations. When compared to other penaeid shrimp species, this species can be easily reproduced in captivity, has a wide tolerance to environmental factors, utilizes low-protein meals well, and develops quickly (Wyban, 2007). Adult *L. vannamei*, like all other marine penaeid shrimps, lives and spawns in the water. The larvae metamorphose in the sea, and the post larvae move to brackish water settings, but the juvenile and sub adult spend their lives in coastal estuaries or lagoons. Males mature at 20g and females at 28g in nature, according to reports. However, broodstock weighing 40-45 g is recommended in hatcheries (Anand *et al.*, 2021). Females attain sexual maturity at 8-10 months, whereas males reach sexual maturity at or after 10 months. *P. vannmei* is a species of open thelycum. It marries when both the male and female are in the hard stage, and the spermatophore may be observed as a white sperm plug adhered to thelycum after mating.

Stocking: Shrimp stocking is a critical component of any biosecurity program. Use seeds from domesticated shrimp stocks that are disease-free ("Particular Pathogen Free" or SPF) or resistant to specific disease agents (SPR) SPF broodstock from a certified Nucleus Breeding Center (NBC) (Saoud *et al.*, 2003). These are biosecurity facilities with at least two years of recorded disease testing to back up their SPF certification. Before purchase, inspect the shrimp post larvae for general condition such as activity, color, size, and so on. If any dead or abnormally colored PL is found in the stock, the entire batch should be discarded. Before stocking in the pond, PL should be treated with 100 ppm formalin.

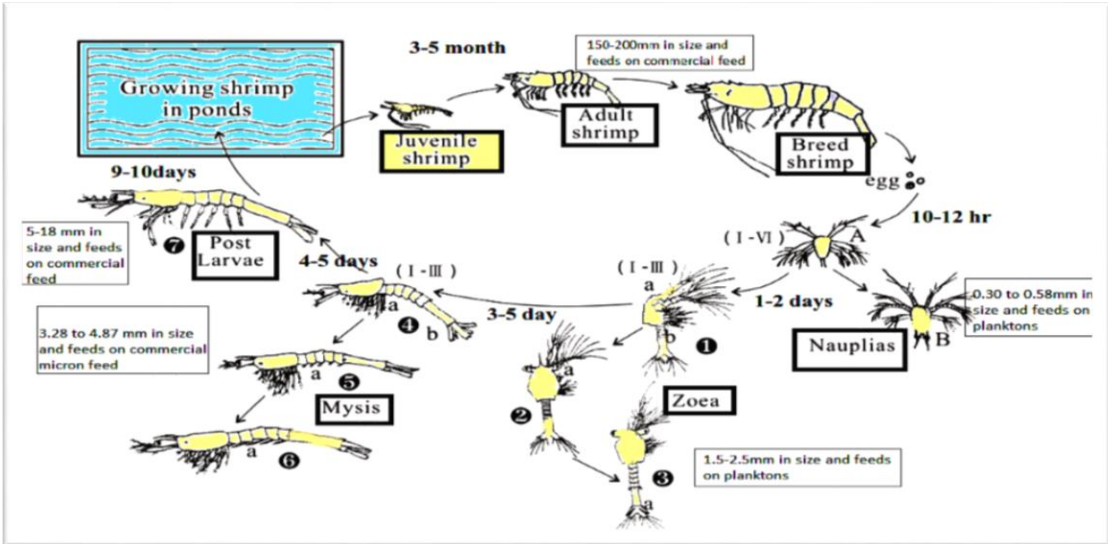

Figure 4: Show life cycle of shrimp

Maintaining a balanced or optimal stocking density is another critical aspect of shrimp production (Qiu *et al.*, 2021)

Feed management:

Management of live food and feed: Aside from hormonal modification, the quality of the maturation diet is critical in shrimp maturation. It is critical to choose an optimal diet that has a steady supply, is easy to handle, is effective in delivering immunostimulants, medicines, or hormones, has a low risk of disease transmission, and so on (Tinikul *et al.,* 2008). Fresh feeds are typically thought to be optimal for shrimp maturation because they are abundant in polyunsaturated fatty acids, particularly Arachidonic acid (ARA, 20:46), Eicosapentaenoic acid (EPA, 20:53), and Docosahexaenoic acid (DHA, 22:63), all of which are required for shrimp maturity. Currently, the shrimp business employs a wide range of fresh feeds, such as squids, bivalves, and polychetes, in conjunction with various artificial diets**.**

Improved feed management: Feeding tables are provided by all feed manufacturers in order to calculate feeding rates and avoid over- or under-feeding. The daily feed is adjusted based on shrimp size and the amount of feed left on the feeding tray from the previous feed raft (Kumar and Engle, 2016). Farmers often feed 3–4% of the daily feed ration into feeding trays (2.8, 3.0, and 3.3 percent for 5–10 g, 10–20 g, and >20 g shrimp, respectively). After two hours of feeding, the feeding trays are examined. If the amount of unfed feed left in the feeding tray exceeds 10%, the farmers cut the feed ration at the following feeding. When the feeding tray is empty, the ration size is raised**.** When the feeding tray is empty, the ration size is raised. Feed conversion rates (FCR) achieved with commercially prepared feeds varies from 1.3:1 to 1.5:1 when well-managed. FCR in poorly managed systems can reach 2.5:1. Yields of upto 7 tonnes/ha/crop can be obtained under intensive cultivation settings (Sung *et al.*, 1991).

Figure 5: Show feed and feed tray

Water quality management:

Total Hardness: A study conducted by Brown et al. (1991) on the growth and carapace mineralization of *Macrobrachium rosenbergii* found that it grows from 9 mg L^{-1} CaCO3 to 326 mg L^{-1} CaCO3 under the conditions of different water hardness. There was no significant change in growth at lower hardness levels but a decline at higher levels at 53 mg L*1 CaCO3. At the highest levels, survival was impaired.

Acidity and pH: Shrimps are able to tolerate acidity between 4.0-11.0 (Chamberlain, 1988) and pH levels 7.5-8.2 (Effendi *et al.,* 2016).

Transparency: Transparent water is one that is saturated with plankton, indicating more plankton is present. However, too much plankton density may affect the pond's pH and dissolved oxygen levels. The level of transparency must be maintained in between 30-40 cm (Flegel *et al.,* 2008).

Dissolved oxygen: Dissolved oxygen should not be less than 4 parts per million in the morning and more than 6 parts per million by late afternoon. Shrimp will rise to the surface of the water to acquire oxygen if DO concentrations are less than 4 ppm (Muralidhar et al.,2012).

Salinity: Shrimps grow best at salinities between 15 and 30 parts per thousand according to Saraswathy et al (2012). When reared in high salinity (5-15 or 25 ppt) than in lower salinity (5-15 or 25 ppt), *Litopenaeus vannamei* juveniles were affected by IHHNV (Infectious Hypodermal and Hematopoietic Necrosis Virus).

Temperature: When shrimp in a pond were exposed to temperatures exceeding 33°C for an extended period of time, the pond's production capacity was reduced. However, when shrimp in a pond were exposed to temperatures between 23.5 and 25.5°C or between 30 and 31.5°C over an extended period of time, the shrimp output in this pond increased (Abdelrahman *et al.,* 2017)**.**

Alkalinity: It is significant because it allows the pH to be maintained after the addition of acid without reducing the pH value. The alkalinity should be at or above 80 ppm (FAO, 2005).

Aeration Management: Paddle wheels are required from the first week. Use six 2-HP paddle wheels for a 1 ha pond with 15/m2 (long-arm aerator 10–12 wheels per unit engine). All paddle wheels are typically driven for 10 hours every 40 days. After the 40th day of culture, expect the aerator to need to be properly operated during feed time. Otherwise, there is a greater risk of oxygen depletion in the pond (Flegel, 2012).

In general, one horsepower is recommended for 500 kg of output and 50 PL/m. The location of aerators is critical to preventing sludge buildup in certain areas. Maintaining an adequate quantity of DO allows nitrifying bacteria to convert ammonia to harmless nitrate (CIBA, 2013).

Biosecurity Management: Biosecurity has been described as "sets of activities that limit the likelihood of a disease introduction and subsequent dissemination from one location to another ".

The following are major biosecurity objectives:

- **Animal management:** It is the process of getting healthy stock and enhancing their health and immunity via proper husbandry.
- **Pathogen management:** It is the prevention, reduction, or elimination of pathogens**.**
- **People management:** It includes educating and supervising employees and visitors**.**

Animal management includes following criteria:

Good husbandry: Avoid any environmental circumstances or procedures that stress the shrimp or may cause harm to the skin, fins, gills, or gut. This will weaken their immune systems and make them more prone to disease (Noga, 2010).

Pathogen-free stocking: Stocking pathogen-free postlarvae does not ensure a disease-free culture since pathogens can still enter the culture environment horizontally and infect the shrimps during the culture (Gunalan, 2015).

Viral pathogens can still infiltrate the culture environment via the methods listed below, and a better understanding of them can aid in the prevention of horizontal transmission. In addition to the above-mentioned carriers, viral particles can enter the farming system by remaining in the soil, *intake water, *aquatic vectors delivered by intake water, by crabs, and other animals* (Kim *et al.*, 2021).

- Land animals and birds contaminated with eagle, crow, or water crow.
- Farm inputs contaminated via live feed and semi-moist feed
- Farm equipment, nets, and automobiles, among other things, were contaminated.

Table 2: Show various chemicals used for shrimp health and disease management

Chemical name	Trade name	Form	Method of usage	Functions
Benzal Konium chloride	BKC	Liquid	Spread with water, 0.5 ppm	Control bacteria and reduce phytoplankton in water,
Chlorine	Bleaching	Powder	Spread with water; 60 ppm	Eradicate virus carrier to prevent WSSV
CaO	Rock lime	Solid	Spread with water, 10 ppm	Improve soil and water quality
$A1_2O_3.SiO_2$;	Zeolite	Powder	Spread with water 10–20 ppm	Improve soil and water quality
$A1_2SO_4$	Aluminium sulfate	Solid	Spread with water 2.5 ppm	Reduce or settle iron in water
$CaCO_3$	Agriculture lime	Powder	Spread with water; 6–10 ppm	Improve water quality
$KMnO_4$	Potassium permanganate	Granular	Spread with water, 0.1–0.2 ppm	Disinfectant
Vitamin C	Vitamin	Powder	Mix with feed, 3 gm/kg feed	Feed supplement to increase resistant powder
Urea	Fertilizer	Solid granular	Spread with water, 1–2 ppm	Improve plankton in water

Tinsen	Tinsen	Powder	Mix with feed, 3 gm/kg feed	Feed supplement to increase resistant powder
Eco-solution	Eco-solution	Liquid	Spread in water, 0.1 –0.2 ppm	Prevent viral disease
38% Formaldehyde	Formalin	Liquid	Spread with water, 1–3 ppm	Control protozoan disease also improve water quality
Sodium percarbonet	Best oxygen	Powder	Spread with water, 0.1–0.2 ppm	Increase O_2 in water
Urea	Fertilizer	Solid granular	Spread with water, 1–2 ppm	Improve plankton in water
Tetravet 200WSP	Tetravet	Powder	Mix with feed, 3 gm/kg feed	Feed supplement to increase resistant powder
Sodium thio sulfate	EDTA	Powder	Spread with water; 0.1–1 ppm	Disinfectant also reduce toxic gases

Good preventive medical practices: Quarantine, frequent monitoring, immunization, and the use of immunostimulants, probiotics, and diagnostics for illness treatment are all examples of good preventative medical practices (Yanong and Erlacher-Reid, 2012).

Shrimp Health Analysis: Shrimps should be tested once a week using cast nets and evaluated for general health concerns such as exterior appearance. A pale yellowish stomach, for example, indicated a gut infection, whereas a typical gut would be bright or golden brown in color. Probiotics, immunostimulants, and bioremediation agents can be used as preventive measures in grow out culture (Shen *et al.*, 2010).

To enhance the overall pond microbial balance, a yeast-based organic product (60 kg rice flour, 30 kg yeast, and 3 kg yeast) can be used. Antibiotics should be avoided in shrimp farming due to major concerns about their usage**.**

Sanitation and disinfection:

- Physical treatments: include heat, sunlight, and drying (dessication)
- Chemical treatments: Virkon Aquatic, Bleach, Phenol derivatives, Alcohol, and other chemical techniques are used.

People and equipment disinfection stations: utilize disinfectant footbaths, hand-washing stations or alcohol spray bottles, net disinfection stations, showers, and vehicle disinfection stations.

Table 3: Show Various disinfectant used in shrimp culture

Chemical name	Trade name	Dosage
Benzal konium chloride	BKC	Spread with water, 0.5 ppm
Sodium thiosulphate	EDTA	0.1–1 ppm
n-Alkyl dimethyl benzyl ammonium chloride + stabilized urea	Emsen	80 g/33 dec
Chlorine	Bleaching	60 ppm
Efinol	Efinol	5–8 gm/liter water
38% Formaldehyde	Formalin	1–3 ppm
Ankul benzyl dimethyl ammonium chloride + poly-2- deoxy-2 amino glucose	Lenocide	500–1000 ml/acre
Iodine 20% Nony alklohenoxypoly ethaneixide iodine complex	Microdine	2–2.5 L/acre
Benzyl ammonium chloride + urea	Omicide	200 ml/33 dec. after 24 h. 150 m
Sodium thiosulphate	Water clear	In case of 5–6 feet deep water body 2–3 L/100 dec.
n-Alkyl dimethyl benzyl ammonium chloride + stabilized urea	Timsen	20 g/33 dec. (for prevention) , 80 g/33 dec. (for treatment)

Farm Records: Records are required to detect various hazards and to correct problems as soon as possible during the production cycle. Record keeping also allows farmers to learn from past failures, lowering risk and production costs in succeeding crops (Roy *et al.,* 2007).

Control worker mobility inside and across the farm, and reduce the amount of personnel involvement in stocking, harvesting, sampling, and so on. It is critical to maintain environmental cleanliness and govern human traffic, visitors, employees, technicians, and movement across fields (Diwan, 2005).

Conclusion:

The two-pronged approach of combining pond management and health monitoring is the key for successful shrimp production. Sustainability of aquaculture depends on the maintenance of a good environment. The understanding of the ecological processes occurring in source water bodies and in *L. vannamei* shrimp culture ponds through regular monitoring will help us understand and solve some of the disease issues faced by shrimp farmers**.**

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NEW DIMENSIONS IN AGRICULTURAL EXTENSION FOR EMPOWERING FARMERS

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Introduction:

India predominantly is an agrarian rural economy. According to NITI Aayog's 2017 statistics, 69 percent of Indians live in rural areas, while 47 percent of the country's workforce is employed in agriculture (Labour Bureau 2015-16). In India, there are 138 million agricultural holdings, and over 85% of these are owned by small and marginal farmers (Census 2010-11)

With a growing tendency in population growth, food security has emerged as the main problem. The production of food grains has expanded significantly in India during the past 50 years, but this has not resulted in an increase in the amount of food grains available per person. As per estimate, the human population and food grain production in India was grown up by 2.09% , 2.36%, 3.47 % respectively from 1961 to 2011 and in 2021, whereas the annual per capita availability of food grains was 171.1 kg in 1961 to a level of 169 kg in 2011 showing a decreasing trend of 1.17 %. But since 2015 the per capita availability of food grains is increasing i.e. from 169.8 kg in 2015 to 185.4 kg in 2021. Although the trend is showing a positive impact in rate of production but still India lacks in disseminating appropriate technology in right time hence impacting the less income generation. To reduce that gap Agriculture extension system plays crucial role between research labs to a farmer’s field. For this, Agricultural research, education and extension are said to be the most critical for promoting farm productivity and enhancing farmer’s income.

In India, the average household income for the agricultural year (July-June) 2018-19 was only Rs. 10,218 per month. Although this is an almost 60% gain over 2012–13, the government's data (found in the most recent Situation Assessment Survey or SAS) show that income stress has increased for Indian farmers over the course of these six years. One of the reason being, farmers are now earning more from wages than from crop cultivation, indicating that cultivation is becoming less lucrative. Then, almost every second agricultural household was still in debt in 2018–19 (much like in 2012–13), but the level of debt has greatly increased. Additionally, the vast majority of farmers continue to possess less of land, with only 0.2% of rural households holding more than 10 hectares in annual year 2018–19. For this reason Prime Minister Shri Narendra Modi had announced the scheme of “Doubling farmers’ income’. With the advancements in the technology there have been many changes in the techniques of Agricultural extension. This chapter mainly deals with the new horizons of agricultural extension to improve the farm earning of farmers, farm women and rural youths.

Agricultural extension approaches in India

Since independence, the public sector has dominated the provision of extension services. Through a two-tier system, the public sector is currently a key provider of extension services. The nodal institution for agricultural research and extension at the federal level is the Indian Council of Agriculture Research (ICAR), while at the state level agriculture extension is facilitated by State Agricultural Universities (SAUs) through Krishi Vigyan Kendra's (KVKs) and the Agriculture Technology Management Agency (ATMA) at the district level. The public extension, however, heavily favors' agriculture husbandry while disregarding related industries. Several private companies, civil-society organisations, particularly farmer-based organisations, and NGOs, in addition to the current public extension service system, play a significant role in delivering extension services.

Paradigm shift of extension to extension plus:

Aspect of Extension	From	To
Form/content	Technology dissemination	Supporting rural livelihoods
	Improving farm productivity	Improving farm and non-farm income
	Forming farmer groups	Building networks
	Offering services	Enabling farmers to access services from other agencies
	Market information	Market development
Monitoring & Evaluation	Input & output targets	Learning
Planning & Implementation	Doing it alone	Through Partnerships
Sources of innovation in extension	Centrally generated	Locally evolved (through experimentation)
Approaches	Fixed/uniform	Evolving/diverse
Staff capacity development	Training	Learning by doing, facilitated experimentation
Capacity development of extension system	Personnel and infrastructure	Development of linkages and networks
Policy approach	Prescriptive/blue prints	Facilitating evolution of locally relevant approaches
Introducing new working practices	Staff training	Changing organizational culture through action learning
Underpinning paradigm	Technology transfer	Innovation system

Now the extension methodologies have shifted to extension plus. Extension Plus is a strategy for bolstering and reforming extension to become a powerful partner and nodal organisation with Agricultural Innovation System (AIS), offering technological and non-technological services to farmers. Agricultural Innovation System is a network of businesses, organisations, and people working to change the institutions and regulations that influence how various agents connect, share, access, exchange, and use knowledge, as well as new products, processes, and organisational reforms, for economic use.

New approaches in extension for enhancing the farmers' income:

Currently extension and advisory services are provided by various agencies representing public and private sector players. Active deployment of ICT (information & communications technology) can, to a great extent if deployed intelligently, address the concerns of manpower deficit. The idea that agricultural extension was just a public sector endeavors is no longer valid. A variety of players are currently present. Agricultural extension has changed significantly over the years from being public to pluralism, top down to bottom up, and technology transfer to broad-based and demand-driven.

1. Individual approach to group approach:

A group approach may also be more practical than an individual approach in places where group work is frequent and groups have already been established for specific activities. It is appropriate for addressing issues that affect the entire community (e.g. post-harvest management, protection of crops, sanitation and health etc.), also when there are activities to be undertaken by a group of farmers, e.g. group nurseries. A women's organisation, a youth group, a cooperative society, or the general public could be the immediate target group.

2. Top-down approach to Bottom-up approach:

There will be a significant development of farming community if we shift our focus from top-down approach to bottom-up approach. Empowerment relies on the use of "bottom-up" strategies aiming to develop capabilities of individuals and communities in making informed choices and to act on their own behalf. Empowering people not only enables them to develop their full potential but also allows them to participate in the creation of solutions to ensure security for both themselves and others. The new extension strategies should work from grass root level to satisfy this concept.

3. Mono cropping to multi cropping:

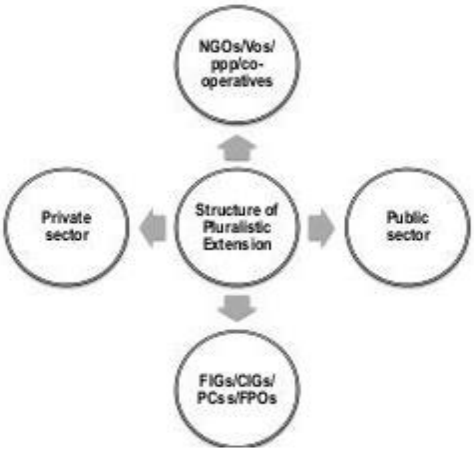
The fact that monocropping can result in nutritional fatigue and declining productivity over time is one of its main disadvantages. Farmers who practice multiple cropping, which is defined as planting various crops sequentially throughout a year, can produce more food on the same plot of land. Increased crop diversity, better agricultural system performance, spare space for biodiversity or other purposes, and a decrease in the use of inorganic fertilizer and pesticides are all additional advantages of multiple cropping that can increase productivity and profitability.

4. Training for skill development:

Globalization has increased the requirement for a professional workforce that can adapt to changing market demands and is knowledgeable. About 18.5 percent of agricultural workers in 2009–10 were skilled, and 38 million skilled people will be needed in agriculture overall by 2022. Therefore, it is important to train rural youth, farmers and farm women from both agricultural and non-agricultural backgrounds to strengthen their abilities. Agri-input sales, farm advisory services, and nursery management should all be included in the training. Production of bio-fertilizers and bio-pesticides, vermicomposting, crop production technology, etc. Other government efforts include the National Skill Development Mission, the National Policy for Skill Development and Entrepreneurship, the Pradhan Mantri Kaushal Vikas Yojana (PMKVY), UDAAN, STAR, and others.

5. Extension delivery in pluralistic extension approach:

The provision of extension services for a community by multiple sources of extended services is known as a pluralistic extension system. Farmers in the villages now have more options to receive information and knowledge from various sources thanks to pluralism in agricultural extension. It is an excellent method of leveraging both public and non-public institutions to give extension services to the farming communities and it is a good balance of public and private finance and delivery mechanisms.



6. Soil management vs. land husbandry:

Applying procedures, techniques, and treatments to protect and improve the performance of soil is known as soil management (such as soil fertility or soil mechanics). The best soil health, soil amendment, and soil conservation are all included. In contrast, land husbandry encompasses more than only soil and water conservation. It tackles the management of land resources, inputs, and outputs in relation to the household livelihood system with the goal of increasing the productivity and sustainability of the production system.

7. Passive farmers as active partners:

Different programs can be viewed as catalysts for accomplishing SDGs (Sustainable Development Goals) as long as farmers are viewed as agents, knowledge producers, and partners. The development of solutions to problems becomes appropriate, significant, and long-lasting when farmers are seen as active collaborators. The programme can empower farmers through the mechanisms built into the programme and interactions between researchers and farmers in addition to making science-based information available to policymakers, programme planners, farmers, and other actors in the value chain.

8. Production led extension to market driven extension:

Agriculture can only be sustainably practiced when the ends justify the means. It also entails strengthening the ability of the agricultural sector to boost productivity and profit maximization through the emerging trend of extension services. This goes beyond just safe production in terms of awareness of the demands of future generations. The paradigm shift of current agricultural situations, which calls for the sector's transformation into a profit-oriented enterprise, makes the need for market-led imperative. In order to effectively distribute knowledge for holistic sustainable agricultural development, extension functionaries need to focus more on the area of marketing through the employment of extension techniques. The farming industry is home to several innovations, many of which go unnoticed and unused. It is imperative that these farmer-led innovations be addressed and documented for future up-scaling and out-scaling. Researchers who study extension should take note of this. For creative farmers, appropriate incentives and recognitions in the form of awards are also set up in a number of Krishi Melas and other institutional settings around the nation.

9. Farmers as Agripreneurs:

Entrepreneurial people involved in Farming and other agricultural activities are termed as Agripreneurs. Now-a-days most of the educated farmers performing the agri-related activities and interested to become an Entrepreneur. The changing environmental factors help the farmers to acquire new entrepreneurial skill and competencies. The economic reforms around the world have compelled the agripreneurs to take up higher responsibility to run their business.

10. Traditional agriculture to climate smart agriculture:

Due to the erratic climatic conditions, climate change issues, increase in population, soil and natural resource degradation, Sustainable food production faces severe challenges. Climate change is regarded as one of the most important threats to the agriculture and Farming practices. As we know, agriculture sector sustain livelihood to maximum number of people, hence a climate-smart approach of agriculture is needed for sustainable food production. In this changing climatic scenario, Traditional agriculture is getting higher attention in the context of sustainable food production.

11. Group of farmers to farmers group organizations:

Small producers lack the number of inputs and outputs necessary to benefit from economies of scale. In addition, there is a long chain of intermediaries in agricultural marketing that frequently work in an opaque manner, resulting in a scenario where the producer only receives a small portion of the value that the final customer pays. The primary producers can profit from economies of scale through aggregation. Additionally, they will be able to negotiate more favourably with large producers and suppliers of raw materials. Farmers' group organizations' primary goal is to increase the producers' revenue through a self-sustaining business.

12. Crop management and crop husbandry:

Crop management is a collection of agricultural techniques used to enhance the growth, development, and productivity of crops. It starts with the planting of seeds, continues with crop maintenance during growth and development, and concludes with crop harvesting, storage, and distribution. Crop husbandry, on the other hand, is the process of cultivating and gathering crops. The major goal is to produce high-quality crops as cheaply as possible without depleting the soil. Therefore, farmers may assure optimum crop output and maintain the health of the land by engaging in crop husbandry.

Developmental approaches in agricultural extension:

1. **Spatial approach:**

This strategy focuses primarily on specific geographic areas, such as a region, subregion, or command area. The goal of spatial planning is to promote a more equitable distribution of economic development within a given region than would otherwise be produced by market forces. This is done through coordinating and improving the impacts of various sectoral policies on land use. Therefore, encouraging sustainable growth and raising quality of life through spatial planning is crucial. Globally, a spatial planning process known as Geode sign has been utilized to establish systematic spatial planning in cooperation with local stakeholders.

2. **Segmental approach:**

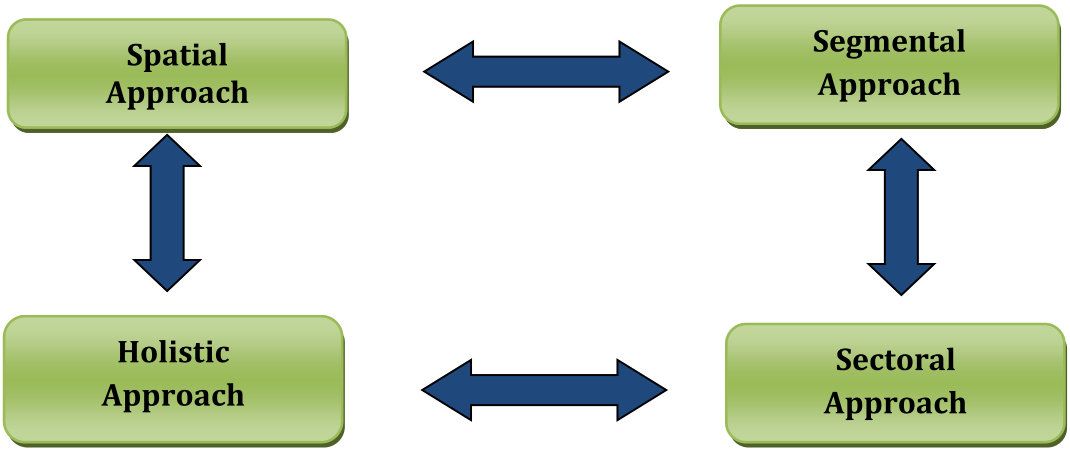
Under segmental approaches, a specific vulnerable segment of population will be considered. For example, to improve the socio economic conditions of the weaker section of community i.e. the farm women. Here, the developmental activities related to farm women can be taken into consideration by forming SHGs, giving training on different vocations etc.

3. **Sectoral approach:**

The planning and growth of a specific economic sector is the emphasis of a sectoral strategy. Sectoral planning refers to the development and implementation of packages of policies or plans for the growth of different economic sectors, such as agriculture, irrigation, manufacturing, power, the built environment, transportation, communication, social infrastructure, and services. In order to revitalize economic activity in specific regions and areas as well as address bad economic performance and widespread job losses (distressed sectors), sectoral planning is used.

4. **Holistic approach:**

Simply said, "holistic" refers to the comprehension of the interactions among all of the constituent elements of a whole. The key links between the land, people, cattle, wildlife, water, etc. must be recognized for holistic management to be effective. The ecological and social repercussions of something should also be taken into account rather than only its economic or financial aspects.



Conclusion:

Different methodologies and techniques of Agricultural extension education played a crucial role in empowering farmers and increasing the livelihoods of farming communities. Transfer of Technology and Agricultural information dissemination is also highly essential for the betterment of Farming community for its sustainable growth and development. For enhancing the Farmers' income various new approached need to followed, such as individual approach to group approach, Top-down approach to Bottom-up approach, Production led extension to market driven extension, Traditional agriculture to climate smart agriculture, Group of farmers-to-farmers group organizations as well as different developmental approach must be adopted.

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A REVIEW ON PHARMACOLOGICAL STATUS OF CARDIOPROTECTIVE PHYTOCONSTITUENTS AGAINST ISOPROTERENOL INDUCED MYOCARDIAL INFARCTION

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Abstract:

Cardiovascular diseases are the major cause of morbidity and mortality in the modern era. Myocardial infarction is a condition where there is a significant decrease or block in the blood (oxygen) supply to the part of heart, leading to degeneration of a portion of the myocardium which triggers a cascade of cellular, inflammatory and biochemical events, leading eventually to the irreversible death (necrosis) of heart muscle cells. Various therapeutic interventions, including lifestyle modification, pharmacological treatment options, and surgical techniques are available. The present review focus on the phytoconstituents that have been evaluated for cardioprotective activity against isoproterenol-induced myocardial infarction.

Keywords: Isoproterenol; Myocardial infarction; Cardioprotective

Introduction:

Beta-sympathomimetic amine Isoproterenol or isoprenaline or isopropyl analog of epinephrine or L-β-(3, 4-dihydroxyphenyl)-α-isopropylaminoethanol hydrochloride or "3,4-dihydroxy-alpha-[(isopropylamino)methyl]benzyl alcohol" is a non-selective β-adrenergic receptor agonist and Trace amine-associated receptor 1 agonist that is available in intracardiac, intramuscular, intravenous and subcutaneous injections for the treatment of heart block, episodes of Adams-Stokes syndrome, for bronchospasm arising through anesthesia, and as an adjunct in the management of septic shock, cardiogenic shock, hypovolemic shock, congestive heart failure, and hypoperfusion states. In the form of nebulizer and metered aerosol inhaler used for the management of asthma. Isoprenaline has effect both on beta 1 and beta 2 receptors with nil activity against alpha adrenoceptors (Kleinau *et al.*, 2011). By acting on beta one receptors present on the heart isoprenaline shows positive inotropic and chronotropic effects thereby causing elevation of systolic blood pressure and by acting on beta 2 adrenergic receptors isoprenaline causes vasodilatation of arteriolar smooth muscle there by lowering the lower diastolic blood pressure, but the predominant effect of the two is vasodilatation of smooth muscles thereby the net effect was reduction in mean arterial pressure. Isoproterenol Induced Model for Myocardial Infarction in rats obliges as a well-accepted consistent screening method to evaluate the effectiveness of the cardioprotective agents due to its simplicity, reproducibility and decreased mortality in rats (Chappel *et al.*, 1959)

Acute administration of increased dose of isoproterenol in experimental rats causes cardiotoxicity which may be due to excessive stimulation of beta-adrenergic receptors that causes catecholamine overload thereby cardiac dysfunction. Isoproterenol by catecholamine-mediated cell signalling may cause decreased oxygen utilization, functional hypoxia and coronary insufficiency thereby leading to myocardial ischemia followed by myocardial infarction. Excessive beta-adrenergic receptor signalling pathways may cause changes in myocardial metabolism, reducing the stores of ATP, increasing the myocardial calcium surplus thereby changing the intracellular electrolyte levels. Increase in the release of catecholamines causes the oxidative stress which occurs due to oxidation of catecholamine that results in the catecholamine-o-quinones known as adrenochromes generation which further undergoes oxidation and forms oxygen free radicals and generate oxidized products (adrenochrome-adrenolutin dimmer, 5, 6-dihydroxy- 1-methylindole or adrenolutin). The oxidized products react with the various proteins mainly by acting on sulphydryl groups thereby leading to the generation of superoxide anions and consequently hydrogen peroxide formation. The generated hydrogen peroxide causes alterations in microsomal permeability, increases in uptake of mitochondrial calcium, reduces the formation of ATP and generates extremely reactive hydroxyl free radicals that produce DNA, lipids and protein impairment (Zhang *et al.*, 2005).

Isoproterenol causes changes intracellular signalling pathways regulating contractility and remodelling by enhancing the activity of adenylcyclase thereby increasing the levels of myocardial cyclic adenosine monophosphate which in turn causes the accumulation of lipids, deposition of fats and depletion of glycogen in cardiac tissue thereby causing the ultra-structural and histopathological changes in the myocardial tissue mainly in mitochondria sarcoplasmic reticulum and sarcolemma. Study has been postulated that excessive stimulation of beta receptors play a role pathogenesis of clinical cardiomyopathy. Increase in protein kinase-A activity following cardiac β-adrenergic receptor activity by administration of isoproterenol causes phosphorylation of the L-type calcium channel and sarcoplasmic reticulum calcium ATPase inhibitor phospholamban which causes increase in calcium overload and accumulation apart from this phosphorylation of the cardiac myofibrillar protein troponin I thereby altering the calcium sensitivity. Changes in calcium homeostasis causes changes in inducible nitric oxide synthase and endothelial nitric oxide synthase activity thereby causing nitrative stress that may be linked to myocardial cell apoptosis. (Bernstein *et al.*, 2011)

Ultra-structural changes caused by myocardial hyperfunction that occurs because of isoproterenol administration includes degeneration and necrosis of cardiac fibers, accumulation of inflammatory cells in the myocardial tissue, formation of lipid droplets, interstitial edema and subendocardial changes. Biochemical changes that occur due to acute over administration of isoproterenol includes changes in lipid profile, increase in lipid metabolizing enzymes, changes in enzymatic and non-enzymatic antioxidants values, overexpression of glycoproteins and reduction in intracellular ATP store. Surplus of intracellular calcium levels and decrease in phosphate reserve are the electrolyte changes seen whereas membrane changes occur in mitochondria, sarcoplasmic reticulum and sarcolemma by acute administration of isoproterenol. (Upaganlawa *et al.*, 2011)

Pharmacological status of cardioprotective phytoconstituents against isoproterenol induced myocardial infarction

1. Panda *et al.* (2017) isolated an iridoid glycoside, agnucastoside C from the leaves of *Moringa oliefera* and evaluated its cardioprotective activity against isoproterenol induced myocardial injury. Agnucastoside C pre-treatment reduced the ST-segment elevation and reduced the activity of serum cardiac biomarkers including CK-MB, troponin-I, ALT, LDH and AST thereby displaying anti-lipids peroxidative besides antioxidative potential against isoprenaline brought on oxidative damage. Pre-treatment with agnucastoside C reduced the levels of inflammatory biomarkers, interleukine-6 and tumor necrosis factor thereby exhibiting cardio protective effect through favorable activity on anti-inflammatory factors.
2. Hussein (2014) evaluated the cardioprotective potency of astaxanthin, a keto-carotenoid found in dietary supplement against isoproterenol induced myocardial infarction. It was noted that astaxanthin pre-treatment enhanced the antioxidant status of plasma and myocardial tissue by showing upsurge in the activity of superoxide dismutase, catalase, GSH and GPx. There was significant reduction in the activity of serum injury markers for instance CK-MB, LDH, ALT besides AST when pre-treated with astaxanthin. It was observed that astaxanthin pre-treatment caused reduction in the activity of MDA and lipid hydroperoxide levels in myocardium thereby showing cardioprotective activity against cardiac toxicity induced by isoproterenol.
3. Sithuraj and Viswanadha (2018) evaluated the cardioprotective effect of berbamine, a bis-benzylisoquinoline group of alkaloids isolated from *Berberis amurensis* against isoproterenol induced myocardial infarction. Pretreatment with 0.025 gm per kg bodyweight daily of berbamine significant decrease in myocardial weight, lipid peroxidation, dyslipidemia and activity of serum biomarker enzymes. There was considerable enhancement in the endogenous myocardial enzymatic and non-enzymatic antioxidants in the berbamine pre-treated group. Apart from this there was berbamine pre-treatment causes upregulation in endothelial NOS expression besides downregulation of inducible nos expression thereby displaying cardio-protection contrary to isoprenaline stimulated cardiac necrosis by its antioxidant besides antilipidemic properties.
4. Meena *et al.* (2014) evaluated the cardioprotective potential of betaine, is an amino acid derivative obtained from plant source such as Quinoa, Spinach, Wheat bran, Lamb's quarters and Beetroot against myocardial infarction induced by isoproterenol at doses of 0.025 gm per kg body weight. It has been viewed that pre-treatment with betaine showed marked decrease in the activities of lysosomal enzymes such as β-galactosidase, β-glucosidase β-glucuronidase besides acid phosphatase in plasma with a related upsurge in activities of lysosomal enzymes within myocardium. Lipids per-oxidation activity of the lysosomal membrane was attenuated in betaine pre-treated group thereby showing cardioprotective

activity by decreasing the degree of lysosomal membrane injury and preserve the lysosomal integrity in myocardial infarction induced by isoproterenol.

5. Kumar *et al.* (2016) investigated the cardioprotective potential of baicalein, a phytoconstituent obtained from roots of *Scutellaria lateriflora* and *Scutellaria baicalensis* on myocardial infarction induced by isoproterenol at dose of 0.05 gm per kg as well as 0.1 gm per kg bodyweight daily. It was observed that pre-treatment with baicalein showed considerable reduction in amount of myocardial biomarkers CK-MB, ALT, AST and cardiac troponin I. There was significant decrease in of reactive oxygen species and reactive nitrogen species in the myocardium and enhancement in antioxidant activity in group pre-treated with baicalein. It was shown that baicalein pre-treatment reduced the activity of pro-inflammatory cytokine interleukin-6 and TNF alpha. Apart from this baicalein restored the activity of expression of nuclear factor kappa B and antioxidant enzyme levels thereby demonstrating considerable cardio-protection against isoproterenol induced myocardial injury.
6. Ameri *et al.* (2015) investigated the cardioprotective potential of Bisabolol, is a natural monocyclic sesquiterpene alcohol found in essential oil from German chamomile and *Myoporum crassifolium* against myocardial infarction induced by isoproterenol. Pre-treatment with bisabolol reduced the levels of lipid peroxidation product malondialdehyde as well as serum biomarker enzymes serum glutamate-pyruvate transaminase, SGOT, CK-MB besides LDH. The inflammatory markers such as interleukin-6, interleukin-1β and tumour necrosis factor alpha were reduced by Bisabolol pre-treatment. The GSH besides levels of CAT as well as SOD were notably enhanced when pre-treated with bisabolol. Histoarchitecture features of myocardium were preserved by pre-treatment with bisabolol there by indicating cardioprotective potential against myocardial ischemia induced by isoproterenol due to its antioxidant, anti-lipid peroxidative and anti-inflammatory potency.
7. Kumaran and Prince (2010) investigated the cardioprotective efficacy of caffeic acid against myocardial infarction persuaded by isoprenaline at dose of 0.015 gm per kg bodyweight. It has been recognized that pre-treatment with caffeic acid decreased the activity of serum troponins and mitochondrial lipid peroxidation product in myocardium. These was increase in the levels of antioxidants reduced glutathione, glutathione peroxidase, NADH dehydrogenases, isocitrate, α-ketoglutarate, succinate, malate and cytochrome-C-oxidase the mitochondria of myocardial tissue. The TC, TG, free fatty-acids as well as calcium are reduced in mitochondria when pre-treated with caffeic acid apart from increasing the activity of phospholipids and adenosine triphosphate. Histopathological and ultrastructural studies confirm that caffeic acid preserved the myocardial cytoarchitecture thereby offering considerable protection against isoproterenol induced myocardial damage and showing cardiac mitochondria protection.
8. Bi (2012) demonstrated the cardioprotective potential of catalpol, an iridoid glucoside obtained from plants belonging to the genus Rehmannia onto isoprenaline incited cardiac damage. Pretreatment with catalpol decreased the oxidative stress by reducing the levels of

lipid peroxide products and enhanced antioxidant intensity with increasing magnitude of SOD. Catapol pre-treatment caused downregulation of the instigation of anti-inflammatory markers for instance interleukins-1β as well as tumor necrosis factor-β thereby providing anti-inflammatory activity. Histopathological studies confirm that the catapol possess cardioprotective effect by its anti0inflammatory property and by preserving endogenous antioxidant enzyme potency against isoproterenol induced cardiotoxicity.

9. Akila and Vennila (2016) investigated the cardioprotective activity against myocardial infarction induced by isoproterenol by chlorogenic acid found in coffee. It was found that pre-treatment with chlorogenic acid caused reduction in intensities of myocardial biomarkers such as CK-MB, creatine kinase, troponin T and I, lactate dehydrogenase, ALT as well as AST in serum. The lipid peroxidation by-products such as TBARS, lipid hydroperoxides and conjugated dienes was reduced when pre-treated with chlorogenic acid both in myocardium and plasma. The activity of antioxidative enzymes for instance GST, GPX, CAT as well as SOD were elevated apart from upsurge in the levels of nonenzymatic anti-oxidants for instance glutathione, vitamin-E as well as Vitamin-C in red blood cells, myocardium and plasma was observed with chlorogenic acid pre-treatment. Reduction in infarct size was noted when pre-treated with chlorogenic acid there by offering cardio-protection against myocardial oxidative stress induced by isoproterenol.
10. Anandan *et al.* (2012) investigated the cardioprotective potential of dietary chitosan supplementation against myocardial infarction induced by isoproterenol. It was shown that supplementation of dietary chitosan supplementation reduced lipids peroxidation besides enhancement in intensities of enzymatic antioxidant for instance GST as well as glutathione peroxidase, superoxide dismutase and catalase activity thereby exhibiting cardio-protection against isoproterenol induced cardiac damage.
11. Zhang *et al.* (2017) evaluated the cardioprotective potential of crocetin, a natural apocarotenoid dicarboxylic acid that is found in the crocus flower and *Gardenia jasminoides* against isoproterenol induced myocardial infarction. The study showed that the crocetin attenuated the changes in creatine kinase-MB, lactate dehydrogenase, catalase, superoxide dismutase, malondialdehyde and glutathione. Pre-treatment with crocetin decreased magnitude of inflammatory cytokine in myocardium apart from reducing magnitude of Nrf-2, Bax as well as caspase-3 suggestively besides improving Bcl-2 activity in cardiac tissue. The changed myocardial cellular architecture of myocardium was reversed near to normalcy by administration of crocetin thereby suggesting its cardioprotective effect by antagonizing the oxidative damage as well as inflammatory cytokine besides decreasing the apoptotic intensity of cardiomyocytes and protecting myocardium against isoproterenol induced cardiac toxicity.
12. Goyal *et al.* (2010) evaluated the cardioprotective activity of crocin, a pharmacologically active constituent of *Crocus sativus* in isoproterenol-induced cardiotoxicity in rats. Pre-treatment with crocin reversed the hemodynamic changes produced by isoproterenol such as decrease of diastolic, systolic and mean arterial blood pressures and reduction of maximum

negative as well as positive amount of established left ventricle pressure as well as upsurge in left ventricular end-diastolic pressure. Crocin expressively modulated antioxidant derangements in the activities of lactate dehydrogenase, myocardial creatine kinase-MB isoenzyme, reduced glutathione, catalase and superoxide dismutase as well as malondialdehyde levels. Crocin pre-treatment reduced the myocardial necrosis, edema and inflammation caused by isoproterenol thereby displaying cardioprotective activity against isoproterenol induced cardiac toxicity.

13. Boarescu *et al.* (2019) evaluated the cardioprotective effect of curcumin a polyphenol produced by *Curcuma longa* (turmeric) and its nanoparticles on isoprenaline caused cardiac necrosis. Curcumin as well as curcumin nanoparticles in three different doses of100 mg/kg, 150 mg/kg and 200 mg/kg body weight prevented the leakage of cardiac biomarker creatine kinase-MB from cardiomyocytes. The oxidative stress parameters were decreased by pre-treatment with curcumin and curcumin nanoparticles thereby enhanced antioxidant response to isoproterenol. The intensities of inflammatory cytokine (IL-1α, TNF-α, IL-6, IL-1β, MCP-1, and RANTES) were decreased after pre-treatment with curcumin and curcumin nanoparticles apart from decreasing serum levels of proinflammatory matrix metalloproteinase expression. Curcumin and curcumin nanoparticles averted myocardial necrosis, decreased interstitial edema and neutrophil infiltration caused by isoproterenol thereby improving the myocardial function and attenuating myocardial injury after myocardial ischemia.
14. Priscilla and Prince (2009) investigated the cardioprotective potential of gallic acid, a type of phenolic acid, found in sumac, gallnuts, tea leaves, oak bark, witch hazel and other plants against isoproterenol induced myocardial infarction. Gallic acid pre-treatment reduced the levels of serum cardiac biomarkers for instance ALT, AST, CK, CK-MB, LDH as well as troponin-T. Altered activity of LDH -isoenzyme band (LDH-1 as well as LDH-2) by isoproterenol were attenuated by gallic acid pre-treatment. The lipid peroxidation products and uric acid levels were significantly reduced both in myocardial tissue and plasma when pre-treated with gallic acid. There was noteworthy enhancement in enzymatic antioxidant for instance GST, GPX, CAT, SOD as well as glutathione reductase in the myocardium besides nonenzymatic antioxidant for instance vitamin E as well as vitamin C and glutathione both within myocardial tissue as well as plasma when pre-treated with gallic acid. Apart from these histopathological studies confirmed that the gallic acid pre-treatment reversed the pathological changes produced in myocardium thereby offering notable cardioprotective activity.
15. Xu *et al.* (2019) investigated the cardioprotective efficacy of hispidulin, a flavone found in *Crossostephium chinense*, *Saussurea involucrate*, *Arrabidaea chica*, *Grindelia argentina*, Salvia and Artemisia in myocardial ischemia induced by isoproterenol. It was found that pre-treatment with hispidulin caused reduction in extent of myocardial diagnostic markers (LDH, Cardiac troponin as well as CK) and products of lipid peroxidation in serum. There were

intensifications in intensities of TC, LDL, TG, in hispidulin pre-treated group. Pre-treatment with hispidulin caused downregulation of protein expression of inflammatory markers such as p65, NF-κB subunits and TNF-α thereby exhibiting considerable cardio fortification contrary to isoprenaline caused cardiac necrosis by augmenting oxidative status in addition to reducing dyslipidemia and inflammatory reactions.

16. Suchal *et al.* (2016) investigated the cardioprotective potency of a dietary flavonoid, Kaempferol on against oxidative stress and myocardial infarction induced by isoproterenol. Pre-treatment with kaempferol at doses of 0.005 mg per kg, 0.010 mg per kg & 0.020 mg per kg daily bodyweight improved the hemodynamic parameters such as significant arterial pressure, restored the left ventricular functions such as rate of development of left ventricle pressure besides LVEDP. Pre-treatment with Kaempferol reduced myocardial biomarkers (LDH as well as CK-MB) in serum, augmented antioxidant levels (GSH, CAT and SOD), decreased lipids peroxidation activity, TNF-α and IL-6 levels. Histopathological studies support cardioprotective consequence of Kaempferol onto isoproterenol persuaded cardiac damage by its anti-apoptotic, anti-inflammatory and antioxidative properties.
17. Garg *et al.* (2019) investigated the cardioprotective effect of the flavonoid, fisetin mainly seen in apple and strawberry against isoproterenol induced cardiac ischemia at the dose level of 10 and 20 mg/kg body weight. It was found that the pre-treatment with fisetin antagonized the damaging modifications in blood pressure and left ventricular pressures. It was shown that pre-treatment with fisetin abridged the myocardial serum biomarkers for instance LDH as well as CK-MB. Fisetin reversed pro-apoptotic proteins (bax, caspase-3, cytochrome-c) and increased the anti-apoptotic protein (Bcl-2) thereby exhibiting cardio protection against myocardial injury caused by isoproterenol.
18. Haque *et al.* (2018) investigated the cardioprotective efficacy of Icariin, a prenylated flavanol glycoside obtained from the plants belonging to the genus Epimedium in the dose levels of 5 mg/kg and 10 mg/kg body weight. Pre-treatment with icariin showed decrease in the lipid peroxidation activity. There was improvement in antioxidant status and decrement in the activity of serum biomarker enzymes for instance CK-MB, LDH as well as C-reactive protein when pre-treated with icariin. The altered levels of protein expression of nuclear factor-like 2 were brought back to normalcy with icariin pre-treatment there by showing cardio-protection against isoproterenol induced cellular damage and maintaining myocardial membrane integrity.
19. Adaramoye *et al.* (2015) investigated the cardioprotective potential of a bioflavonoid from seeds of *Garcinia kola*, kolaviron onto isoprenaline incited myocardial injury by modifying myocardial dys-function. At the doses of 100 mg/kg and 200mg/kg body weight. It was observed that supplementation of kolaviron caused noteworthy raise of myocardial antioxidative enzyme for instance SOD, catalase, GST, reduced glutathione besides reduction of lipid peroxidation by-product malondialdehyde. Administration of kolaviron produced noteworthy raise in myocardial antioxidative enzyme, normalized the marker enzymes

(serum creatine phosphokinase, lactate dehydrogenase, alkaline phosphatase, ALT as well as AST) and serum lipid profile thereby reversing the changes produced by isoproterenol and displaying cardioprotective action against cardiotoxic drug isoproterenol.

20. Murugesan and Manju (2013) investigated the mitochondrial protection after isoprenaline caused cardiac necrosis of Luteolin a flavanoid obtained from the plant *Reseda luteola*. It was observed that there was diminution in magnitude of lipid peroxidation by-product TBARS besides enhancement in the activity of antioxidant enzymes apart from decreasing the abnormal lipid profile in groups pre-treated with luteolin.
21. Ojha *et al.* (2013) investigated the cardioprotective efficacy of carotenoid lycopene against isoprenaline caused cardiac necrosis in doses of 0.5 mg/kg, 1 mg/kg as well as 1.5 mg/kg bodyweight every day. It was observed that pre-treatment with lycopene attenuated isoproterenol induced cardiac dysfunction as evidenced by improved heart rate, myocardial contractility and relaxation, systolic blood pressure, diastolic blood pressure and mean arterial blood pressure and reduced left ventricular end-diastolic pressure. Pre-treatment with lycopene also considerably averted the depletion of antioxidants (superoxide dismutase, glutathione, catalase and glutathione peroxidase), myocardial biomarkers (CPK-MB as well as LDH) besides hindered lipids peroxidation and malondialdehyde formation in the myocardial tissue. Histopathological studies revealed that pre-treatment with lycopene decreased myocardial necrosis, myocardia edema and infiltration of inflammatory cells thereby proposed that lycopene antagonized the cardiotoxic effect of isoproterenol and offered significant cardio-protection.
22. Nair and Devi (2006) investigated the cardioprotective activity of mangiferin, a xanthonoid extracted from leaves, bark, kernels and peels of *Mangifera indica*, *Bombax ceiba*, *Anemarrhena asphodeloides* rhizomes and *Iris unguicularis*. against isoproterenol induced myocardial infarction. Pre-treatment with mangiferin diminished the levels of free fatty-acids, triglycerol as well as TC activity in myocardium and blood offering protection by hypolipidemic effect. Apart from this upsurge in magnitude of myocardial phospholipid was noted by pre-treatment of mangiferin there by antagonizing the effect of isoproterenol induced changes in lipid levels.
23. Wei *et al.* (2017) evaluated the cardioprotective activity of malvidin (alvidin-3-glucoside) which is a polyphenol plentifully found in colored fruits, red wines and the skin of red grapes against myocardial infarction induced by isoproterenol. Malvidin displayed noteworthy cardioprotective action by reinstating the defensive activities of endogenous antioxidants such as GPX, CAT as well as SOD; by decreasing lipids peroxidation activity and serum biomarker enzymes such as creatine kinase and lactate dehydrogenase. Pre-treatment with malvidin decreased the levels of anti-inflammatory enzymes such IL-6 and TNF-α as well as ameliorated the histopathological changes caused by isoproterenol thereby showing cardioprotective effect by reversing the antioxidant and anti-inflammatory changes produced by mitochondria.

24. Mutneja *et al.* (2019) investigated the cardioprotective activity of morin a phytoconstituent obtained from *Maclura pomifera, Maclura tinctoria and Psidium guajava* onto isoproterenol induced myocardial necrosis. It was found that the morin pretreatment improved the hemodynamic parameters changed by isoproterenol apart from enhancing the antioxidant status. The activity of pro-inflammatory cytokines such as TNF-alpha and IL-6 and apoptosis markers such as Bax, Caspase-3, p-JNK, p-38 and NF-kappa B, Bcl-2 were brought back to normalcy in group pre-treated with morin. Apart from this morin pre-treatment normalized myocardial architecture which was changed due to administration of isoproterenol thereby offering significant cardio protection against isoproterenol induced cardiotoxic effect.
25. Rajadurai *et al.* (2006) studied the cardioprotective potency of naringin a major flavonoid glycoside in grapefruit onto isoproterenol persuaded myocardial damage at doses of 0.01 mg per kg, 0.02 mg per kg as well as 0.04 mg per kg bodyweight daily. Pre-treatment with naringin displayed a noteworthy reduction in activities of lipid peroxides in serum as well as myocardium and improved the antioxidant status by enhancing the activities of enzymatic antioxidant and nonenzymatic antioxidants for instance GST,SOD, GPX as well as CAT in the myocardium and activities of tocopherol, reduced glutathione and ascorbic acid within myocardium and plasma and ceruloplasmin in plasma. Histopathological findings of heart displayed the protective effect of naringin on isoproterenol induced cardiotoxicity by anti-lipid peroxidative and antioxidant potency.
26. Hao *et al.* (2019) evaluated the cardioprotective potency of naringenin, a flavanone found in citrus and grape fruits against isoproterenol induced cardiotoxicity. This investigation revealed that naringenin pre-treatment enhanced the antioxidant activity by increase the levels of endogenous antioxidants such as CAT and SOD aw well as improvement in hemodynamic parameters such as systolic blood pressure and diastolic blood pressure. There was significant reduction in the activity of inflammatory biomarkers such as tumor necrosis factor alpha, Nuclear factor kappa bp65 subunit, Interleukin-1 β and Interleukin-6 when pre-treated with naringenin. The activity of serum myocardial biomarkers for instance troponin C, CK as well as LDH were reduced within naringenin pre-treated animals. Considerable reduction in cardiac to bodyweight ratio and lipid peroxidation products in naringenin pre-treated group thereby showing cardio protection against isoproterenol induced changes in oxidative stress and inflammatory responses.
27. Asaikumar *et al.* (2019) evaluated the cardioprotective effect of nerolidol, sesquiterpene alcohol found in the essential oils of many types of plants and flowers against myocardial infarction induced by isoproterenol. It was observed that pre-treatment with nerolidol reversed the changes caused by isoproterenol administration in the magnitudes of myocardial and hepatic biomarkers for instance CK, LDH, CK-MB, ALT, AST as well as troponin T and I in the serum. Nerolidol pre-treatment reduced the activity of lipids peroxidation compounds for instance MDA, conjugated dines, and lipids hydroperoxides within myocardial tissue and plasma. Thereby exerting anti-lipid peroxidative property. Nerolidol pre-treatment enhanced

the levels of enzymatic antioxidants such as superoxide dismutase, catalase, glutathione peroxidase, glutathione-S-transferase in erythrocytes and myocardium and the activity of nonenzymatic antioxidants like tocopherol, vitamin C, and reduced glutathione in myocardium and plasma. Nerolidol pre-treatment also brought back histopathological changes induced by isoproterenol near to normalcy thereby conferring cardioprotective effect against isoproterenol cardiac toxicity.

28. Roy and Prince (2013) investigated the cardioprotective efficacy of p-Coumaric acid found in garlic, basil, carrots, peanuts, tomatoes and navy beans against isoproterenol induced myocardial infarction. It has been shown that pre-treatment with p-Coumaric acid antagonized the ST-segment raise in the electrocardiogram. Activities of myocardial sensitive biomarkers were reduced considerably by pre-treatment with p-Coumaric acid. There was significant diminution in the activity of free fatty-acids, triglycerides and TC within myocardium and plasma when pre-treated with p-Coumaric acid. Pre-treatment with p-Coumaric acid also showed noteworthy upsurge in amount of HDL with concurrent lessening in activities of LDL and VLDL. Apart from this p-Coumaric acid pre-treatment showed reduction in intensity of HMG Co-A reductase activity in liver thereby reversing the changes produced by isoproterenol.
29. Li *et al.* (2018) evaluated the cardioprotective efficacy of Puerarin-V, bioflavonoid found in root of Pueraria (*Radix puerariae*) by isoproterenol induced cardiotoxicity. It was observed that Puerarin-V pre-treatment inhibited the ST segments and T waves also showed depression seen by isoproterenol. Puerarin-V pre-treatment decreased the infiltration of inflammatory cells with multiple localized necrosis in myocardial tissue and other pathological exacerbation caused due to isoproterenol administration. The magnitude of myocardial biomarkers cardiac troponin T, LDH and aspartate aminotransferase were significantly reduced when pre-treated with Puerarin-V. proinflammatory cytokines expression including IL-6, TNF-α, and IL-1β in the myocardium was attenuated with Puerarin-V pretreatment caused diminution of TUNEL labelling-positive cells thereby exhibiting anti-apoptotic activity on cardiomyocytes and increase in B-cell lymphoma-2 protein expression in myocardial tissue was observed which indicates anti-apoptosis activity against isoproterenol induced apoptosis. Puerarin-V pretreatment exhibited considerable anti-inflammatory potency by including NF-κB transcriptional activity stimulation besides modulation of PPARγ transcription extent thereby exerting myocardial protective outcome counter to isoproterenol persuaded cardiac inflammation.
30. Khan *et al.* (2018) studied the cardioprotective potency of raspberry ketone against myocardial infarction induced by isoproterenol. Pre-treatment with raspberry ketone shows the decrease in the cardiac biomarkers for instance CK-MB besides LDH. Altered lipid profile which shows dyslipidemia by isoproterenol treatment was brought to near normalcy by raspberry ketone pre-treatment. Antioxidant status was improved as the activity of reduced glutathione, catalase and superoxide dismutase was enhanced. Biomarkers of

inflammation TNF-alpha besides inducible NOS were brought to normal which were altered by isoproterenol administration. Apart from this histopathological change which were noted by isoproterenol administration were brought to normal structure thereby confirming cardioprotective activity in isoproterenol induced cardiotoxicity by decreasing oxidative stress, dyslipidemia and inflammation.

31. Zuo *et al.* (2011) investigated the cardioprotective potential of grape seed proanthocyanidins against isoproterenol induced myocardial necrosis. It was observed that proanthocyanidins pre-treatment ameliorated oxidative stress by refining superoxide dismutase activities and decreasing TBARS activity. Apart from this proanthocyanidins caused seemingly decrease in the expression apoptosis signal-regulating kinase 1 and nuclear factor-κB and its targeted gene cyclooxygenase-2. Histopathological changes showed proanthocyanidins pre-treatment caused reduction in deposition of collagen in myocardium, and enhanced the haemodynamic index thereby protecting against isoproterenol induced cardiac remodeling.
32. Fan (2019) investigated the cardioprotective effectiveness of Rhapontigenin a stilbenoid that was isolated from *Gnetum cleistostachyum* and *Vitis coignetiae* in rats having acute cardiac ischemia persuaded by isoproterenol. Pre-treatment by rhapontigenin elicited amelioration of myocardial infarct size, heart/body weight index, creatinine kinase, lactate dehydrogenase and cardiac troponin-T activity in rats. Pre-treatment of rats with rhapontigenin increases the antioxidant activity (levels of superoxide dismutase and malondialdehyde) there by ameliorating the effct of isoproterenol on oxidative stress. Pre-treatment of rats with rhapontigenin decreased the activity of inflammatory mediators (tissue necrosis factor-alpha and interleukin-6) there by confirming its anti-inflammatory property. INOS, p38, caspase-3, and connexin 43 expressions were downregulated by pre-treatment with rhapontigenin thereby showing that that the extract possesses notable antiapoptotic activity against isoproterenol induced apoptosis.
33. Toutounchi *et al.* (2017) evaluated the cardioprotective potential of Rosmarinic acid is a polyphenolic compound found in *Ocimum basilicum*, *Rosmarinus officinalis*, *Melissa officinalis*, *Ocimum tenuiflorum* and many other culinary herbs on Isoproterenol-Induced Myocardial Infarction at the dose level of 10, 20, 40 mg/kg body weight. Pre-treatment with Rosmarinic acid expressively decreased peripheral neutrophil percentage shows inhibition in ST-segment elevation and R-amplitude depression induced by isoproterenol. The heart rate, mean arterial pressure and left ventricular end diastolic pressure which were altered by isoproterenol were brought back to normal. Myocardial necrosis, myocardial edematous and cardiac fibrosis where inhibited by rosmarinic acid pre-treatment which were induced by isoproterenol confirmed through histopathological studies which suggests rosmarinic acid improves the cardiac performance offers protection against isoproterenol induced oxidative stress.
34. Karthick and Prince (2006) investigated the cardioprotective activity of rutin, a bioflavonoid found in apples, buckwheat, figs, utmost citrus, and both black and green tea against

myocardial infarction induced by isoproterenol. Pre-treatment with rutin showed noteworthy lessening in levels of myocardial biomarkers for instance AST, ALT, CK and LDH besides a substantial enhancement in the levels of these enzymes in myocardium. These was augmentation in the antioxidant activity with increase in magnitude of endogenous antioxidative enzyme CAT, SOD and GPX as well as non-enzymatic antioxidants ascorbic acid and reduced glutathione. Apart from this pre-treatment with rutin reduced the extent of lipids peroxidative compounds for instance lipid hydroperoxides and TBARS thereby showing cardio-protection by its antioxidant property against isoproterenol induced cardiotoxicity.

35. Vennila and Pugalendi (2012) studied the cardioprotective activity of sesamol, a phenolic antioxidant obtained from *Sesamum indicum* seeds and oil against isoproterenol induced myocardial infarction. Pretreatment with sesamol displayed reduction in magnitude of phospholipids, FFA,free fatty-acids, triglycerides, and total cholesterol in plasma along with enhancement in phospholipids in myocardium. VLDL as well as LDL activities were decreased by pretreatment with sesamol along with upsurge in amount of HDL thereby offering cardio-protection against isoproterenol persuaded variations in lipid profile.
36. Yang *et al.* (2017) evaluated the cardioprotective of Shikonin, a naphthoquinone obtained from *Lithospermum erythrorhizon* roots on isoproterenol induced myocardial damage. nuclear transcription factor κB, toll like receptor 4, caspase-3 and glucose-regulated protein 78 signalling pathways activity was brought back to normalcy with pre-treatment by Shikonin. It was noted that pre-treatment with shikonin upgraded myocardial function, reduced cardiac fibrosis, decreased apoptosis, decreased myocardial inflammation and endoplasmic reticulum stress through hindering collagen deposition in myocardial tissue thereby offering protection against cardiac injury by isoproterenol.
37. Huang *et al.* (2018) evaluated the cardioprotective potency of scutellarin the active phytoconstituent of *Erigeron breviscapus* against myocardial infarction induced by isoproterenol at the dose level of 10 mg/kg, 20 mg/kg, 40 mg/kg body weight. Serum injury markers troponin T, troponin I, aspartate aminotransferase and lactate dehydrogenase were reduced when pre-treated with scutellarin. The antioxidant activity such as catalase, reduced glutathione and superoxide dismutase in myocardium were enhanced and reduction in lipid peroxidation (malondialdehyde) and inducible nitric oxide synthase activity when pre-treated with scutellarin. Pre-treatment with scutellarin caused the reduction in expression of Bax, P53, cytochrome C, Caspase9, Caspase3, nuclear factor kappa-light-chain-enhancer of activated B cells, neutrophil gelatinase-associated lipocalin, IL-6 and IL-1β in myocardium, whereas the expression of Bcl2 was enhanced thereby proving the anti-apoptotic activity of scutellarin. There was reduction in histopathologic heart changes induced by isoproterenol thereby confirming scutellarin cardio-protective activity by refining the antioxidant, anti-inflammatory and anti-apoptotic abilities of heart.

38. Farvin *et al.* (2006) appraised myocardial protective potency of squalene a polyunsaturated hydrocarbon obtained from olive oil. It was found that pre-treatment with squalene displayed substantial lessening in amount of LDL besides enhancement in amount of HDL concurrently enhancing the phospholipids in cardiac tissue. Squalene pre-treatment also stabilized the lipid peroxidation by-products to the normal levels there by showing cardio-protection by reversing the squalene induced changes in lipid accumulation and cardiac injury.
39. Fu *et al.* (2018) investigated the cardioprotective activity of Tangeretin, a citrus polymethoxyflavonoid contrary to cardiac dysfunction persuaded with isoprenaline. It was found that pre-treatment by tangeretin augmented the antioxidant such as, glutathione peroxidase, superoxide dismutase and catalase along with hemodynamic parameters. Tangeretin pre-treatment caused reduction in infarct size, apoptotic markers such as caspase-3 and caspase-9, inflammatory markers such as nuclear factor kappa B p65 subunit, interleukins-6, TNF-α as well as interleukin-1 and lipids peroxidation by-products. myofibrillar degeneration/disruption seen with isoproterenol administration was brought to normal myocardial cytoarchitecture with noticeable myofibrillar structure by tangeretin pre-treatment thereby confirming its cardioprotective efficacy by diminishing oxidative stress, inflammation and apoptosis induced by isoproterenol in experimental rats.
40. Shiny *et al.* (2005) investigated the cardioprotective potency of taurine, an essential amino acid present in broccoli, garlic, brussels sprouts, oats, onions, sprouted lentils, red peppers and wheat germ upon cardiac ischemia produced by isoprenaline. The diagnostic biomarker enzymes in plasma such as ALT, AST, LDH and CPK were notably reduced by pre-treatment with isoproterenol. Taurine exerted an antioxidant potential by averting the accretion of lipid peroxides and by preserving the magnitudes of catalase, SOD, GSH GST as well as GPX close to normalcy against myocardial infarction induced by isoproterenol thereby indicating cardioprotective effect due to antioxidant and antiperoxidative properties of taurine against isoproterenol induced cardiac toxicity by its membrane stabilizing property against oxidative stress.
41. Pinelli *et al.* (2010) evaluated the cardioprotective activity of Tetrandrine, the active principle of *Stephania tetrandra* radix extracts against isoprenaline incited cardiac injury in rabbits. Pre-treatment with Tetrandrine counteracted the advent of myocardial necrotic lesions and ischemic electrocardiographic modifications, such as alterations in ST segment, averted the activity of the plasma cardiac necrosis markers cardiac troponin I and myoglobin, reduced the activity of lipid peroxidation by reducing malondialdehyde activity, and prolonging partial thromboplastin time. The cardioprotective efficacy of tetrandrine against myocardial infarction induced by isoproterenol is attributed to its antioxidant action in decreasing lipid peroxidation activity and its capability to counteract coagulating activity thereby showing anti-infarction effects.
42. Hemalatha and Prince (2016) investigated the cardioprotective potency of zingerone on isoprenaline prompted cardiac ischemia. Zingerone pretreatment elicited decrease in the

levels of serum cardiac injury markers and upsurge in the activity of heart mitochondrial reduced glutathione, glutathione peroxidase, superoxide dismutase, respiratory chain and tricarboxylic acid cycle enzymes. There was decrease in the activity of cardiac mitochondrial lipid peroxidation, calcium ions and ATP when pre-treated with zingerone thereby preventing isoproterenol induced cardiac damage.

Conclusion:

Isoproterenol a beta-adrenergic receptors agonist causes severe stress in myocardium resulting in the infarct-like lesion and produced cardiotoxic effects by elevating the levels of cardiac biomarkers and causing changes in ECG. Phytoconstituents with their antioxidant, antiapoptotic, antihyperlipidemic, platelet antiaggregatory, anti-lipid peroxidation property provides substantial evidence for the management of Ischemia. This review gives a glance on the clinical effectiveness, minimal side effect profile and relatively low costs of herbal drugs in management of myocardial infarction. Further research should be done to exact mechanism responsible for their activity.

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TACTICS FOR MANAGEMENT OF STORED FOOD MITES

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Abstract:

Storage pests are a major concern so, this chapter discusses the many techniques used to manage arachnids mainly mites that cause issues with food and agricultural products during storage and after harvest. Physical, chemical, or biological elements can be used to categorize the control procedures now in use. Techniques based on high temperatures, altered atmospheres, screening, sanitation, inert dusts, natural and synthetic chemical, fumigants, pathogens, parasites, or predators are described for successful control of pests are discussed.

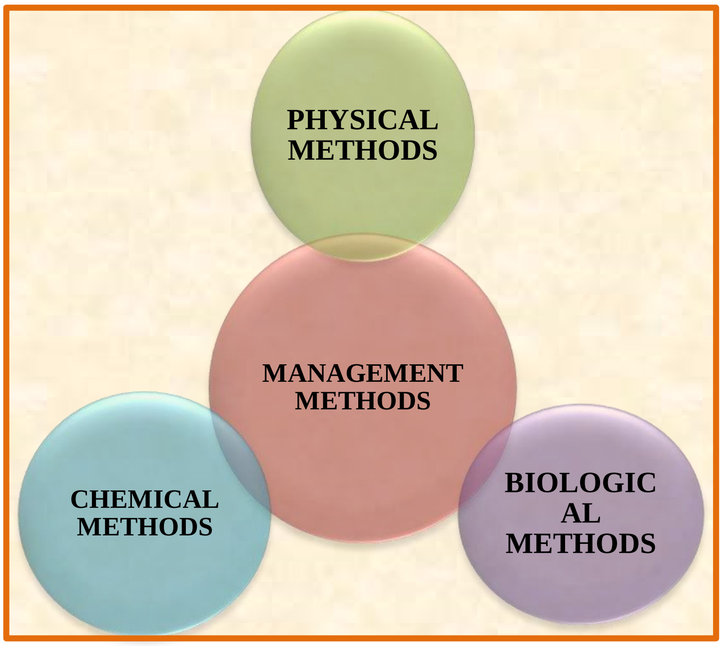
Keywords: Stored pests, mites, pest detection, pathogen, pest management.

Introduction:

Insects, mites, and other stored pests are a major issue in the food industry. Mites can be found at every stage of the food production process, from open fields and greenhouses to residential larders and pantries. These are common pests in grains, cereals, oilseeds, and other agricultural products that have been preserved for a long time. These are in the phylum Arthropoda subphylum Chelicerata and subclass Acari. The body is unlike any other arthropods (Kumari and Gond, 2020). There is a chelicerate present, but the mandible, maxillae, and antennae are missing. Mites are the most diverse organisms, adapting to any suitable environment (Atkinson *et al.,* 1999). Wakefield and Dunn, 2005 found that *Acarus siro* L., *Lepidoglyphus destructor* (Schrank), *Tyrophagus longior* (Gervais), and *Tyrophagus putrescentiae* (Schrank) are the most common species. Mites are a pest of horticulture and crops and stored products that can be found all over the world (Rees, 2004)

Mites eat cereal germ and hollow down rapeseed, diminishing germination and lowering the value of seed for malting (Collins, 2006). Grain can be tainted by heavy infestations, making it unfit for grinding and unpleasant to cattle. Heavy infestations contaminate the grain, rendering it unfit for processing and unpleasant to livestock, resulting in lower growth rates (Wagacha and Muthomi, 2008). These are also extremely allergic, posing major health concerns to employees, as well as being linked to the spread of microorganisms and cause skin allergies, asthma, and systemic anaphylaxis (Stejskal *et al.*, 2018; Mullen and OConnor, 2019; Sushma *et al.*, 2022)

Even though mites are common in homes, strong evidence of their physical presence in food has only lately been established (Dhooria, 2016). Although the number of times ingestion of storage mites or their feces harms human health is small but the presence of mites is incompatible with rising customer demands for high-quality, risk-free food (Vogel *et al.*, 2015). The use of traditional insecticides to manage insects and mites has become increasingly difficult, and effective alternative treatments are urgently needed (Hoy, 2011). A variety of management methods in use or at an advanced level of investigation are mentioned here.



Physical methods

Physical control measures are the most effective way to avoid and tackle pest management issues.

Aeration: It has long been recommended that aeration be used to create somewhat low temperatures to prevent storage insect infestations (Burges and Burrell, 1964). Aeration is commonly used to chill bulk grain in a temperate environment. A fan attached to a specially constructed ducting system creates the effect. This provides airflow to the base of a silo or to equally spaced channels beneath the grain store's floor, which are covered by fine mesh metal panels to prevent grain infiltration. In the absence of a ventilated floor, reinforced perforated ducts can be installed on the floor and manifolded to a fan-driven airflow before the arrival of the grain (Navarro, 2012). Grain drying or conditioning is frequently thought to be a secondary application for aeration. Many mite management programs include aeration, which plays a critical role in preventive control at a cost that is competitive with other disinfestation methods (Bell, 2014).

Cold: Cold treatments are commonly employed as part of integrated pest management (IPM) systems for stored items such as grains, cereals, oilseeds, and seeds, in addition to the usage of aeration systems. Fields, 1992 examined the effects of cold on mites of durable stored products.

Their reproduction stops at 10 degrees Celsius, and populations dwindle and finally die out. Various major pest species, such as bruchids, mites, and some Lepidoptera, have tolerant immature stages (Fields, 1992; Bell, 2014). But, cooling typically necessitates extremely long holding times to be effective.

Heat: Elevated temperatures are a strategy that has been used successfully for many years against stored-product pests. The thermal limitations of insects and mites are usually between 0 to 4580C, and the rates of population increase are determined by temperatures within these limits (Mourier and Poulsen, 2000). More extreme temperatures have an acute influence. High temperatures, at their extreme, disrupt phospholipid membranes and intracellular proteins (Bale and Hayward, 2010). Heat disinfestation needs just that all particles of an infested grain batch be heated to a suitable fatal temperature/time combination, which is a rather straightforward process. Heat treatment affects different mites and bug species and stages differently; however most species will not survive more than 12 hours at 458°C, 5 minutes at 508°C, and 30 seconds at 608°C. Death is related to the temperature to which the mites are exposed and the duration of exposure, but a recent study indicates that the rate at which the grain is heated is also important, with a faster rate of heating resulting in more mortality (Hallman and Denlinger, 2019).

Inert dusts: Inert dusts have long been utilized as stored-grain protectants (Stejskal *et al.*, 2021). These are made of inert ingredients such as silica gel or diatomaceous earth (DE). Because they have a physical mode of action and are picked up as pests walk over a treated surface, they have proven useful as grain protectants. The most widely accepted theory of their mode of action is that damage to the cuticle is caused by the removal or sorption of cuticular waxes, resulting in water loss from the body, which, depending on the relative humidity of the air, leads to death by desiccation. Stored product mites rely entirely on cutaneous respiration and are hence poorly sclerotized and susceptible to desiccation. The key advantages of inert dusts are that they have low mammalian toxicity, do not contain insecticides or knock-down agents, do not leave harmful residues, are efficient against chemically resistant species, and are persistent and stable at high and low temperatures (Ziaee *et al.*, 2021).

Screening, sorting and sanitation: Sanitation is currently regarded as the foundation for many integrated pest management (IPM) programs for stored products by industry experts. Increased stock rotation, crack and crevice treatments with residual chemical products, regular sweeping, vacuuming, and removing food dust and debris, closing doors and windows, using air curtains near entrances, screening, and space treatments that include fogging with aerosols are common IPM tactics for improving sanitation in food facilities. Other parts of excellent warehouse practice, such as stock rotation and, where appropriate, insect-proof packaging, also help to lessen pest population pressure. Other methods include sieving, screening, projection separation, and aspiration (Trematerra and Fleurat-Lessard, 2015).

Chemical methods

Chemical control was the mainstay of the agricultural and food sectors throughout the majority of the twentieth century, but there has recently been increased demand to reduce chemical use and reliance on pesticides to minimize long-term health and environmental effects. Chemicals continue to play an important role in the preservation of food commodities and products, although the number of compounds accessible for usage is decreasing, and increasing focus is being directed to non-chemical alternative control approaches (Mohapatra *et al.*, 2017).

Botanicals and natural products: Use of chemical methods, such as fumigation, spraying with organophosphorus compounds, or treatment with benzyl benzoate, dibutyl phthalate, and N, N diethyl-m-toluamide, to control stored mites is prohibited because of human health hazards associated with their consumption. Therefore, the search is on for more selective, natural compounds non-toxic to humans and which do not affect the organoleptic character of the treated product. Research into plant-derived acaricides is now being intensified as it becomes evident that plant-derived acaricides have enormous potential in this regard. . Plants and their derivatives are being employed effectively against mites in many ways around the world to build such a pest control strategy for stored-food mites (Gulati and Mathur, 1995; Divekar *et al.*, 2022). Since many of them are largely free from adverse effects and have excellent biological activity, they could lead to the development of new classes of possibly safer stored-food mite control agents. Little work has been done concerning managing stored food mites, although extracts and essential oils of *F. vulgare* fruits are insecticidal agents (Kim and Ahn, 2001). Plant alkaloids, secondary metabolites, and essential oils are among the substances generated from plants. Some recent research has revealed that plant byproducts or extracts, such as *Azadirachta indica*, *Satoreja hortensis*, *Datura stramonium*, *Citrullus colocynthis*, *Eucalyptus sp.*, and *Melia azedarach*, have substantial value (Idrees *et al.*, 2016). Pyrethrin has activity on a wide range of insects and mites, including flies, fleas, beetles, and spider mites (Ujvary, 1999). The key advantages of botanical pesticides are that they are environmentally friendly, quickly biodegradable, and harmless to nontarget creatures. Furthermore, many plant-derived natural compounds that function against insects can be made using locally accessible raw materials.

Fumigation: It is an important control strategy used when an infestation is discovered in bulk commodities in storage or during shipment, as well as for whole-site treatment of food processing facilities. Adult and nymph mortality was determined by a lack of movement in response to physical stimulation after a two-day recovery period, and unhatched eggs were deemed dead four days after fumigation (Abbar *et al.*, 2018). Phosphine fumigation is particularly successful at controlling both the mobile stages and the eggs of *T. putrescentiae* at label rates and normal operating temperatures, with little effect on market quality (Zhao *et al.*, 2016). The temperature has a significant impact on insect control fumigation efficacy. Higher temperatures stimulate insect metabolism and respiration, causing treated insects to consume more fumigant at a faster pace. Chemical approaches such as fumigation and spraying with organophosphorus chemicals are used to control *T. putrescentiae*. However, persistent exposure to organophosphorus chemicals has resulted in resistance in some cases.

Biological control

Biological control is described as the action of natural enemies that check the host's or pest's population density Predators, parasites (or parasitoids), and pathogens are the three types of natural enemies of mites. Biological agents, which range from microbiological diseases to predatory insects, are often host-specific and are best used as preventative control techniques to prevent pest populations from growing. To overcome pests before they may cause harm, mass-release or augmentative approaches are required. Bacteria, viruses, protozoa, nematodes, and fungi are examples of mite pathogens. This diverse range of species happens in nature. They must be applied to the exact scenario in which they are being used as control agents. Entomopathogenic fungi have long been thought to have the ability to control insect pests, there have been questions about their safety and specificity of action. Recently, one species *Beauveria bassiana* (Balsamo) has been brought back into focus as a subject of the current study for usage against grain pests. *Metarhizium* is another genus of fungal disease having the ability to manage pests in stored product environments. Predatory mites are another group of predators, preying on insect eggs and small larvae. The ascid mite *lattisocius dentriticus* (Berlese) and the cheylitid *Cheyletus eruditus* (Schrank) prey on stored food mite species (Bell, 2014).

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ORGANIC FARMING- CONCEPTS

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Abstract:

The introduction of high-yielding varieties, the expansion of irrigated areas, the use of high-analysis NPK fertilizers, and an increase in cropping intensity during the green revolution propelled India toward food self-sufficiency. As a result, the relative contribution of organic manures as a source of plant nutrients compared to chemical fertilizers has significantly decreased. Multi-nutrient deficits and a general reduction in the soil's productive capacity have been frequently observed as a result of injudicious fertilizer use. Organic farming can provide a solution to such worries and problems posed by modern-day agriculture production. Organic farming is a comprehensive production management method that promotes and improves agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It prioritizes the use of on-farm management approaches above off-farm inputs, recognizing that regional conditions necessitate regionally customized solutions. This is accomplished by using agronomic, biological, and mechanical approaches to fulfil any specific function within the system, rather than synthetic materials.

Keywords: Crop production, Organic farming, Manures, Soil, Yield

Introduction:

Organic farming is a production management system that does not use any synthetic off-farm inputs and instead relies on on-farm agronomic, biological, and mechanical methods such as crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives, and a biological system of nutrient mobilization and plant protection, among other things, to promote and enhance biodiversity, biological cycles, and agro-ecosystem health. It is a system that prohibits the use of chemical chemicals like inorganic fertilizers, insecticides, fungicides, herbicides, growth regulators, and other similar substances. It can keep soil health, agro ecosystems, biodiversity, microbial activity, and human health in good shape. Improved agro-ecological engineering technologies, market intelligence, organic standards, and certification/regulatory mechanisms are some of the primary concepts involved in organic farming. Cereals, pulses, oilseeds, fruits, and vegetables are among the food crops grown in India.

History of organic farming in India in the world

Organic farming is as old as human civilization. The concept of organic farming started about 1000 years on the river belts. History marks the practice of organic farming during the Indus valley civilization on the banks of the river Indus. There is a clear mention in Mahabharata about the importance of the cow in the life of human beings and in maintaining soil fertility. The script of Ramayana describes that all dead things – rotting corpses or stinking garbage returned to earth are transformed into wholesome things that nourish life. *Rig Veda*, *Vrukshayurveda* acknowledged the use of cow, goat and sheep manures for healthy growth of the crop. *Kautilya* in his *Arthasastra* also mentioned the use of oil seed cakes and animal manures. Many other scripts referred to the role of organic farming as a way to achieve ecological balance and sustainable living. Organic agriculture has its origin in traditional farming practices that have evolved over millennia in various villages and farming groups.

The origins of organic farming in the world can be traced back to Germany in 1924 with the work of Rudolf Steiner, the *Father of Biodynamic Farming* in the form of a course on "Social-Scientific Basis of Agricultural Development" which conceptualized the knowledge of life forces to channelize physical and biochemical balance in the above-ground environment including plant and soil. Sir Albert Howard is considered the Father of Organic Farming. He conducted research for about 25 years in Indore, India and worked on the development of the Indore composting process and documented his work in the book "***An Agricultural Testament***". The term 'organic' was first coined by Northbourne, in 1940, in his book entitled 'Look to the Land'. Northbourne also defined organic farming as 'an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity organic produce is not grown with synthetic pesticides, antibiotics, growth hormones, application of genetic modification techniques (such as genetically modified crops), sewage sludge, or chemical fertilizers

In the year 1972, the International Federation of Organic Agriculture Movement (IFOAM), the world's largest non-governmental organization for organic agriculture was founded in Bonn, Germany which takes care of which formulates the international standards for organic production, and processing, marketing, accreditation and certification process.

The definition approved by The World Board of IFOAM:

"Organic agriculture is a production system that sustains the health of soils, ecosystem and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and good quality of life for all involved".

Need of practicing organic farming

The green revolution started in India during the 1960s to achieve self-sufficiency and ensure food security with the increasing demand of the rising population which introduced the use of high-yielding varieties, synthetic fertilizers for raising crop production, productivity and pesticides for biotic and abiotic stress management. Though there was a rise in crop production in the early stages, the excessive agrochemicals gradually decelerated crop growth and yield. The external input-intensive agriculture with the least attention to ecological agricultural principles leads to declined soil fertility with the increased soil and water erosion and runoff, leaching of nutrients and contamination of groundwater and thus resulting in soil, water and environmental pollution and disturbance of ecological balance. As a result, a need for an alternative to conventional agriculture arose, to save the soil from degradation, increase soil fertility and crop productivity, avoid synthetic pesticides, prevent pollution, increase biodiversity, reduce reliance on costly external inputs and reverse the trend of borrowing, and teach farmers to rely more on local natural resources and increase the resource use efficiency to instil self-reliance and self-respect which can be achieved through the practice of organic farming.

Scope of organic farming in India

There is a wide scope for the practice of organic farming in India with rich diversity and resource availability. The North-Eastern region of India provides considerable opportunity for organic farming due to the least utilization of chemical inputs. It is estimated that 18 million hectares of such land are available in the NE, which can be exploited for organic production. With the sizable acreage under naturally organic/default organic cultivation, India has tremendous potential to grow crops organically and emerge as a major supplier of organic products in the world's organic market. The report of the Task Force on Organic Farming appointed by the Government of India also observed that vast areas of the country, where a limited amount of chemicals is used and have low productivity, could be exploited as potential areas for organic agriculture.

Statistics of organic farming in India

The area under organic farming

As of 31st March 2021 total area under the organic certification process (registered under National Programme for Organic Production) is 4339184.93 ha (2020-21). This includes 26,57,889.33 ha cultivable area and another 16,81,295.61 ha for wild harvest collection. Among all the states, Madhya Pradesh has covered the largest area under organic certification followed by Rajasthan, Maharashtra, Chhattisgarh, Himachal Pradesh, Jammu & Kashmir and Karnataka. In 2016, Sikkim has achieved a remarkable distinction of converting its entire cultivable land (more than 75000 ha) under organic certification.

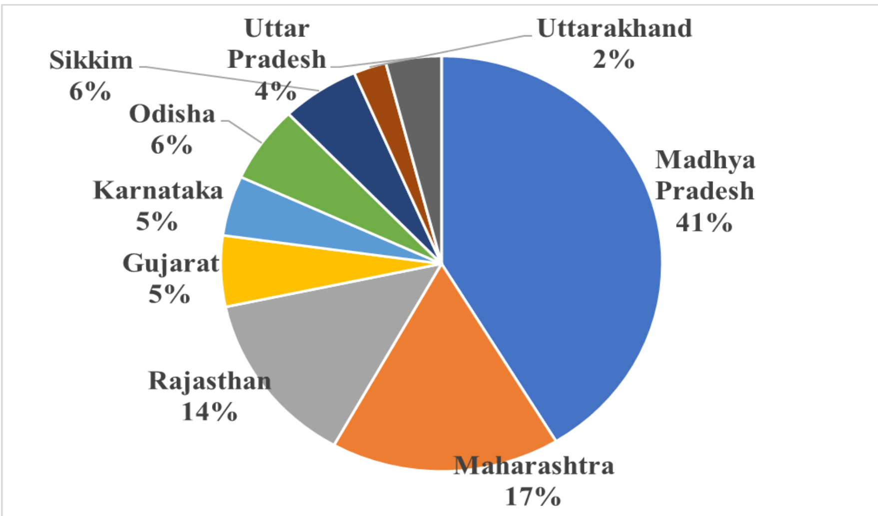


Figure 1: State-wise cultivated farm area for the years 2020-21

Production

India produced around **3496800.34 MT** (2020-21) of certified organic products which include all varieties of food products namely Oil Seeds, fibre, Sugar cane, Cereals & Millets, Cotton, Pulses, Aromatic & Medicinal Plants, Tea, Coffee, Fruits, Spices, Dry Fruits, Vegetables, Processed foods etc. The production is not limited to the edible sector but also produces organic cotton fibre, functional food products etc. Among different states, Madhya Pradesh is the largest producer followed by Maharashtra, Karnataka, Rajasthan and Uttar Pradesh. In terms of commodities, Oil seeds are the single largest category followed by Sugar crops, Cereals and Millets, Tea & Coffee, Fibre crops, fodder, Pulses, Medicinal/ Herbal and Aromatic plants and Spices & Condiments.

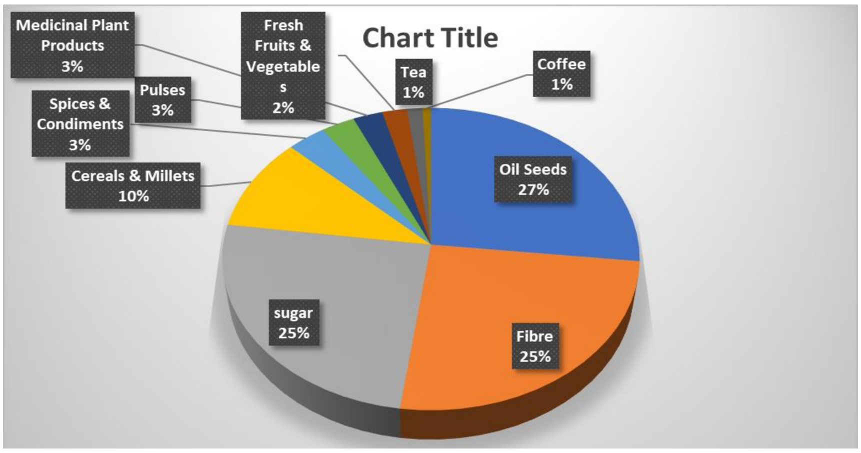


Figure 2: Category-wise Production of Organic commodities during the Year 2020-21

Exports

The total volume of export during 2020-21 was **888179.68 MT.** The organic food export realization was around **INR 707849.52 Lakhs (1040.95 million USD).** Organic products are exported to the USA, European Union, Canada, Great Britain, Korea Republic, Israel, Switzerland, Ecuador, Vietnam, Australia etc. In terms of export value realization Processed foods including soya meal (57%) lead among the products followed by Oilseeds (9%), Cereals and millets (7%), Plantation crop products such as Tea and Coffee (6%), Spices and condiments (5%), Medicinal plants (5%), Dry fruits (3%), Sugar (3%), and others[2].

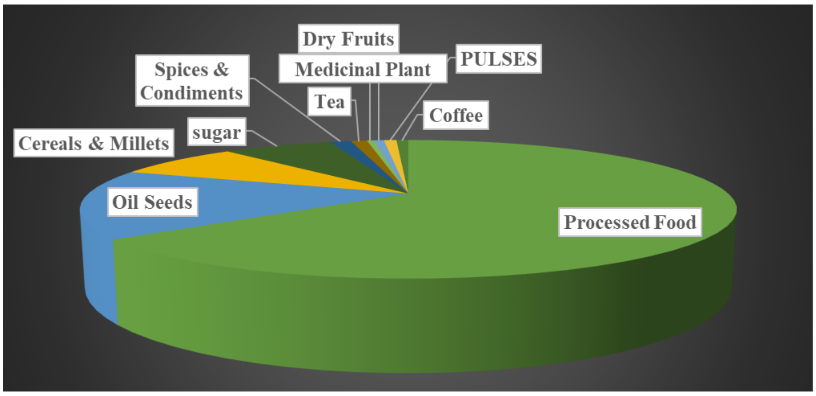


Figure 3: Category Wise Comparative Report of Organic commodities Exported from India-2020-21

Principles of organic farming

The Principle of Health - Organic agriculture should sustain and enhance the health of soil, plant, animal and human as one and indivisible.

The Principle of Ecology - Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

The Principle of Fairness - Organic agriculture should build on relationships that ensure fairness concerning the familiar environment and life opportunities.

The Principle of Care - Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

These basic principles provide organic farming with a platform for ensuring the health of the environment for sustainable development, even though the sustainable development of mankind is not directly specified in the principles.

Benefits of organic farming:

Organic farming has numerous benefits for the cost of cultivation, soil fertility, sustainability and maintenance of ecological balance and plays a major role in reducing pollution and soil erosion and runoff. The benefits of organic farming are listed here:

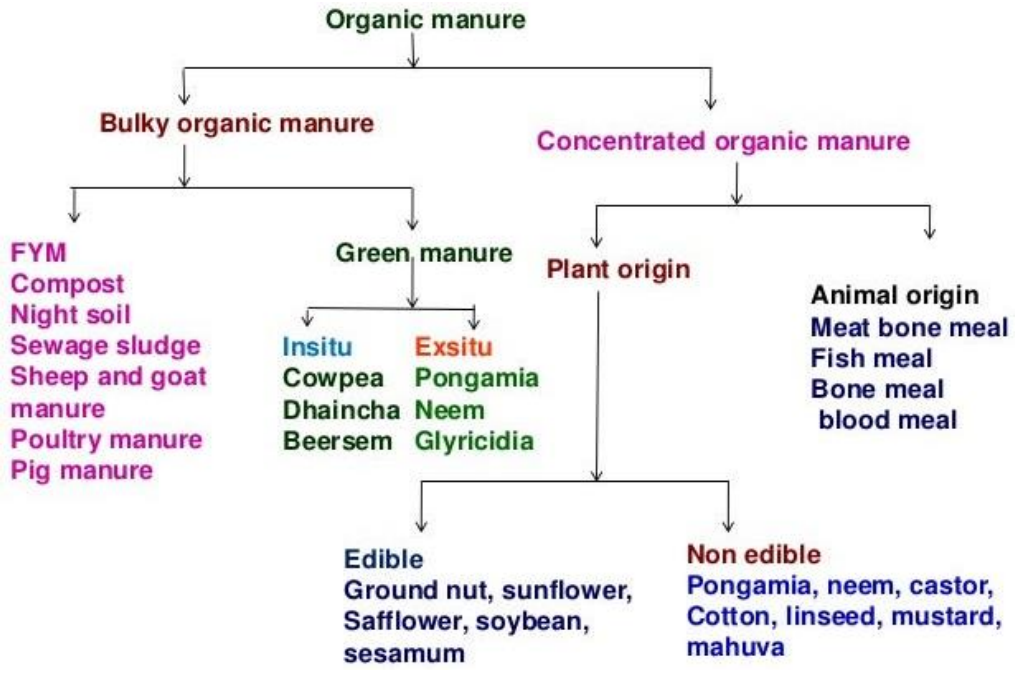
1) Provision of tasty, nutritious and chemical-free food
2) Environmentally friendly cultivation practices
3) Restoration of soil fertility and improves soil nourishment
4) Reduction of soil, water and air pollution
5) Facilitation of carbon sequestration
6) Reduction of cost of cultivation and renders profits to the farmers
7) Increased resource and energy use efficiency
8) Efficient utilization of farm labour[3].

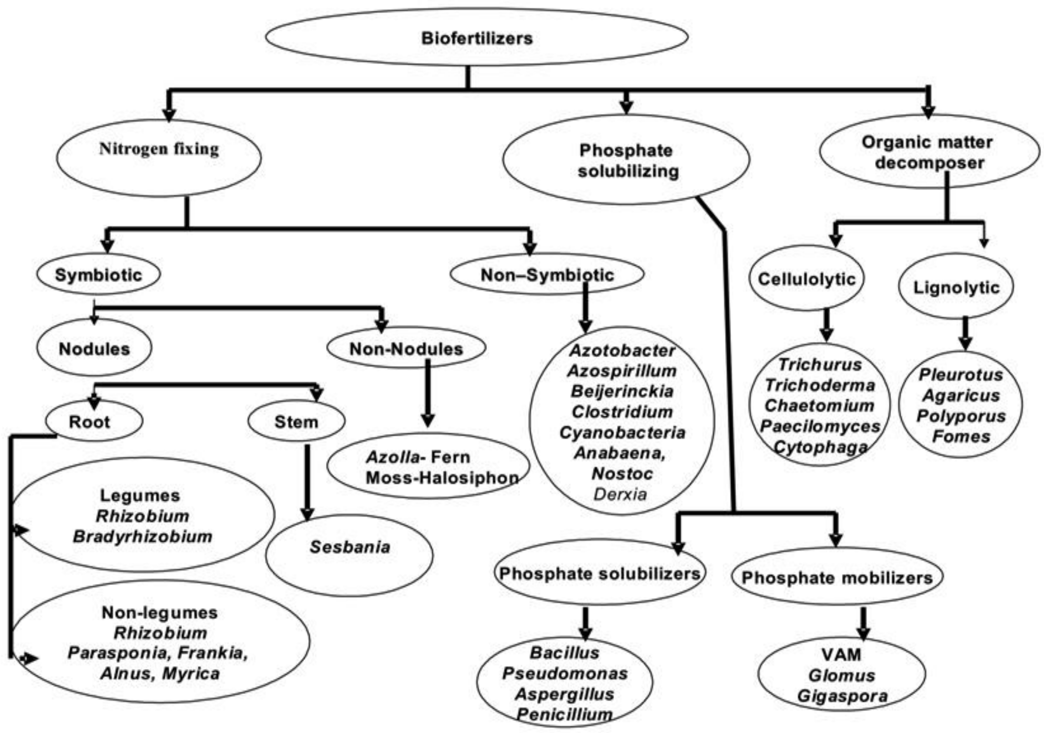
Components of organic farming

(i) Organic manures: Organic manures are generally applied in place of synthetic fertilizers. The organic manures directly increase the crop yields and indirectly provide a favourable environment to build up the population of beneficial microbial activity and increase the availability of nutrients in the soil.

(ii) Crop residue management: Crop residue plays a significant role in nutritional provision. They have a positive impact on the soil's physical, chemical, and biological processes, as well as delivering nutrients to plants. The incorporation of crop residues will increase the soil organic carbon and restore soil fertility. The crop residues can also act as organic mulch which prevents soil erosion and prevents weed growth.

(iii) Biofertilizers: The biofertilizers are capable of mobilizing the nutritive elements by converting the fixed nutrients to available forms for plant uptake. They improve soil texture and structure while also increasing nutrient availability.





(iv) Crop rotation: Crop rotation helps in preventing soil diseases, insect pests, and weed problems, and building healthy soils. When the various inputs and outputs are brought together, the notion of crop rotation promotes the security and stability of revenue and the total production of the farm.

(v) Inter-cropping: It allows farmers to cultivate at least one high-value crop while also suppressing weeds and providing agronomic benefits for the following crop year and also helps in achieving adequate weed control

(vi) Cover crops: Cover crops promote microbial activity in the soil, which aids in the breakdown of organic materials and improves soil characteristics. They have the potential to increase soil organic matter and nutrient status, control erosion, reduce runoff, improve soil structure, promote water infiltration, and limit pest and disease outbreaks.

(vii) Bioagents: The bioagents include parasites and predators for pest and disease management and all the organisms that are employed for weed management.

Natural enemies: Predators and parasitoids that dampen pest insect populations. Examples:

Predators: Coccinellids, mantids, dragonflies, spiders,

Egg parasitoids: *Trichogramma, Telenomus*; Larval parasitoids; *Bracon, Apanteles*; Pupal parasitoids: *Xanthopimpla* etc. *Beauveria bassiana, Metarhizium anisopliae, Nomuraea rileyi, etc.,* are used against many pests like brown plant hopper and lepidopteran pests etc. In India, the weeds like water hyacinth, *Parthenium hysterophora* and *Salvinia sps.* Have been successfully controlled by the introduction of biocontrol agents like *Zygogramma, Neochetus*, *Ortheris* etc.

(viii) Pheromone traps: Pheromone traps are used for monitoring the target pest infestation in the field and also lessen crop damage.

Examples: Helilure – *Helicoverpa armigera*; Gossyplure- Pink bollworm; Littolure for *Spodoptera litura*.

(ix) Organic fertilizers: Oil seed cake meal, seaweed fertilizers, grass clippings, rock phosphate, humic acid etc are some of the organic fertilizers which enhance the plant nutrient availability.

(x) Botanical pesticides: They are used as an alternative to synthetic pesticides as they render quick action on pests and rapid degradation. Pyrethrum and neem-based products like neem oil, and neem seed kernel extract are a few well-established commercially available botanical pesticides.

Crop production in organic farming

1. **Seed/ planting material:** The seed should not be treated with synthetic chemicals.
2. **Nutrient management:** Soil enrichment should be taken up using liquid manures

1. Panchagavya

Panchagavya (PG) is a traditional fermented organic product extensively utilized to grow various agricultural and horticultural crops, which is prepared by mixing five by-products from cows such as dung, urine, milk, and curd, ghee and other ingredients. This preparation contains beneficial microorganisms beside from macro and micro-nutrients, amino acids, and growth-promoting substances

Ingredients: Cow dung, cow urine, milk, curd ghee, water, tender coconut water, jaggery and well-ripened banana.

Preparations:

Step 1:

- Cow dung: 7 kg
- Cow ghee: 1 kg

Mix the above two ingredients thoroughly both in the morning and evening hours and keep it for 3 days.

Step 2:

- Cow urine: 10 litres
- Water: 10 litres

After 3 days mix cow urine and water and keep it for 15 days with regular mixing both in the morning and evening hours.

Step 3:

- Cow milk: 3 litres
- Cow curd: 2 litres
- Tender coconut water: 3 litres
- Jaggery: 3 kgs
- Well ripened poovan bananas: 12

All the above ingredients can be added to a wide-mouthed mud pot, concrete tank or plastic can as per the above order. The container should be kept open under shade. The contents are to be stirred twice a day. The Panchagavya stock solution will be ready after 30 days. It should be covered with a wire mesh or plastic mosquito net to prevent houseflies from laying eggs and the formation of maggots in the solution.

Beejamrutha

Preparation of Beejamrutham for one acre of seeds

1. Required 20 litres of water
2. 5kg of local *desi* cow dung
3. 5 litres of local desi cow urine
4. 50gms of lime
5. A handful of soil from the farm

- Take a thin cloth to add 5kg of desi cow dung. Hang this cloth inside the 20-litre water drum. Leave it undisturbed for 12 hours.
- Take one litre of water and add 50gms of lime (to reduce the acidity) into it. Leave it overnight.
- The next day morning, take out the cloth containing cow dung. Squeeze the cloth to remove water from the cow dung mixture.
- Now add a handful of the fertile soil into the water solution.
- Finally, add 5 litres of desi cow urine and the lime solution to the final mixture. Stir well.
- Now Beejamrutham is ready to treat the seeds.
- Beejamrutham should be used within 48 hours after preparation[6].

Jeevamrutham

Jeevamrutham is a low-budget preparation that makes the soil enriches and helps to grow microorganisms and improve the mineralization of the soil. Jeevamrutham is prepared from native cow's urine, dung, jaggery, and horse gram. The fungal infections and tick burning are effectively kept under control by Jeevamrutham. Jeevamrutham was sprayed in the nursery and given irrigation every night in the main fields.

Types of Jeevamrutham

- The liquid state of Jeevamrutham
- The semi-solid state of Jeevamrutham
- Dry Jeevamrutham (Ghana Jeevamrutham)

Semi-solid state Jeevamrutham

- The ingredients are 5 litres of cow urine, 100kg of cow dung, 1 kg of pulses flour, 1 kg jaggery and a handful of fertile soil.
- Take a small amount of water and mix all of them.
- Make the mixture as a small ball and keep these balls in direct sunlight to dry them.
- Keep the dried balls near the mouth of the sprinkler or dripper.
- The microbes get activated again. When the waterfalls on the semi-solid Jeevamrutham

Ghana Jeevamrutham

1. Take 200 kg of cow dung manure and spread the manure uniformly on the floor to form a layer.
2. Take 20 litres of liquid Jeevamrutham and add to the manure.
3. Mix the mixture completely.
4. Then put a heap of the cow dung and closed it again using a jute bag for 48 hours.
5. Allow it for fermentation. After that spread on the ground for drying under the sunlight.
6. After drying collect dry manure and kept it in jute bags in the room.
7. Ghana Jeevamrutham can be stored for six months.
8. 200 kg of ghana Jeevamrutham can be used per acre in the sowing period.
9. Use 50kg of Ghana Jeevamrutham in between two crops for obtaining good yields.

   The liquid manures are extensively used for soil fertility management which also helps in pest and disease management and overall crop growth.

3. Weed management:

Ecological weed management promotes weed suppression, rather than weed elimination, by enhancing crop competition and phytotoxic effects on weeds. The only objective of organic farming is to keep the weeds under control at a cost-effective and controllable level. Weeds in organic farming can be managed by the following practices:

Preventive measures

- Avert the weed-infested seed material for sowing.
- Feeding farm animals' screens and other materials containing weed seeds should be avoided.

- Clean the farm machinery thoroughly before moving it from one field to another.
- Prevent the usage of weed-infested sand and soil.
- Keep irrigation channels, fence lines and uncropped areas clean.
- Apply weed-free mulch, compost and manure.
- Weed quarantine

Cultural method: The cultural practices in weed management include:

- Seedling rate and selection of cultivar
- Smother crops
- Crop rotation
- Intercropping
- Trap crops
- Cover crops
- Field scouting technique
- Irrigation management
- Nutrient management
- Tillage
- Optimum plant density and planting geometry
- Field sanitation
- Mulching

Mechanical method

- Hand weeding
- Inter-cultivation
- Flooding
- composting
- Mowing
- Stale seedbed technique
- Grazing
- Thermal weed control
- Soil solarisation

Biological method:

Here the natural enemies are involved to maintain the weed population below the economic injury level. The bioagents weaken the plant structure, collapse and finally destroy the plant parts.

Examples: Bioagents

Sr. No.	Weed	Bio agent
1.	Common lantana (*Lantana camera*)	*Crocidosema lantana* (moth)
2.	St John's weed (*Hypericum perforatum*)	*Chrysolina quadrigemina* (beetle)
3.	Water hyacinth (*Eichhornia crassipes*)	*Neochetina eichhorniae* (weevil)
4.	Silver leaf nightshade *(Solanum eleaegnifolium*	
5.	Water fern (*Salvinia molesta*)	*Marsia cornuarietis* (snail)
6	Prickly pear (*Opuntia dellini*)	*Tetranychus desertorum* (mite)
7	Aquatic weeds	*Ctenopharyngodon idella* (carp fish)

Mycoherbicides

Sr. No.	Mycoherbicide	Fungus	Weed controlled
1.	Devine	*Phytophthora palmivora*	Strangler-vine (*Morrentia odorata*)
2.	Collego	*Colletotrichum gloesporiodes*	Jointvetch (*Aeschynomone sp*)
3.	Bipolaris	*Bipolaris sorghicola*	Johnsongrass (*Sorghum halepense*)
4.	Biolophos	*Streptomyces hygroscopicus*	General vegetation
5.	Caset	*Alternaria cassia*	Cassia (*Cassia obtusifolia*)
6.	ABG-5003	*Cercospora rodmanii*	*Eichhornia crassipes*
7.	Velgo	*Colletotrichum coccoides*	Velvet leaf (*Abutilon theophrasti*)

Management with organically approved chemicals

1. **Corn gluten meal and mustard meal (pre-emergent herbicide)**

Suppresses many common grasses and herbaceous weeds. Example: WeedBan™ and Corn Weed Blocker™

2. **Commonly based on vinegar or lemon juice or clove oil ingredients (post-emergent burndown herbicide)**

Perennials may require multiple applications Burnout™, Bioganic™, AllDown™, MATRAN™ and Weed Bye Bye™. Post-emergent chemicals are phytotoxic (burn plant tissue); use caution when applying to crops.

4. Pest and disease management:

i. **Cultural control:** Deliberate manipulation of the environment to make it less favourable for pests by disrupting their reproductive cycles, eliminating their food or making it more favourable for their natural enemies.

1. Sanitation
2. Tillage
3. Time of planting
4. Water management

5. Habitat diversification
    i. Crop rotation
    ii. Trap cropping
6. Crop competition

ii. **Biological control:** It is the beneficial action of predators, parasites, pathogens and competitors in controlling pests and their damage.

The principal ways for biocontrol are:

1. Collection and use of biotic agents, viz. parasitoids and predators.
2. Isolation and non-production of antagonizing microbial organisms containing bacteria, fungi, viruses, nematodes, protozoa, etc. which are known as a microbial pesticides.
3. Using plant-based materials, e.g., neem which is known as botanical pesticides.

Biotic Agents

- **Parasitoids (egg, larval, pupal and adult)**

  Complete their life cycle on different stages of insect pests. Examples: *Trichogramma spp*., etc.

- **Predators**

  Hunt/kill the insect pests. Example: frogs, lizards, spiders, ants, sparrows, dragonflies, etc.

Biochemical pesticides

1. Insect Growth Regulators/ IGRs/ Third generation insecticides
2. Attractants & Repellants

   Attractants: e.g., Citronellol, Indole, Cinnamaldehyde, Geraniol, etc.

   Repellants: e.g., Cedarwood, Citronella, Jojoba, Eucalyptus, etc.
3. Suffocating agents: e.g., Soyabean oil, Mineral oil (registered by the EPA as a suffocating agent)
4. Desiccants: e.g., Avachem®Sucrose octanoate.
5. Coatings: e.g., Kaolin, Jojoba, etc.
6. Pheromones: e.g., Synthetic sex pheromones
7. Systemic acquired- response

Botanicals

Neem (*Azadirachta indica*) Extracts

There are more than 60 target insect pests of them. For example, American bollworm (*Helicoverpa armigera*), Brown planthopper (*Nilaparvata lugens*), etc.

Types of Biopesticides

Bioinsecticides:	*Bacillus thuringiensis* (or Bt),
	Bacillus sphaericus
Biofungicides:	*Trichoderma spp,*
	Pseudomonas fluorescence
Entomopathogenic Fungi:	*Metarhizium anisopliae,*
	Beauveria bassiana,

	Verticillium lecanil
Entomopathogenic Viruses:	Baculoviruses: Nucleopolyhedrovirus (NPVs) and the Granulovirus (GVs)
Paecilomyces:	*Paecilomyces lilacinus*

Government of India's Role in Promoting Organic Agriculture

The government is supporting the organic farmers with various schemes by providing them financial help and inputs in the form of subsidies which not only encourages the existing organic farmers but also attracts the conventional farmers to practice organic farming. The following are the schemes implemented by the Government of India for the promotion of organic farming in India:

(1) The Paramparagat Krishi Vikas Yojana,
(2) Organic Value Chain Development in North Eastern Region Scheme,
(3) Rashtriya Krishi Vikas Yojana,
(4) The mission for Integrated Development of Horticulture

- a. National Horticulture Mission,
- b. Horticulture Mission for North East and Himalayan states,
- c. National Bamboo Mission,
- d. National Horticulture Board,
- e. Coconut Development Board,
- f. Central Institute for Horticulture, Nagaland,

(5) National Programme for Organic Production,
(6) National Project on Organic Farming, and
(7) National Mission for Sustainable Agriculture.

Accreditation

1. **Application for accreditation**
2. **Allocation of accreditation number**
3. **Approval/ non-approval of accreditation**

- NAB shall consider the application, after reviewing the evaluation report submitted by the EC.
- Approval/ disapproval
- If not approved, refunded after deducting 25% thereof towards processing charges.
- Certification of Accreditation will be valid for 3 years from the date of issue of Certificate of Accreditation.
- NAB will allow the applicant to fulfil/ rectify any deficiencies.

4. Accreditation contract

APEDA will inform an approval & send the Accreditation contract to Certification Agency. The Certification Agency shall execute the contract within fifteen days, from the date of receipt of approval. On the receipt of this, APEDA shall issue the Certificate of Accreditation within fifteen days, from the date of receipt of the contract.

5. Updating and renewal of Accreditation number

Eg: NPOP/NAB/0014: Vedic organic Certification Agency

6. Power to issue guidelines

7. Logo

All Accredited Agencies shall be entitled to use this logo for certified organic products. The logo used under the certification programme will be called "India Organic". To identify that the product is organically produced and originates from India.

8. Suspension or termination of accreditation under violation of laws.

9. Appeals and revision of award for appeal

10. Amendment to the regulation

11. Jurisdiction

Categories for accreditation

Accreditation shall be granted for each category of products as follows:

- Organic agricultural production
- Organic processing operations
- Wild products
- Forestry
- Organic animal production and processing

Must have been in operation for a minimum period of one year before the evaluation

Accreditation- Globally

Worldwide, these are significant accreditation schemes

- IFOAM
- US NOP
- EU Regulations
- JAS (Japanese Agricultural Standard)
- ISO 65

Labelling of organic product

Definition

Any written, printed or graphic matter that is present on the label accompanies the food or is displayed near the food, including that to promote its sale or disposal.

Advantages of Labelling an organic product

- Labelling is for easy recognition of organic quality and certification system
- It confirms the fulfilment of the label regulations and legal rules

- They help to achieve a better price for organic products

General Principles (NPOP)

Labelling shall convey clear and accurate information on the organic status of the product

Recommendations

- When the requirements of the full standard are fulfilled, products shall be sold as "produce of organic agriculture" or a similar description.
- Product labels should list processing procedures which influence the product properties.
- Additional product information shall be made available on request.
- All components of additives and processing aids shall be declared.
- Ingredients or products derived from wild production shall be declared as such.

Standards

- Single-ingredient products: labelled as "produce of organic agriculture" or a similar description
- Mixed products where not all ingredients, including additives, are of organic origin are labelled in the following way:
  - ✓ A minimum of 95% of the ingredients are certified: "certified organic"
  - ✓ 95% to 70% of the ingredients are certified: "made with organic ingredients"
  - ✓ <70% of ingredients only organically certified: Cannot use "organic"
- The label for in-conversion products shall be distinguishable from the label for organic products.
- All raw materials of a multi-ingredient product shall be listed on the product label in order of their weight percentage.
- All additives shall be listed with their full name.
- If herbs and/or spices constitute less than 2% of the total weight of the product, they may be listed as "spices" or "herbs" without stating the percentage.
- Organic products shall not be labelled as GE or GM-free

What do you mean by NSOP?

- Standard developed for Organic production under the government's programme- National Programme for Organic Production (NPOP).
- Standards apply to:
  - ❖ Crop Production
  - ❖ Animal Husbandry
  - ❖ Food Processing and Handling

Organic Certification

- The mechanism used to verify compliance with National Standards of Organic Production.
- Performed by Accredited Certification Agencies
- 20 Certification Agencies in India Accredited by APEDA

Certification

To regulate the export of certified organic products, the Director-General of Foreign Trade, Government of India has issued a public notice according to which no certified organic products may be exported unless they are certified by the certification bodies in India

The following the certification bodies in India:

- ECOCERT International
- IMO India Pvt. Ltd- Institute for Marketology
- INDOCERT
- LACON GmbH
- SGS India Pvt. Ltd.
- SKAL International[7].

Conversion Period

- **Perennial Crops**

  National Standards are to be followed for 3 years before the harvest is certified organic.
- **Annual Crops**

  The conversion period starts two years before sowing.

Seed Material

- Use Certified Organic Seed & Plant material
- When not available, use chemically untreated material
- Genetically engineered seeds and transgene plants are not allowed.

Contamination Control

- Make sure soil and water are suitable for organic cultivation- Test heavy metals for accumulation & for the presence of other pollutants.
- Poly Ethylene: Plastic Mulching

  Poly Propylene: Insect Netting

  Poly Carbonate: Silage Wrapping
- The use of Poly Vinyl chloride is not allowed

Soil and Water Conservation

- Soil and water should be handled in a sustainable manner
- Clearing of Primary Forest prohibited
- Prevent soil erosions - Bunds
- Prevent Salination
- Minimize burning Organic matter for land clearing

Packaging

- Use ecologically sound material
- Use of PVC is prohibited
- Laminates and Aluminum should be avoided
- Use Biodegradable packing material

Processing & Handling

Approved processes

- Mechanical & Physical
- Biological
- Smoking
- Extraction
- Precipitation
- Filtration

Extraction with water, ethanol, plant and animals' oils, Vinegar, Carbon dioxide, Nitrogen or Carboxylic acids.

- ✓ Irradiation not allowed
- ✓ Asbestos is not allowed for filtration purposes.

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MOLECULAR APPROACHES TO IMPROVE INSECT PEST AND DISEASE RESISTANCE IN RICE

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Abstract:

Rice yield has been stagnant for the last three decades despite the improved varieties and technologies due to several factors, of which biotic stresses constrain the rice production prominently. Molecular approaches provide a safer way for the development of crop varieties with durable and broad spectrum resistance. Recent development in the field of molecular biology have unveiled a new path for the production of genetically engineered plants having desired traits transferring the novel genes from donor to recipient crop plants. Molecular technologies like, transgenic approaches using *Bacillus thuringienesis* and protease inhibitors, RNA interference, breeding with marker assisted selection may provide ample scope for improving pest resistance and enhancing rice yield. *Bacillus thuringiensis* (*Bt*) derived *Cry* genes have been introduced against insect resistance in rice. Plant protease inhibitors (PIs), chitinase, are considered as candidates for increased insect as well as disease resistance in transgenic plants. Marker assisted selection is an indirect selection method of a desirable trait based on a marker linked to a trait of interest. Gene suppression via RNA interference (RNAi) is an emerging molecular tool in insect pest management. The trinity of DNA marker technology, genetic engineering and RNAi will certainly accelerate rice improvement programmes combating biotic stresses with enhanced resistance.

Keywords: Transgenic, Protease Inhibitors, *Bacillus thuringiensis,* RNA interference, Marker Assisted Selection

Introduction:

Rice is used as a basic diet by almost half of the global population and one of the most important cereal crops for human nutrition being the staple food and of crucial importance to national food security (Birla *et al*., 2017). Due to the Green Revolution, a quantum leap in rice yield took place over the past three decades, although increased food production did not eliminate poverty and hunger. The yield increase did help to avert famine and prevent a greater disruption of the food supply in developing countries. It has been estimated that 40% more rice is needed to be produced by 2050 to meet the food demands of the ever increasing population

(Anonymous, 2021). Rice yield has been stagnant for the last three decades despite the improved varieties and technologies due to several factors including continuously decreasing arable land for crops, abiotic and biotic stress amongst many other factors. The two major biotic stresses, which greatly constrain rice production, are insect pests and diseases. Host plant resistance plays an important role in formulating integrated pest management system especially in low input farming conditions as in India. The cultivation of insect resistant variety provides an ideal way to suppress the insect pests and diseases in rice ecosystem. It involves minimum production cost and leaves no residues in food and environment as well as is compatible with other management practices. As chemical insecticides pose risk to both environment as well as human health, thus molecular approaches provide a safer way to manage insect pests in rice by transferring genes from different sources. The scientists have to opt for the development of crop varieties with increased host plant resistance based on the frequently short life time of vertical resistance genes.

Considering the above mentioned issues, a scientifically sound approach should be designed for minimizing the extent of losses caused by insect pests. Molecular strategies like, transgenic approaches, RNAi, breeding with marker assisted selection, proteinase inhibitors may provide ample scope for improving pest resistance and enhancing rice yield enable to combat insect pests and diseases incidences.

What is molecular approach?

Molecular approaches are biotechnological techniques to combat against insect pests and disease management. With the recent progress in molecular biology and biotechnology, researchers are able to address several problems at the molecular level and identify new avenues to overcome the problems. Molecular approach-based insect pest and diseases resistance and breeding of rice crop with multiple and durable insect resistance have gained momentum to overcome the limitations of classical approach. Molecular approaches have widely been used for the management of insect pests and diseases across the World. Successful implications of these techniques have resulted in improving efficacy, cost effectiveness and time saving, because of which many stakeholders have been adopted in agricultural and allied sectors. Molecular tools are being enormously used in the fields of insect taxonomy, phylogenetic studies, strain improvement of entomopathogenic microorganisms and natural enemies, insect pest interactions and resistance breeding programmes of insect pests and diseases. Novel approaches like transferring genes through transgenics, marker assisted breeding, gene editing and RNA interference are commonly used biotechnological tools are being developed (Firake and Behere, 2021).

Different molecular approaches

1. Transgenic approaches

A transgenic plant is a normal crop plant with one or more additional genes from diverse sources engineered into the plant genome. There are several advantages to using transgenic plants for insect control as opposed to breeding for insect as well as disease resistance from related varieties or ancestors of crop plants. Transgenic technology allows for horizontal transfer of genetic information from one species to another, so that a trait that evolved for benefit of one species can be directly utilized by another species.

In order to generation of transgenic plants against insect pests and diseases, different sources of target genes are used. Most important sources are as follows:

a) Insecticidal proteins – *Bacillus thuringiensis* endotoxin
b) Plant protease inhibitors and alpha amylase inhibitors
c) Chitinases
d) Lectins

a) Insecticidal proteins – *Bacillus thuringiensis* endotoxin

Bacillus thuringiensis (*Bt*) derived genes namely *Cry* genes have been introduced in rice against insect resistance via different methods of gene delivery electroporation, biolistic method and *Agrobacterium* mediated method.

Bacillus thuringiensis is a soil inhabiting gram-positive, facultative aerobic, rod-like, motile and sporulating bacterium. *Bt* is a ubiquitous naturally-occurring soil borne bacterium. Bacterium produces proteinaceous crystal protein (ICP) also known as Cry protein during sporulation. Bt toxins are highly effective for many insect pest, like lepidopterans, coleopterans and (Talukdar, 2013). Bt is a potent insecticide containing crystal protein endotoxin that are highly specific and represent a class of numerous proteins with insecticidal action on larvae from various orders, such as Cry1 and Cry2 aretoxic for lepidopteran pests, Cry2A for lepidopterans and dipteran pests, and Cry3 for coleopteran pests. Cry protein is toxic to insects, but safe to humans and animals. When the insect larvae feed on transgenic plant, the crystals become toxic to insect leading to septicaemia due to alkaline nature of mid gut.

b) Plant protease inhibitors and alpha amylase inhibitors

Protease inhibitors inhibit the protease activity of various proteolytic enzymes which causes over production of digestive enzymes which enhances the loss of sulphur amino acids ultimately leading to stunted growth and weaker insects. (Hilder et al. 1992). The digestive enzyme, proteases catalyze the breakdown of proteins to generate free amino acids necessary for growth and development in insect and these enzymes are potential targets for management of many agricultural pests. The proteolytic events catalysed by protease serve as mediators of signal transduction, transmission and termination in various cellular events i.e. inflammation, apoptosis, blood clotting. Despite the enzymes are essential to the organisms, they may damage when over expressed or present in higher concentrations. For these reasons, the activities of these enzymes need to be regulated and controlled (Lawrence and Koundal 2002). Plant protease inhibitors (PIs) are plant defense proteins that inhibit proteases of invading insect herbivores.

Table 1: Different examples of transgenic approaches for insect pest resistance in rice

Variety	Gene
IR-64	ASAL
Tachisugata	DB1/ G95A-mALS
IR-64	ASAL
4008S	Cry2Aa
Xiushui 134	cry1Ac1
Jijing 88	cry2A
ASD16	cry2AX1
	cry1Ac
Minghui 86	cry2A

Table 2: Different examples of transgenic approaches for combating disease resistance in rice

Target trait	Gene
Rice blast	PemG1 gene
Bacterial blight & Rice blast	*OsRLCK176* and *OsRLCK18*5
Rice blast	mohrip1 and mohrip2
Bacterial blight	OsRLCK118
Bacterial blight	broad-spectrum resistance 1 (BSR1)
Rice blast	(*Oryza sativa*), chitin elicitor receptor kinase 1 (OsCERK1)

Cowpea trypsin inhibitor

The cowpea trypsin inhibitor constitutes some-what larger gene family of four major isoinhibitors. Three of the isoinhibitors are specific for trypsin at each active site and fourth is a trypsin-chymotrypsin bifunctional inhibitor. The cowpea protease inhibitor protein comprises of identifiable core region covering the invariant cysteine residues and active serine centres that are bound to highly variable amino and carboxy terminal regions.

Kunitz trypsin inhibitor

The kunitz inhibitors are the second major family of inhibitors which are widely distributed and often very abundant in seeds of leguminous plants, but also occurs in other groups of plants including cereal seeds. The Kunitz trypsin inhibitor inhibits trypsin through interaction with a single site on the inhibitor and that is encoded by the KTi3 gene. Specificity of trypsin inhibitor is determined by the two amino acids residues, arginine and isoleucine, at the active site of the KTi protein; these amino acids are considered essential for inhibitor function.

Alpha- amylase inhibitors

Amylase inhibitors play a major role in the natural defense mechanisms. Amylase inhibitors are of great potentiality as a tool of natural and engineered resistance against pests in transgenic plants. Digestive enzymes alpha amylases and proteinase, which play a key role in the digestion of plant starch and protein. Carbohydrate metabolism in insects has been used through the use of alpha amylase inhibitors. Insect pests like, *Callasobruchus maculates* seed weevils and maxican bean weevil, *Zabrotus subfaciatus*, Red flour beetle, *Tribolium castaneum* are extensively starch dependent insects and utilize alpha amylase for their survival (Cinco 2008).

Resistant biotypes in insects may evolve after prolonged exposure to selection pressure that is mediated by an insecticidal protein or plant resistance gene. Laura Vila *et. al*. (2005) stated that the expression of the maize proteinase inhibitor (*mpi*) gene in rice plants enhances resistance against the striped stem borer (*Chilo suppressalis* and effects on larval growth and insect gut proteinases.

c) Chitinases

Chitin is composed of ß-(1,4) linked units of the amino sugar, N-acetyl-glucosamine in the outer skeleton of insects. Chitinase catalyzes the hydrolysis of the ß-(1,4) linkages of the N-acetyl-D glucosamine polymer chitin. Genes encoding chitinase can deteriorate fungal cell-wall components to develop fungal disease-resistant plants via recombinant DNA technology through direct transfer and *Agrobacterium* mediated transfer. Chitinase Gene *LOC_Os11g47510* from Indica Rice, Tetep Provides Enhanced Resistance against Sheath Blight *Rhizoctonia solani* in rice (Richa *et al.* (2017)

d) Lectins:

Lectins are carbohydrate binding proteins that are highly specific for sugar groups.The use of lectins in transgenic plants, expressing Cry toxins from Bacillus thuringiensis (Bt) provide resistance to Lepidoptera, Coleoptera, and Hemiptera. 336

Snowdrop lectin (Galanthus nivalis agglutinin or GNA)

The snowdrop lectin (Galanthus nivalis agglutinin or GNA) has been popular due to its toxic effects against hemipterans and other economically important insect pests. Powell et al. (1998) showed GNA binding to cell surface carbohydrate moieties in the midgut epithelium of brown plant hoppers (*Nilaparvata lugens*) in rice therby these snowdrop lectin to confer resistance towards BPH and white backed plant hopper (WBPH). Transgenic rice (*Oryza sativa* L.) containing the gna gene in constructs, its expression was driven by a phloem-specific promoter (from the rice sucrose synthase RSs1 gene) and by a constitutive promoter (from the maize ubiquitin ubi1 gene). There is an urgent need to explore the strategies for delaying resistance such as integrated pest management as well need to explore alternative sources for pest resistance other than cry genes such as plant lectins.

2. Marker Assisted Selection

Molecular marker is a fragment of DNA sequence that is associated to a part of the genome. MAS can be useful to select the desired traits that are difficult or expensive to measure, exhibit low heritability and are late expressed in development. DNA markers are classified as southern hybridization based markers and polymerase chain reaction (PCR) based markers. PCR based markers, which utilize the technique of polymerase chain reaction (PCR) are the most useful markers due to their simplicity, robustness and speed of assay. The suitability of a marker is determined by several considerations such as ease of assay, ability to discriminate between individuals, the frequency of occurrence of the marker (abundance) and the type of marker that may be co-dominant or dominant. An ideal marker has some adavantages such as, they should be easy recognition of all possible phenotypes (homo- and heterozygotes) from all different alleles and demonstrates measurable differences in expression between trait types or gene of interest alleles, early in the development of the organism and be abundant in number and polymorphic. RAPDs, RFLPs and PCR based markers are isogenic lines, double haploids and recombinant lines (RILs).

Table 3: Marker assisted selection against insect pest and disease resistance in rice

Sr. No.	Target trait	Gene(s)/ QTL(s	Type/name of marker(s) use	Remarks
1	Bacterial blight (BB) resistance	Xa4, xa5 & Xa10	Gene linked RFLP and RAPD markers	MAS applied for gene pyramiding
2	Bacterial blight (BB) resistance	Xa4, xa5, xa13 & Xa2	STS for Xa4 CAPS for xa5 (RG556+DraI) CAPS for xa13 (RG136+HinfI) STS for Xa21 (pTA248)	MAS applied for gene pyramiding
3	Bacterial blight (BB) resistance	Xa21	STS (pTA248	MAS applied for early generation selection for BB resistance
4	Bacterial blight (BB) resistance	Xa21	STS (pTA248	MAS applied for Marker assisted backcross
5	Bacterial blight (BB) resistance	Xa5, Xa13 & Xa2	CAPS for xa5 (RG556+DraI CAPS for xa13 (RG136+HinfI) STS for Xa21 (pTA248)	MAS applied for gene pyramiding

6	Bacterial blight (BB) resistance	Xa21	STS (pTA248	MAS applied for Marker assisted backcross breeding
7	Bacterial blight (BB) resistance + stem borer tolerance	Xa21& B	STS for Xa21 (pTA248	Target variety: Minghui 63
8	Bacterial blight (BB) resistance + stem borer Tolerance + sheath blight tolerance	Xa21, Bt & Chitinase	STS for Xa21 (pTA248)	Target variety: IR72
9	Bacterial blight (BB) resistance	Xa5 and Xa13	CAPS for xa13 (RG136+HinfI) STS for Xa21 (pTA248)	MAS applied for Marker assisted backcross breeding
10	Bacterial blight (BB) resistance + Blast resistance	Xa21 & Piz	STS for Piz, transgene specific marker for Xa2	Target variety: IR50
11	BPH resistance	Bph1 & Bph2	STS markers	MAS applied for gene pyramiding
12	Rice tungro spherical virus	Translation initiation factor 4 gamma (eIF4G) gene	RM336	MAS applied for gene pyramiding

Collard and Mackill (2008) described three fundamental advantages of marker-assisted selection (MAS) compared with conventional phenotypic screening based breeding. (i) MAS is simple, cost effective, time saving and facilitates a non-destructive assay. (ii) Selection can be carried out at any growth stage from seed to maturity. (iii) Facilitates differentiation of homozygous plants from heterozygous ones in backcross, bulk and pedigree breeding methods, thus facilitating early –generation selection of superior recombinants, particularly for those traits controlled by recessively inherited genes. (iv) Screening can be done even without having the incidence of pests and disease.

3. RNA interference (RNAi)

It is a highly conserved post-transcriptional gene regulatory mechanism that controls gene expression at the mRNA level within living cells (Zhuang and Hunter 2012). RNAi is a precise, efficient, stable and better than antisense technology for gene suppression. RNA interference (RNAi) was first discovered in plants as a mechanism to recognise and defend against non-self nucleic acids. Initiation of RNAi production occurs after double stranded RNA or endogenous micro RNAs are processed by Dicer like proteins. RNAi based resistance can be engineered against many viruses by expressing 'hairpin' structures, double stranded RNA molecules that contain viral sequences, or simply by over expressing dysfunctional viral genes. RNAi is responsible for gene regulation and defense against pathogens. RNAi mediated silencing of pectin degrading enzyme of *Rhizoctonia solani* gives a high level of resistance against sheath blight disease of rice. 12

Table 4: Examples of RNAi applications against disease and insect resistance in rice

Sr.No.	Target trait	Gene(s)/ QTL(s	Remarks
1	Sheath blight	AG1IA_04727	Stable expression of PG-RNAi construct in rice showed efficient silencing of AG1IA_04727 and suppression of sheath blight disease.
2	Sheath blight	PATHOGENICITY MAP KINASE 1 (PMK1) homologues, RPMK1-1 and RPMK1-2,	First report demonstrating the effectiveness of Host Delivered RNA Interference (HD-RNAi) against sheath blight
3	Sheath blight	Oryza sativa WRKY80 gene (OsWRKY80)	Silencing OsWRKY80 gene enhanced sheath blight resistance
4	Blast	MoAP1	silencing of MoAP1 by feeding as iRNAs targeting MoAP1
5	Yellow stem borer	Dicer1 (*Dcr-1*), Dicer2 (*Dcr-2*)	Silencing Dicer1 (*Dcr-1*), Dicer2 (*Dcr-2*) and showed enhanced resistance
6	Yellow stem borer	Aminopeptidase (APN) and CYP450 (CYP6	Resistance to feeding by YSB larvae with dsRNAs
7	Rice dwarf virus	RDV segment 10 and RGDV segment 11	Silencing the genes against RDV
8	Rice stripe virus (RSV)	pC3 gene	Enhanced resistance against RSV
9	Rice grassy stunt disease	Pc5 gene	Enhanced resistance against RGSV

Mechanism of RNA interference

The first step, referred to as the RNAi initiating step, involves binding of the RNA nucleases to a large dsRNA and its cleavage into discrete RNA fragments (siRNA). In the second step, these siRNAs join a multi nuclease complex, RISC,which degrades the homologous single-stranded mRNAs. RNAi is triggered by doublestranded RNA (dsRNA). In insects, RNAi is triggered by the presence of dsRNA or siRNAs .Dicer1 and Dicer2 are known to cleave the long dsRNA into siRNAs.

4. CRISPR technology:

Genome editing or gene editing is one of the most promising tools in modern biology and comprises technologies that enable to change or edit an organism's DNA thereby has immense potential to combat against biotic stresses.. Genome editing tools enable us to edit the genome or specific genes of an organism by addition or deletion or replacement of nucleotides with high precision. Genome editing is a successful technology against various fungal, bacterial, and viral diseases in different agricultural crops. Plants have devised various strategies in response to the attack of biotic stress factors. While the resistance genes (R genes) decide the ability of plants to resist pests or diseases, susceptible genes (S genes) make them succumb to the stress. CRISPR/Cas9-based technology encoding *CYP71A1* gene and the enzyme, tryptamine 5-hydroxylase that catalyzes the conversion of tryptamine to serotonin resulted in reduced growth in plant hopper in rice. (Tyagi *et al.* 2020)

Table 5: Examples of CRISPR technology against disease in rice

Sr. No.	Target trait	Gene(s)/ QTL(s	Remarks
1	Bacterial blight	OsSWEET13	Improved resistance toward bacterial blight disease in indica rice, IR24
2	Blast	ERF transcription factor gene OsERF922	Enhanced resistance to rice blast
3	Rice tungro virus (RTSV)	Translation initiation factor 4 gamma (eIF4G) gene	Responsible for RTSV resistance
			A new source of resistance to RTD in susceptible variety IR64

Future thrust

- The recent progress in molecular biology has tremendous scope in identifying resistant and susceptible rice varieties as suitable donor and recipient for resistant breeding program.

- Rice research should be given more focus on identifying more durable and broad spectrum resistant genes, tagging of these genes with molecular markers and pyramiding or QTLs through molecular marker assisted selection.
- Extensive studies of rice disease resistance responses using genomics and proteomics approaches will lead to identification of novel genes that are involved in the defence signalling pathways.
- Refugia can play an important role in resistance management and should take into account the pest complex, the insect hosts and the environment.
- There is an ample future thrust to pursue the management strategy that reflects the pest biology, insect plant interactions, secondary metabolites and their influence on the natural enemies to prolong the life span of the transgenic.

Conclusion:

The continuous use of pesticides for crop protection had resulted in damaging impact on biological ecosystems. The use of target specific compounds with low persistence of intrinsic plant resistance mechanisms are safer alternative strategies for effective insect pest management. The transgenic crops developed for insect resistance need to be compatible with other components of integrated pest management programmes for pest resistance to be durable and impact on agricultural systems. The ideal transgenic technology should be commercially feasible, environmentally benign (biodegradable), and easy to use in diverse rice ecosystems as well as show a wide-spectrum of activity against the crop pests. It should be safer to the natural enemies, target specific and preferably produce acute rather than chronic effects on the target insects. However, the molecular approaches bring questions regarding the potential impact of those genetically modified organisms (GMOs) or plants to human, animal and environment.

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INTEGRATED CROP MANAGEMENT

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Introducation

ICM, or integrated crop management, was initially launched in 1991 in an effort to enhance public view of farming. Linking Environment and Farming (LEAF) was founded with the goal of encouraging excellent agricultural practise and ensuring consumers that output from Indian agriculture was safe to eat by enlightening them about both the logic and techniques of food production (Finch *et al.*, 2014).

Continuous planting of rice-wheat cropping system (RWCS) with heavy input consumption has posed a severe challenge to agricultural sustainability in the Indo-Gangetic Plains Region (IGPR), resulting in various output restrictions. This would include the concepts of good farming that farmers have been practising for many years, as well as components of environmental management to offset complaints about the negative impacts of intensive agriculture on the countryside. With increasing production- and resource-vulnerabilities in India, our agricultural approach needs to be redefined with a focus on climate resilient integrated crop and resource management (ICRM) with low-risk vulnerability, high factor productivity, and sustained farm profitability with safe food and environmental quality. In this setting, integrated crop management (ICM) approaches with economic, social, and environmental sustainability have enormous promise (Choudhary *et al.*, 2020).

Definitions

ICM is a farming approach that mixes the needs of a successful company with responsibility and environmental awareness. It covers techniques that reduce waste, increase energy efficiency, and reduce pollution. Adoption of ICM by many farmers or producers involves certain adjustments to current practises. However, it must assure a steady livelihood for the producer and a steady supply of inexpensive, high-quality product for the customer (Oberč *et al.*, 2020).

ICM integrates the finest of current technology with certain fundamental framing concepts. ICM is a long-term plan for the whole farm. It cannot be applied to a single crop, field, or season. Although crop productivity is the primary priority, livestock management is equally vital on mixed farms (Integrated Farming Systems) since animals eat crops and produce organic nutrients.

Concept

Integrated Crop Management may be conceived of as a concept that defines objectives and aims, which must then be 'translated' into concepts that producers can use. At its most fundamental, the idea is to combine the management of separate crops in order to profit from their interactions. In many ways, combining crop production practises to deliver advantages such as pest management, soil fertility maintenance, and so on is an old approach.

IPM, soil, social, and environmental management may all be included in the ICM. In recent decades, the emphasis on agricultural production has shifted from yields to quality and safety, and subsequently to sustainability. Farmers and producers face additional hurdles as a consequence of this. There is also a massive collective challenge from other sectors on agricultural scientists, policymakers, and industry. Extension workers and the farming community to improve and sustain agricultural productivity with a focus on sustainable resource management, safe food, and environmental harmony by implementing appropriate technology research and development programmes to harness technological advancements for food and environmental safety.

Five goals of ICM are as under

- ✓ Food security
- ✓ Environmental security
- ✓ Economic viability
- ✓ Social acceptabilay
- ✓ Food safety and quality

Why integrated crop management?

Over the last 50 years, dramatic advancements in agricultural efficiency and production in the world have resulted in a bountiful supply of food produced without placing undue strain on land that is not ideally suited to cultivation.

Increased land productivity, on the other hand, necessitates an increase in inputs, particularly energy. The general public perceives excessive exploitation of scarce resources as well as devastation of animals and the landscape. The difficulty is that, with supermarkets accounting for well over half of all food consumed in India, there is little public understanding of the reality of agricultural food production, much alone the advantages provided by contemporary technology. Meanwhile, extensive fertiliser and pesticide use has led to a decrease in cultivated area biodiversity. These concerns, along with a secure and taken-for-granted food supply, have increased pressure on farmers to be more attentive to wildlife and environmental challenges.

ICM has become an important option to attain the following objectives:

- ✓ Natural resources conservation, generation and utilization for sustainability
- ✓ Quality food and fodder, Ecological balance

- ✓ Sustainable output growth and adequate buffer stocks
- ✓ Sustainable employment generation and livelihood security
- ✓ Risk reduction and resilience/stability in production
- ✓ Sustained profitability

Table 1: Key elements of integrated crop management

S. No.	Component	Aim
1	Minimum tillage and soil conservation techniques Use of biofertilizers, nitrogen-fixing plants, green manures and agro-forestry techniques.	Low-cost maintenance of soil structure and fertility improvement in soil health
2	IPM for pests and disease control	Cheap and sustainable plant protection with minimal chemical use.
3	Crop diversification / Crop rotations	Prevent build-up of pests, diseases and weeds
4	Rational use and disposal of plant and animal residue	Resource recycling for better soll, plant and human health
5	Maintenance and improvement of ecological diversity	Avoid loss of soil and ecological biodiversity
6	Minimum use of purchased inputs and non-renewable fuel resources	Reduce production costs and environmental

(Source: - Modern concept of Agronomy)

Components of Integrated Crop Management

Integrated crop management encompasses almost everything that occurs on the farm, including animal management when applicable. The key components of integrated crop management, on the other hand, are shown in Fig. 1 and explained more below:

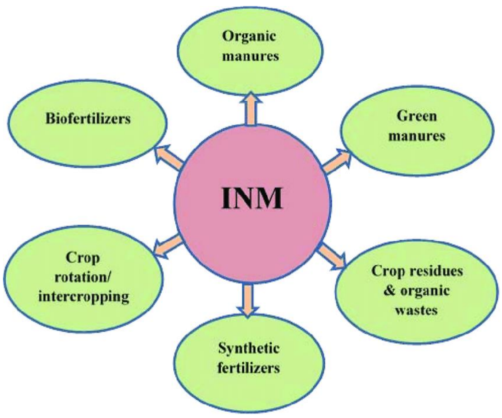

Figure 1: Component of ICM

1. Selection of Suitable Crops, Varieties and Cropping Systems

1.1 Major Factors to Consider in Crop Selection

In addition to the aim of farming, the following are important aspects to consider in crop selection:

1. Prevailing farm conditions
2. Marketability and profitability
3. Resistance to pests and diseases
4. Available technology
5. Farming system
6. Security
7. Availability and cost of planting materials
8. Availability and cost of labor

1.2 Varieties: The importance of sowing only the highest-quality seed cannot be stressed, since planting better seed results in stronger seedlings, which enhances the possibility that a crop will generate a higher yield. The survivability of seedlings throughout the early stages of growth is mostly due to meticulous seed selection and preparation. This is also one of the most effective methods for improving a farmer's overall quality of life (**Luna *et al.*, 2014).**

1.3 Only the best seed -should be selected for planting for the following reasons:

- Good seed results in healthier, heavier, and potentially higher-yielding seedlings.
- Good see results in seedlings which recover quickly from transplanting shock.
- Good seed results in rapid root growth, enabling seedlings to draw nutrients from the soil quickly and effectively.
- Good seed results in uniform germination and growth of seedlings, making it easier for the farmer to time crop management practices (e.g., Transplanting, irrigation, fertilization, weeding).
- Good seed has a high germination rate, facilitating exact calculation of seed requirements and thus preventing wastage damage to nursing of too few or too many seedlings.

1.4 **Appropriate crop rotation:** A conservation crop rotation involves planting various crops on the same plot of land in a scheduled, recurrent sequence year after year. This might involve rotating row crop cultivation from a high residue generating crop like corn to a low residue producing crop like soybeans. It may also comprise crops planted for cover or nutritional increases, as well as a rotation to a small grain or a grass legume meadow according to Francis. (2005).

a) General Principles to Guide Crop Rotations

- ✓ Following a legume crop, plant a high-nitrogen-demanding crop.
- ✓ In the second or third year following a legume sod, plant a crop that requires less nitrogen.
- ✓ Grow annual crops in a specific place for just one year.
- ✓ Do not follow one crop with another that is closely similar.
- ✓ Crop sequences that promote better crops should be used.
- ✓ Use crop sequences that help in weed control.
- ✓ Use perennial crops for extended periods of time on sloping ground.
- ✓ As part of the rotation, try to cultivate a deep-rooted crop.
- ✓ Grow certain crops that will produce a large quantity of residue.

- ✓ When cultivating a diverse range of crops, consider grouping them into blocks based on plant family, crop timing (all early season crops, for example), crop type (root vs. fruit vs. leaf), nutritional requirements, or crops with comparable cultural practises.

b) Selecting the right crops for your system

Choose crops for which you can easily manage the seeds, sowing and harvesting equipment and other inputs.

- ➢ Crop types: A crop rotation should be constructed using crop types that compliment one other. Cereals, for example, are supplemented with legumes. Crop rotation advantages will be diminished if various crops of the same sort are planted in succession (for example, growing two different cereals in rotation).
- ➢ The type of crop roots: Some crops have robust roots that may reach deep into the earth. These crops thrive in compacted soils because their roots increase soil structure, porosity, and other physical qualities. They also pull minerals from deep into the soil profile, making them accessible to following shallow-rooted crops.
- ➢ The need to enhance soil fertility. Legumes fix nitrogen in the soil, allowing it to be used by future crops. Nitrogen-fixing crops are good for planting before nitrogen-demanding crops or for replenishing nitrogen levels after nitrogen-demanding crops.

2 Field, Soil and Tillage Management

Soil is the primary natural resource that must be carefully managed in order to optimise the advantages of integrated crop management while minimising the requirement for external chemical inputs. Comics soil management begins with recognising the soil kinds, its physical structure: the chemical nutrients it contains, the organisms that dwell in it, the farm operations that impact each of them, and generating a soil map. The soil health is influenced by

a) Cultivation procedures
b) Crops and cropping systems grown
c) Machinery type and size
d) Tillage operations Water management in the soil
e) Field topography and relief
f) Use of animal manures and fertilisers Disposal and management of straw and agricultural residues
g) Natural soil fertility.
h) As a result, necessary steps must be taken to maintain or enhance the soil's bin physicochemical characteristics. The following are some examples of such measures and practises:
i) Create a cultivation approach that minimises soil structure and compaction damage.

j) Choose suitable cultivation methods, such as minimal or reduced tillage land layout, alternating ploughing with non-inversion techniques, and integrate cultivation and sowing processes as much as feasible.

k) Identify erosion-prone regions and take necessary measures, such as cover/strip/buffer cropping and contour cultivation. Bunding, drainage management, and avoiding over-cultivation are all recommended.

3 Nutrient management

The effective utilisation of crops to boost production is referred to as nutrient management. The soil nutrient supply must be balanced with crop requirements. If fertilisers are administered at the proper time and in sufficient amounts, crop output is maximised. It will damage the crop if used in large quantities, and it will reduce production if used in modest amounts.

The green revolution of 1970's paved the way for food security in India attributed to introduction of high yielding dwarf and fertilizer responsive genotypes of wheat and rice. Contribution of fertilizer inputs towards crop yield has been represented to be about 30 – 40 %. However, use conventional blanket fertilizer recommendations and skewed dependence on high analysis fertilizer has led to numerous deficiencies of macro and micro-nutrients, especially phosphorus, potassium and zinc. Ironically, this has negatively affected the soil health, human prosperity aside diminishing crop response ratio and about 8-10 million tonnes of NPK mining in India**.** The application of urea, DAP and MOP have been found to have lower fertilizer efficiency which ranges from 20 - 50 % for nitrogen, 10-25 % for phosphorus, 70-80 % for potassium and 2% for micronutrient owing to various losses which not only contribute to the greenhouse gases emission, certain health hazards such as blue baby syndrome and increase in cost of cultivation (Shaviv, 2000; Chinnamuthu and Boopathi, 2009).

Shortage of arable land, limited water and nutrient resources, necessitates increase in resource use efficiency without sacrificing production through effective use of modern technologies**.** In the context Integrated nutrient management can go a long way in ensuring sustaining soil health and crop production (Naderi and Shahraki, 2013).

3.1 Integrated Nutrient Management

The simultaneous use of chemical fertilisers and organic manures for crop productivity is known as integrated nutrient management.

Its primary goal is to maintain soil fertility and provide appropriate plant nutrients. It is environmentally, socially, and economically feasible.

a) Concepts of Integrated Nutrient Management

- Nutrients stored in the soil.
- Nutrients bought from sources other than the farm.

- Plant nutrients found in agricultural leftovers, manures, and household waste.
- Nutrient absorption by crops during harvest.
- Plant nutrients lost in the field due to crop harvesting or volatilization.

b) Manures and Fertilizers in Nutrient Management

Manures

- Contains modest amounts of nutrients and substantial amounts of organic matter;
- formed as a consequence of the breakdown of plant wastes and animal excreta;
- enriches soil with nutrients and organic matter, boosting fertility
- Organic matter in bulk promotes soil structure, increasing water retention capacity in sandy soil and assisting in drainage and water clogging in clayey soil.
- Manure is recommended over the usage of fertilisers since it comprises biological wastes collected via recycling.
- Manure is divided into two forms depending on the biological material used: compost and vermicompost.

Green manure: Some green plants are mulched into the soil while sowing seeds, which helps enrich the soil with nitrogen and phosphorous.

Fertilizers: Fertilizer use must be carefully controlled since excess fertiliser is washed away without being absorbed by the soil, resulting in contaminated water. The continued use of fertilisers harms the microorganisms that reside in the soil. These are advantageous in agricultural procedures.

Importance of Nutrient Management

Nutrient management is important for the following facts:

- Nutrient management aids in reducing plant nutrient pollution of waterways.
- Increase soil fertility.
- Increase plant production.
- Lower the price of chemical fertilisers.
- Providing crops with balanced nourishment.
- Promotes carbon sequestration and reduces soil, water, and ecological degradation, as well as nutrient loss from soil.

When deciding on nitrogen management options for crops and cropping systems, keep the following basic considerations in mind.

- Nutrient management based on soil tests Fertilizer management based on soil test and crop response (STCR)
- Nutrient application that is both balanced and exact.
- Legumes inclusion Residual impact of applied fertilisers

- Customized nutrient management using high-nutrient-use-efficiency products and practises such as specialty fertilisers (SF), liquid fertilisers, foliar feeding, fertigation, and delayed and controlled release fertilisers (SCRF).

4. Weed Management:

Weed management is the use of specific ideas and appropriate procedures to promote crop vitality and uniformity. At the same time, disregard or discourage weed invasion and development.

IWM strategies provide a broad variety of alternatives and levels of sophistication. Many IWM strategies may be incorporated into existing management programmes without requiring significant changes, whilst others need more intensive preparation and execution. Equipment cleaning, timely scouting, and changing herbicide tank mixtures are some of the simpler solutions; more complex options include modifying crop rotation, cover cropping, changing tillage methods, and harvest time weed seed management.

Figure 2: IWM

4.1 Components of an IWM Plan: The purpose of IWM is to integrate several weed management strategies into a collaborative effort to control weeds. Using the same herbicide repeatedly may lead to resistance, and relying on any of the ways listed below over time can limit its potency against weeds. When establishing an IWM strategy, two main things to consider are (1) target weed species and (2) the time, resources, and capabilities required to apply these approaches.

a) Cultural practices / crop husbandary practices:

1. Proper crop stand and early seedling vigor.
2. Planting time
3. Selective crop simulation
4. Crop rotation
5. Summer fallowing
6. Stale Seedbed

7. Lowering area under bunds
8. Minimum tillage
9. Flooding and drainage
10. Smother crops
11. Proper planting method Hand cultivator Push hoe Weeding Fork

b) Physical and mechanical methods

The mechanical methods include

1. Hand weeding
2. Hand hoeing
3. Spudding
4. Digging
5. Sickling
6. Flooding
7. Soil Solarisation
8. Burning
9. Cheeling
10. Tillage
11. Mulching
12. Dredging and chaining

Chemical: Herbicides are an integral part of most weed management plans and will continue to be so, even in IWM programs.

Good management practices for applying herbicides include:

- Timely inspection.
- Correct weed identification and knowledge of herbicide-resistant weeds in the region.
- Appropriate herbicide application, which entails using the correct product at the right rate and at the right time.
- Increased variety by using herbicide tank mixes with several, effective sites of action (SOA) and rotating herbicides throughout the season if feasible.

Biological: This strategy employs live creatures to target weeds, such as bacteria, fungus, or insects that favour a certain weed type. This approach is likely the least employed of all methods, although it has received much investigation (lecture notes on weed management).

Bio control started in the year 1900 (Neser *et al.*, 1988). There are 2 approaches in biological control.

1. Classical biological control approach. 2. Bio-herbicide philosophy approach.

Classical biological control: This technology is slow to operate and is presently employed in uncropped regions. Due to the widespread use of pesticides and fungicides in contemporary agriculture, the bio-agent will not have the chance to operate on host weeds in agricultural fields. Other wise *Cyperus rotundus* can be controlled in crop fields with moth "*Bactra verutana*". and selective bio control of *Ludwigia parviflora* (water purslane) by *Haltica cyanea* (steel blue beetle) in rice fields.

Bioherbicide philosophy of weed control: Bioherbicides are pathogens that have been intentionally cultivated and made accessible in sprayable formulations, similar to conventional herbicides. The pathogen used for the purpose is generally from the weed's natural environment, although it might come from anywhere. Mycoherbicides are another name for bioherbicides.

5. Water Management

Water management is the control and flow of water resources with the goal of minimising harm to life and property while maximising efficient beneficial usage. Dams and levees with good water control lessen the danger of floods.

5.1 Water Requirement: Crop water requirement is the amount of water plant uptake for life, growth, and development, as well as the production of economic components. This demand is met either naturally via precipitation or artificially through irrigation.

5.2 Integrated water management (IWM): Integrated water management (IWM) is vital for the sustainable use of existing water resources since it promotes water conservation, justice in water sharing, and delivery efficiency. An integrated policy for the responsible use of river, rain, ground, sea, sewage, and other water resources is required. Integrated ware management is the best strategy for attaining these objectives. It comprises micro-irrigation, rainwater collecting, and watershed management to achieve the aforementioned objectives (Irrigation agronomy book).

1. Micro-irrigation: This is a form of irrigation in which water is supplied to the crop's root zone at a slow, low-pressure, and monitored pace. It is beneficial in fertigation and chemigation. Drip, sprinkler, trickle, and micro spray are all types of micro-irrigation.

2. Rainwater harvesting: Rainwater is the world's largest and most abundant source of freshwater. In low to high rainfall locations, yearly precipitation ranges from less than 50 mm to more than 2000 mm. Water harvesting represents a paradigm change away from the current reliance on rivers and groundwater to supply household, irrigational, and industrial water needs.

3. Watershed management: Watershed management is a comprehensive strategy to developing an integrated forming system on a watershed scale. It seeks to optimise the utilisation of land water and plants in a given region in order to relieve drought, reduce floods, minimise soil erosion, boost water availability, and raise fuel, folder, and agricultural output on a long-term basis**.**

To make a water resource sustainable, there is need for an integrated water management system which should include policy and management actions like.

* Improved water conservation and storage measures.

* Incentives for selection of draught tolerant crop varieties.

* Efficient irrigation systems.

* Crop that reduce water loss

6. Integrated pest management

Integrated Pest Management (IPM) is a cost-effective and ecologically friendly strategy to pest control that employs a variety of common-sense approaches. IPM programmes make use of up-to-date, comprehensive knowledge on pest life cycles and interactions with the environment (Vreysen *et al.* 2007). This information, in conjunction with current pest management technologies, is utilised to manage pest damage in the most cost-effective and environmentally safe manner feasible.

6.1 Components of IPM

The major components of IPM in increasing order of complexity are as under:

A) **Cultural practices:** Cultural pest management approaches include doing routine agricultural activities in such a manner that the pests are either destroyed or prevented from causing economic damage. The numerous cultural practises are listed below.

- Keeping nurseries and main fields pest-free involves clearing plant waste, cutting bunds, treating soil and thorough summer ploughing, which kills several stages of pests.
- Soil testing for nutrient deficits to determine which fertilisers should be used.
- For seed borne disease management, choose clean and certified seeds and treat them with fungicides or bio-pesticides before planting.
- Selection of seeds from pest-resistant/tolerant cultivars that play an important role in pest control.
- Adjustment of planting and harvesting times to avoid peak insect attack season.
- Crop rotation using non-host crops It aids in the decrease of the occurrence of soil-borne infections.
- Proper plant spacing promotes plant health and makes plants less vulnerable to pests.
- Optimal fertiliser usage. FYM and bio-fertilizers should be promoted.
- Proper water management is essential because excessive wetness in the soil for an extended length of time promotes the growth of pests, particularly soil-borne illnesses.
- Weed control that is effective. It is a well-known fact that most weeds, in addition to competing with crops for micronutrients, also house a variety of pests.
- Setting up yellow pan sticky traps for white flies and aphids at a height high above the canopy.
- Sowing that is timed. In this case, a community method is necessary to plant crops concurrently throughout a large region so that pests do not acquire various stages crops ideal for population growth, and if pests arise in a destructive percentage, control operations may be conducted efficiently across the whole area.

- Growing trap crops on the edges or boundaries of fields. Certain crops that are chosen by a pest species are referred to be trap crops for that pest. By cultivating such crops along the field's edge, insect populations develop there, which may be either destroyed using pesticides or allowed to proliferate for natural management.
- When feasible, intercropping or multiple cropping. All crops are not favoured by every pest species, and some crops operate as repellents, keeping pest species away from desired crops and lowering pest occurrence.
- Harvesting as near to the ground as possible. This is due to the fact that some developmental stages of insect pests/diseases linger on plant components, acting as major inoculum for the next crop season. As a result, harvesting crops at ground level will reduce insect occurrence in the next season.
- Nursery plants should be sprayed/dipped in copper fungicide/bio pesticide solutions before planting to protect them from soil-borne illnesses.
- Remove and eliminate crowded/dead/broken/diseased branches when trimming fruit plants. Do not pile them in orchards, since this may serve as a breeding ground for pests.
- To protect the plants from pest/disease assault, large pruning wounds should be coated with Bordeaux paste/paint.
- Keeping bee colonies or putting flower bouquets of pollinizer cultivars aid in pollination and fruit set.
- Choosing high-yielding cultivars for various crops.
- The selection of pest resistant/tolerant cultivars.

Mechanical practices:

- Wherever feasible, remove and destroy insect pest egg masses, larvae, pupae, and adults, as well as unhealthy plant components.
- Setting a bamboo cage cum bird perchers in the field and putting parasitized egg masses within for natural enemy conservation and pest species avoidance whenever possible.
- Using light traps and destroying caught insects
- Use rope to dislodge leaf feeding larvae such as caseworms and leaf folders.
- Where necessary, install a bird scarer in the field.
- Field installation of bird perches to enable birds to sit and feed on insects and their juvenile stages, such as eggs, larvae, and pupae.
- Using pheromones to interrupt mating and create death zones.
- Using pheromone traps to monitor and control insect populations.
- Mass trapping using pheromone traps.

Regulatory practices: During this procedure, the government enacts regulatory restrictions that prohibit seeds and infected plant materials from entering the nation or moving from one region of the country to another. Quarantine procedures are classified into two types: domestic and overseas quarantine.

Biological practices: The most significant component of IPM is biological control of insect pests and illnesses. Biocontrol, in a wide sense, is the use of live organisms to control undesirable living species (pests). In other words, the intentional employment of parasitoids, predators, and diseases to maintain pest populations at levels lower than those causing economic loss, either by introducing a new bioagent into the pest's habitat or by improving the efficacy of those already present in the field.

Parasitoids: These are the creatures that lay eggs in or on their hosts' bodies and complete their life cycles on host bodies, causing hosts to perish. A parasitoid may be of varied types depending on the stage of development of the host through which it completes its life cycle. Egg, larval, pupal, adult, egg-larval, and larval pupal parasitoids are examples are different species of *Trichogramma, Apanteles, Bracon, Chelonus, Brachemeria, Pseudogonotopus* etc.

Predators: These are free living organisms which prey upon other organisms for their food. Examples are different species of spiders, dragon flies, damsel flies, lady bird beetles, Chrysopa species, birds etc.

Bio-pesticides: These are microorganisms that infest and induce illnesses in their hosts, causing the hosts to die. Fungi, viruses, and bacteria are the three major categories of pathogens. Some nematodes cause illnesses in insect pests as well. Different species of Hirsutella, Beauveria, Nomurae, and Metarhizium have been found to infest and kill a considerable number of insects (up to 90 percent) in the fields. The most notable viruses are nuclear polyhedrosis virus (NPV) and granulosis viruses. Outbreak of viruses in armyworms, cut worms, leaf folders, hairy caterpillars and plant hoppers have been reported many times. Among bacteria, Bacillus thuringiensis (B.t.) and B. popillae are very common examples.

Chemical practices: When all other approaches fail to maintain insect populations under economic loss, chemical pesticides are used as a last option. Despite significant advances in pest control research, pesticides will continue to play a vital part in crop protection due to the complexity of pest issues. As a result, pesticide usage should be need-based, careful, and based on pest monitoring to decrease not just the expense involved, but also the related difficulties. When it comes to chemical control, we must completely grasp what to spray, when to spray, where to spray, and how to spray while keeping the following considerations in mind.

The pest defender ratio must be followed.

Pesticides that are relatively safer, such as neem-based and biopesticides, should be chosen.

If the pest is present in strips or isolated areas, do not treat the whole field.

Because of their particular way of consumption by humans, IPM techniques are especially significant in vegetable and fruit crops. Pesticides certified by the CIB&RC should be used against the target pest in indicated crops. Farmers should not apply another pesticide until the waiting time for the previous pesticide has expired, and crops should be harvested after the waiting period has expired. We must be more cautious and cautious when using pest control measures in field crops.

Summary:

Integrated crop management (ICM) has lately been embraced in agriculture and is much more significant and relevant than the separate approaches of soil, water, nutrients, crops, pests, and energy management. It incorporates appropriate agronomic management strategies for growing a productive crop, such as integrated nutrient management (INM), integrated weed management (IWM), integrated disease management (IDM), and integrated pest management (IPM), among others. Integrated crop management benefits farmers, consumers, planners, and the environment. For farmers, integrated crop management may provide economic benefits as well as marketing advantages for products cultivated in a manner that is more acceptable to consumers. ICM is the greatest route ahead for agriculture. ICM caters for society, farmers, the countryside, and the environment all at the same time by ensuring a consistent supply of inexpensive, high-quality food.

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