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PREFACE

We are delighted to publish our book entitled ***"Research and Reviews in Agriculture Science".*** *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

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BOTANICAL INSECTICIDES AND NANOTECHNOLOGY: A SUSTAINABLE APPROACH FOR CROP PROTECTION AND ENVIRONMENTAL HEALTH

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Abstract:

Pest management in agriculture is of paramount importance to safeguard crop yields and mitigate economic losses due to pests. Synthetic pesticides have long been used for pest control but have led to environmental and health concerns. Botanical pesticides, derived from plants, offer a promising alternative with various advantages, including low toxicity, target specificity, and non-phytotoxicity. This chapter provides comprehensive information on the significance of botanical insecticides, their sources, chemistry, mode of action, and applications in pest control. It also highlights recent developments in the field, including advancements in nano formulations. Key botanical pesticides like neem, pyrethrum, rotenone, and nicotine are discussed, along with their mechanisms of action. However, the commercialization of botanicals in India faces challenges such as quality control, pest resistance, and human toxicity. Overcoming these barriers is essential for realizing the full potential of botanical insecticides in sustainable pest management and modern agriculture.

Keywords: Botanical, Insecticides, Nanotechnology, Crop Protection and Environmental Health

Introduction:

Pest management plays a crucial role in agricultural practices due to the detrimental impact pests have on crop yields and economic losses. Globally, major agricultural crops such as rice, wheat, maize, and potatoes suffer annual losses of approximately 10-15% due to pests, resulting in significant economic repercussions for nations (Laxmishree and Nandita, 2017). This threat to agricultural productivity and financial well-being has spurred extensive research and the development of novel pest control methods. While synthetic pesticides have been widely adopted to mitigate these losses, they have given rise to serious environmental and health concerns. Therefore, it is imperative to explore alternative solutions, such as botanical pesticides, to address these disadvantages. Botanical pesticides, derived from plants, offer a promising alternative for combatting pest-related challenges. They exhibit a broad spectrum of actions, serving as repellents, antifeedants, growth regulators, and oviposition deterrents. Botanical insecticides are gaining prominence due to their non-toxicity to plants (non-phytotoxicity), biodegradability, and rapid decomposition in the environment (Shivkumara *et al.*, 2019). This chapter aims to provide comprehensive information on the significance of botanical insecticides, their various sources, the chemistry behind their effectiveness, their mode of action, and their applications in pest control. Additionally, it will explore recent developments in the field of botanical insecticides.

Challenges of synthetic pesticide use

Agricultural crops are constantly exposed and or threatened by pests which affects their growth and later quality. To protect the crops from pest attack farmers usually rely on quick pest management options mainly synthetic insecticides. Despite the efficacious attributes of synthetic pesticides, continuous and overuse/ abuse has its challenges such as development of insecticide resistance, secondary pest outbreak, pest resurgence etc. Overuse and misuse of synthetic pesticides results in harmful effects on humans and the environment and elimination of beneficial organisms, thus impact negatively on biodiversity (Sande, *et al.,* 2011). Many synthetic pesticides, due to their poor biodegradability, tend to accumulate in the environment, resulting in soil and groundwater pollution, as well as contributing to ozone layer depletion. Use of synthetic pesticides has negatively affected farmers involved in export trade especially horticultural products (Nashwa and Abo Elyouser 2012). The detection of banned pesticides or the presence of pesticide residues above regulatory limits has had detrimental effects on both growers and exporters in developing countries, leading to market and income losses. The current global trend is towards consumption of food produced using safe and natural plant protection products. Detection of hazardous chemical pesticides residues in food and increased consumer awareness on food safety has resulted in the ban of certain pesticides in agricultural production.

Advantages of botanical pesticides

Botanical pesticides offer several advantages compared to synthetic pesticides:

1. **Low mammalian toxicity:** Botanical pesticides have minimal or no harmful effects on humans and wildlife, reducing health hazards and environmental pollution.
2. **Resistance prevention:** When used in their natural forms, botanical pesticides are less likely to lead to pest resistance, a significant concern associated with synthetic pesticides.
3. **Target-specific:** These pesticides are highly selective, posing minimal risk to non-target organisms, including beneficial insects like parasites, predators, and pollinators.
4. **No resurgence of pests:** Botanical pesticides are not known to cause a resurgence in pest populations, which is a common issue with some synthetic alternatives.
5. **Non-phytotoxic:** They do not harm crop plants, ensuring that the application of botanical pesticides won't damage the crops themselves.
6. **Residue-free:** Botanical pesticides do not leave harmful residues on agricultural produce or in the environment, contributing to the safety and conservation of the products and the well-being of consumers.

Diversity of plant families with anti-insect properties

Much before the advent of synthetic organic insecticides, Neem, Pyrethrum, Rotenone, Nicotine, Ryania, Sabadilla and other lesser-known botanical insecticides were used to protect agricultural crops from the ravage of insects.

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Promising insecticidal plant species with their properties

Table 1: Botanical insecticide traditionally used for pest control in agricultural crops in different crops

Plants	Active compounds	Activity
Abiesbalsamea	Juvabione	JH agonist
Acoruscalamus	Asarone	Antifeedant
Ageratum houstonianum	Precocene, Anacylin	Anti-JH
Ajugaremota	Ajygarin	Feeding deterrent
Allium sativum	Diallyl sulfide	Repellent
Atlantiaracemosa	Luvangetin	Antifeetan
Citrulluscolocynthis	Cucurbitacin-B	Antifeedant
Citrus paradisi	Isolimonic acid	Oviposition deterrent
Clerodendroninfotunatum	Clerodin	Antifeedant
Curcuma longa	Termeron	Growth inhibitor
Glycine max	Glyceollin	Antifeedant activity
Tagetes minuta	E-Ocimenone	Repellent
Ricinus communis	Ricinine	Oviposition deterrent
Medicago sativa	Butyric acid	Repellant
Ocimum basillicum	Juvocimene	JHA
Parthenium hysterophorus	Parthenin	Growth inhibitor
Piper nigrum	Piperin	Oviposition deterrent
Quassiaamara	Quassin	JHA
Pongamia pinnata	Karanjin	Antifeedant, JHA

Table 2: Botanical insecticide, plant source and region

S. No.	Pesticides	Plant Source	Country/Region
1	Neem	*Azadirachta indica A.* Juss	India
2	Dharek	*Melia azedarach* L.	China, India
3	Pyrethrum	*Chrysanthemum cinerariaefolium*	Middle East and Europe
4	Rotenone	*Derris elliptica*	East. Africa and Europe
		Lonchocarpus nicou	South America
		Tephrosia vogelii	East, South Africa, China
5	Nicotine	*Nicotiana tabacum*	Europe
		Nicotiana rustica	Europe
		Nicotiana glauca	Argentina, Uruguay
6	Ryanodine	*Ryania speciosa*	South Africa
7	Sabadilla	*Sabadilla officinarum*	Central, South America, Venezuela
8	Quassin	*Quassia amara*	Central America and Brazil

Source: Dhaliwal and Arora, 2001

At present there are four types of botanical products used for insect control i.e., Pyrethrum, Rotenone, Neem and essential volatile oils along with the three others in limited use (Ryania, Nicotine and Sabadilla) and additional plant extracts (Ex: garlic oil, capsicum oleoresins). Botanical pesticides are either utilized as plant extracts, essential oils or both. The plant parts used to make botanical pesticides includes barks, leaves, roots, flowers, fruits, seeds cloves, rhizomes and stems the plant part used is dependent on the targeted bioactive compounds and their abundance within that particular part. The plant parts are dried and ground into fine powder and extracted with organic solvents that will maximize extraction of the targeted bio-active compounds. The extracts are then concentrated, formulated and evaluated for efficacy under laboratory control and in field conditions later.

Challenges in the widespread use of botanical pesticides

According to Isman and Grieneisen (2014), the major factors limiting the wide scale exploitation of botanical pesticides are:

1. Due to the lack of practically applicable results in many of thepublished studies
2. Lack of the availability of good quality botanical pesticides atafforable prices
3. Strict legislation
4. Short persistence of the compounds in the environment, due to rapiddegradation
5. Extraction of oils from plants grown under different climatic conditions, resulting in different compositions in terms of active agents, with potentially weaker effects in pest control and likelihood of variability among batches

Nanotechnology in the development of botanical pesticides

In this context, the successful exploitation of emerging technologies seems to offer a way to overcome many of the difficulties that hinder the large-scale production and commercialization of the botanical pesticides (Pavela and Benelli, 2016). For instance, research in plant biotechnology has demonstrated that genetic manipulation of specific field crop species has the potential to enable the production of substantial quantities of natural compounds that were originally isolated from other plant species. This advancement in biotechnology offers promising opportunities for agricultural and economic sustainability. The nano/microencapsulation of natural compounds in different matrices has been shown to be an effective way of overcoming stability problems, increasing the effectiveness of the compounds due to: Increased solubility, Protection against premature degradation (by high temperatures, photodegradation, and biodegradation), Increased residual activity due to sustained release.

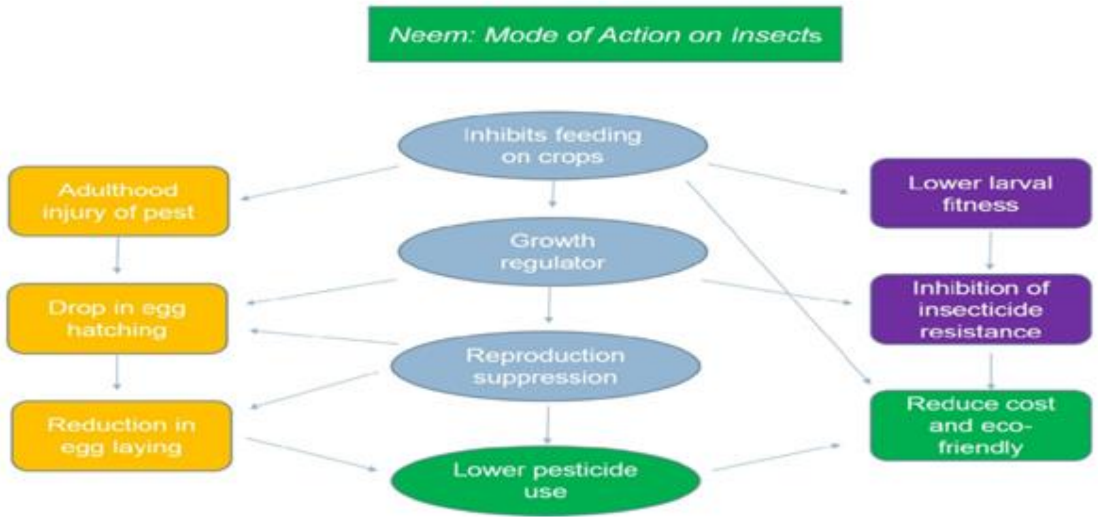
Commercialised botanical pesticides in Agricultural pest management

- **Neem tree:** *Azadirachta indica A. Juss*, commonly known as the neem tree, belongs to the Meliaceae family, which includes mahogany trees. It's also referred to as margosa or Indian lilac.
- **Dual properties**: Neem is renowned for its dual properties, with applications in both pest control and human health enhancement.
- **Pesticidal use:** Neem-based pesticides play a vital role in pest management, particularly

in agriculture.

- **Antifeedant effects:** In 1952, the antifeedant effects of neem were scientifically described, with desert locusts refusing to feed on neem plants.
- **Azadirachtin isolation:** The active ingredient, Azadirachtin, was isolated from neem seeds by David Morgan. Its full structural determination took around 17 years to complete.
- **Breakthrough observation:** In 1962, entomologists at IARI, New Delhi, observed a significant breakthrough regarding neem's insecticidal application. A water suspension of neem seed kernel, when sprayed at a concentration of 0.001 percent on standing crops, effectively protected the crops against migratory and desert locusts.
- **Versatile pest control:** Neem has a multi-pronged effect against insects, serving as a repellent, antifeedant, oviposition deterrent, molting and growth disruptor, sterilant, ovicide, and oviposition deterrent. These properties make it a versatile solution for controlling various pests and pathogens affecting agricultural, plantation, and cash crops.
- **Broad pest control:** Neem-based products are known to control more than 500 pest species worldwide, making it a valuable tool in pest management.

The presence of liminoids in neem makes it a safe and efficient solution for various agricultural purposes, including insecticides, pesticides, nematicides, and fungicides. Among the most significant liminoids in neem, with a proven ability to disrupt insect growth, are azadirachtin, salanin, meliantriol, and nimbin. Notably, azadirachtin, in particular, shares a structural resemblance with insect hormones known as "ecdysones," which regulate the process of metamorphosis in insects as they transition from larva to pupa to the adult stage. It's intriguing to observe that neem doesn't kill insects but rather modifies their life processes. Several different kinds of azadirachtin (A-K) have been isolated, the most abundant of which is Azadirachtin-A. Neem terpenoids are distributed throughout almost all parts of the plant, particularly in the living tissues. Recent research has pinpointed the site of synthesis and storage of Neem chemicals in secretory cells. Among the plant's parts, these secretory cells are most densely concentrated in the seed kernels.



Neem extracts affect various insects by disrupting or inhibiting the development of eggs, larvae, or pupae, blocking the moulting of larvae or nymphs, disrupting mating and sexual communication, repelling larvae and adults, deterring females from laying eggs, sterilizing adults, poisoning larvae and adults, deterring feeding, blocking the ability to "swallow" (reducing gut motility), and sending metamorphosis awry at various stages.

- **Neem Kernel Aqueous Extract (NKAE):**

Prepared from neem seeds. Used as a preventive or protective spray on crops, with concentrations ranging from 1.25% to 5%. The spraying should be done in the low-intensity sunlight, and it remains effective for 7-10 days. It's essential to cover all plant foliage.

- **Neem leaf extract:**

Made from green neem leaves. Effective against leaf-eating caterpillars, grubs, locusts, and grasshoppers. Used in nurseries and kitchen gardens. Requires a significant quantity of leaves for preparation.

- **Neem cake extract:**

Prepared from neem cake. Soaked in water and filtered before use. Effective against pests when used as a spray.

- **Neem oil spray:**

Prepared by mixing neem oil with water and emulsifier. Must be used immediately. Effective for controlling insects that lay eggs on the underside of leaves. Avoid exposing it to heat, boiling, acidic or alkaline emulsifiers, and direct sunlight.

- **For protecting stored grains:**

Neem is traditionally used to protect stored grains from pests. Neem leaves, oil, or extracts act as repellents against insects that damage stored products. Neem can be mixed with grain, treated jute sacks, or used to make bins for storage to reduce pest damage. While neem treatments can't completely replace chemical pesticides, they can reduce the amount needed, thereby decreasing the pesticide load in stored food grains. This is especially important for reducing post-harvest losses in developing countries.

Neem chemistry

Main active ingredients of the neem are azadirachtin, meliantriol, salannin, desacetylsalannin, nimbin, desacetylnimbin, and nimbidin. Azadirachtin concentration from 0.2 to 0.6% in seeds compared to other parts This ingredient belongs to an organic molecule class called tetranortriterpenoids. These compounds are classified within a broader category of natural products known as "liminoids." The liminoids found in neem are what make it a safe and efficient choice for insecticides, pesticides, nematicides, fungicides, and more. Additionally, neem includes over 20 sulphurous compounds that are responsible for the distinctive odor emitted when neem seeds and neem oil are crushed.

Leaves: Leaves mainly yield quercetin (flavonoid) and nimbosterol (β- sitosterol) as well as number of liminoids (nimbin and its derivatives). Quercetin, a polyphenolic flavonoid, is recognized for its antibacterial and antifungal properties. Limonoids like nimocinolide and isonicotinamide affect fecundity in house flies (*Musca domestica*) at a dose ranging between 100 and 500 ppm. They also show mutagenic properties in mosquitoes(*Aedes aegypti*) producing intermediates. Fresh matured leaves produce a fragrant and viscous essential oil, which has demonstrated antifungal activity against fungi such as *Trichophyton mentagrophytes* in laboratory settings.

Flowers: Besides, the essential oil consisting of sesquiterpene derivatives, the flowers contain nimbosterol and flavonoids like kaempferol, melicitrin etc. Flowers also yield a waxy material consisting of several fatty acids, viz., behenic (0.7%), arachidic (0.7%), stearic (8.2%), palmitic (13.6%), oleic (6.5%) and linoleic (8.0%). The pollen of neem contains several amino acids like glutamic acid, tyrosine, arginine, methionine, phenylalanine, histidine, aminocaprylic acid and isoleucine.

Bark: The trunk bark contains nimbin (0.04%), nimbidin (0.001%), nimbidin (0.4%), nimbosterol (0.03%), essential oil (0.02%), tannins (6.0%), a bitter principle margosine and 6-desacetyl nimbinene. Several diterpenoids, *viz*., nimbinene, nimbolinin, margocin, nimbidiol, nimbione, etc. have been isolated from stem bark and root bark.

Seed: Seed is very important both because of its high lipid content as well as the occurrence of a large number of bitter principles (azadirachtin, azadiradione, fraxinellone, nimbin, salannin, salannol, vepinin, vilasinin, etc.) in considerable quantities. Azadirachtin has been documented to be highly effective as a pesticide against approximately 300 different insect species, and it is also reported to be non-toxic to humans.

Mode of action

Azadirachtin:

Structural similarity: Azadirachtin is structurally similar to insect hormones called ecdysones, responsible for insect metamorphosis.

Antifeedancy: It causes antifeedancy by stimulating deterrent cells in insect chemoreceptors and blocking sugar receptor cells, reducing feeding.

digestive efficiency: Azadirachtin reduces post-ingestive digestive efficiency, which is termed "secondary antifeedancy."

physiological effects: It disturbs hormonal and physiological systems, hindering food movement in the insect's midgut and inhibiting digestive enzyme production.

Interference with growth: Azadirachtin interferes with insect growth and molting by affecting ecdysteroid hormone synthesis and the neurosecretory system.

Salannin:

Insect-growth regulator: Salannin acts as an insect-growth regulator with antifeedancy properties.

feeding deterrent: It deters feeding in insects, reducing their food intake.

Molting effects: Salannin increases the duration of the larval stage, causing delayed molting, and ultimately leads to a decrease in pupal weight.

Larval and pupal mortality: The combination of delayed development and reduced pupal weight can result in larval and pupal mortality.

Tables 3: Mechanism of action of some botanical insecticides

Compound	Botanical Species	Mechanism of Action
1. Pyrethrin	*Chrysanthemum cinerariaefolium*	Agonists of Voltage sensitive sodium channels (GABAergic systems)
2. Azadirachtin	*Azadirachtin indica*	Inhibits the activity of Ach E activity
3. Rotenone	*Derris* spp.	Mitochondrial cytotoxin
4. Citronella	*Cymbopogon nardus*	Antagonist of octopamine
5. Nicotine	*Nicotiana* spp.	Against of Acetylcholine
6. Methanol	*Mentha piperita*	Positive allosteric modulator of GABA receptor
7. Eugenol	*Syzygium gromaticum*	Stimulate octopamine receptors
8. Thymol	*Thymus vulgaris*	Stimulate GABA receptors

Recent advancements in botanical insecticides have brought a focus on improved nano formulations, offering more effective and persistent pest control. Here's a summary of these developments:

- **Improved nano formulations:** Nanopesticides are playing a significant role in reducing the environmental impact of conventional pesticides. They come in various forms, including encapsulated nanopesticides and nanoparticles of silver, silica, copper, iron, and carbon, and are being used for insect pest management.
- **Balancing rapid biodegradation:** One challenge with botanical insecticides is their rapid biodegradation. While this is advantageous for safety and environmental reasons, it limits their field persistence. Recent developments aim to enhance both the efficacy and persistence of botanical insecticides by exploring innovative formulation chemistry and physics.
- **Silver nanoparticles for disease control:** Studies have focused on synthesizing green nanoparticles using plant extracts and metal nanoparticles, especially silver (Ag) nanoparticles, for mosquito larvicides to control vector-borne diseases. Although these materials have shown promising bioactivities, they have not yet been commercialized. Botanical ingredients used in these studies include azadirachtin, rotenone, essential oil monoterpenoids, curcumin, and various essential oils. Common matrices for encapsulation include chitosan, cyclodextrins, sodium alginate, zein, and polyethylene glycol.
- **Azadirachtin nanoformulations:** Azadirachtin, a predominant active ingredient in neem, can be loaded into both organic and inorganic nanoparticles. This process uses neem leaf extracts to synthesize silver nanoparticles, which effectively deliver biopesticides for insecticidal activity. Additionally, neem oil can be loaded onto silica-based nanoparticles, reducing pests like the tomato leaf miner.

- **Nanoemulsions for enhanced stability:** Nanoemulsions of neem oil, extracted from neem seeds, have been developed to address the high degradability of neem-based biopesticides. These nanoemulsions provide stability to the biopesticidal ingredient and offer controlled release, leading to significant reductions in storage pests. They also exhibit high UV stability.
- **Polymeric nanocarriers for pest control:** Polymeric nanocarriers, such as Poly (ε-caprolactone) (PCL) and β-cyclodextrin, have been utilized to load neem oil for pest control, particularly against Bemisia tabaci. While effective in causing insecticidal activity, their efficacy is somewhat lower compared to commercial neem oil.

Table 4: List of various encapsulated botanical nanopesticides used against insect pest management (Sweta Bhan *et al.*, 2018)

Botanical product	Targeted Insect
Garlic Oil	*Tribolium castaneum* Adult
Moringa oleifera seeds	*Stegomyia aegypti* Larvae
Lippia sidoides oil	*Aedes aegypti* Larvae
Oleoresin	*Aedes aegypti* Larvae
Azadirachta indica (Oil)	*Culex quinquefasciatus* Larvae
Artemisia arborescens (Oil)	*Bemisia tabaci* Adult
Azadirachta indica (Oil)	*Bemisia tabaci* Eggs and Nymphs

Essential oils

Approximately 20 years ago, studies on neem and azadirachtin dominated the scientific literature on botanical insecticides. In the past decade, essential oils have challenged and even eclipsed neem as the most popular subject in this field. There is now a vast body of published research containing reports on the toxicity of essential oils derived from specific plants towards particular insect species. Limonene, the major constituent (>90% by weight) of orange oil, is obtained by cold pressing orange skins, ostensibly a byproduct of the citrus industry. In the past decade, this botanical insecticide has seen the highest utilization in California. However, more than 90% of limonene (XT2000^R) is used in structural pest control (i.e., against wood-destroying termites and ants), although an agricultural formulation developed in South Africa (PrevAM^R) has recently been registered in the United States and the European Union A plant identified as *Chenopodium ambrosioides* produces an essential oil that was determined to have potential for insect pest management (Chiasson and Bostanian, 2004). From this oil, a formulated insecticide was developed now marketed as Requiem^R in North America, this product quickly became the botanical that is most heavily used exclusively for crop protection in California.

A US company, EcoSMART Technologies, was a pioneer in developing essential oil-based pesticides -agricultural insecticide and miticide, Ecotrol™, is now produced which includes rosemary oil, peppermint oil and geraniol as active ingredients, is sold in a dozen countries. Ecoflor Agro in Colombia developed a formulation containing *Capsicum* oleoresin and garlicoil as active ingredients; this product was approved in 2014 by the EPA inthe United States under the trade name Captiva[R]. This product and its related products from the company are presently registered and available for purchase in ten countries. In China, several newer commercial insecticides contain active ingredients derived from matrine and related quinolizidine alkaloids found in *Sophora flavescens* (Fabaceae), veratrine and related cevadine-type alkaloids from *Veratrum nigrum* (Melanthiaceae), or celangulin and related dihydroagarofuran sesquiterpenes from *Celastrus angulatus* (Celastraceae).

An insecticide based on seed extracts from the soursop (*Annona squamosa*) and the sweetsop (*Annona reticulata*), containing squamosin as the active ingredient, has been developed in India under the trade name Anosom[R].

Effects of botanicals on insects

Botanical insecticides affect various insects in different ways depending on the physiological characteristics of the insect species as well as the type of the insecticidal plant (biomolecules). The constituents of various botanical insecticides can be categorized into six groups, which include repellents, feeding deterrents/antifeedants, toxicants, growth retardants, chemosterilants, and attractants.

Scope of botanicals in present Indian agriculture

Botanical pesticides are environmentally safer, unique with novel and diversified mode of action and are rich source of biologically active compounds. The field of agrochemicals is often an underexplored domain, yet complex mixtures of various stereoisomers have demonstrated excellent efficacy in the pharmaceutical industry. Naturally occurring botanical pesticides are in high demand in the pesticide market. Numerous botanical products have been introduced, with some assuming a prominent position in the insecticidal market. Approximately 6,000 plant species have been identified and screened for their effectiveness against pests worldwide Several plant-derived products from various sources, including neem, custard apple, tobacco, pyrethrum, and others, have been employed as safer insecticides due to their environmentally friendly attributes, which are less harmful to predators, parasitoids, and pollinators. Naturally occurring native plant species contain secondary metabolites such as phenolics, terpenes, alkaloids, lignans, and their glycosides, which play a significant role in defending plants against various pests. These unique characteristics are attracting the researchers and farmers for commercialization of novel botanicals in India. The collective efforts of farmers play a crucial role in gathering, preserving, and cultivating botanical plant species, ultimately leading to increased production of cost-effective biopesticides as a more sustainable alternative to synthetic insecticides.

Botanical pesticides status in India

For the use of pesticides in agriculture or any other application, it is mandatory to register the pesticides and their formulations in accordance with the Insecticide Act, 1968, following the guidelines and regulations set forth by the Central Insecticide Board & Registration Committee (CIBRC) within the Department of Agriculture and Farmer’s Welfare. In India, only three botanical pesticides are Azadirachtin (Neem Based Formulations), Pyrethrum, and Eucalyptus Leaf Extract has been registered and allowed to use as botanical pesticides commercially for various purposes. Out of these three botanicals, neem based pesticidal products have mostly used as the botanical pesticides in the agricultural purpose followed by pyrethrum, and Eucalyptus Leaf Extract respectively.

Problems/barriers in commercialization of botanicals in India

- **Quality control and standardization**: Commercializing botanical pesticides faces challenges in ensuring quality control and product standardization. Maintaining consistent quality and efficacy is difficult.
- **Pest resistance**: Botanical pesticides, like synthetic ones, can develop resistance in pests, raising concerns about long-term effectiveness.
- **Toxicity**: While botanical pesticides aim for low mammalian toxicity, they can be highly toxic to fish and aquatic invertebrates. For example, pyrethrum and rotenone are toxic to fish.
- **Human toxicity**: While many botanical plant extracts are considered safe for humans, some, like Aconitum spp. and Ricinus communis, are known for their high toxicity.
- **Photosensitivity**: Some botanical pesticides, such as those derived from neem (e.g., Azadirachtin), are photosensitive and break down rapidly in sunlight.
- **Synergism**: Developing pyrethrum products for the organic market faces challenges related to synergism. Conventional synergists like piperonyl butoxide (PBO) are synthetic and not suitable for organic agriculture.
- **Commercialization barriers**: Challenges include the production of raw materials at a commercial scale, formulation standardization for complex extracts, the need for regulatory approval due to slow action and lack of residual effects. Most plant-derived pesticides lack official recommendations for pest management.

Conclusion:

Naturally occurring insecticides have greater scope in international level as present days botanical insecticides have promoted modern agriculture and gradually replace the synthetic pesticides. In insect pest management, anumber of plant products derived from neem, pyrethrum, tobacco, custard apple, etc. have been used as safer insecticides as compared to chemical pesticides Neem based pesticides are more common botanicals in India than remaining botanical pesticides. Botanical pesticides have less environmental hazards, easily volatility, fast degradation, less phyto toxicity, less insect resistance, low resurgence effect and provides residue free commodity. At last we need to tackle all the problems/ barriers and formulate a newer formulation with greater stability of the botanical pesticide, regulation of registration formalities to be made easier to tap the market demand in a huge way for commercialization of botanical insecticides in India.

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AN OVERVIEW OF DATA ANALYTICS IN SMART AGRICULTURE

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Abstract:

Data analytics is becoming immensely important in the field of smart agriculture to improve farming efficiency, provide accurate real time estimates and thereby increase yields. The application of modern technologies such as sensors, internet of things (IoT) devices, and other technologies like unmanned aerial vehicle (UAV), blockchain methodology, etc. generate large amounts of data, which needa to be analysed accurately to provide scientific insights about crop growth, soil health, weather patterns, and other factors affecting agricultural production. With this data, farmers can confidently determine the optimal timing for planting, fertilizing, and harvesting their crops, and identify the specific areas of their land that need focused attention. Data analytics can also be used to optimize resource allocation, such as water usage, to reduce waste and minimize environmental impact. Overall, the use of data analytics in smart agriculture has the potential to revolutionize the way we produce food, making it more sustainable, efficient, and resilient in the face of climate change and other challenges. This chapter will provide an overview of data analytics in smart agriculture, focusing on how data can be collected, analysed, and used to improve crop yields, reduce costs, and increase sustainability. The challenges associated with data collection and analysis in agriculture including issues related to data quality, privacy, and security will be discussed. Some of the most promising applications of data analytics in smart agriculture, including precision agriculture, predictive analytics and remote monitoring will also be elucidated. Finally, the chapter will conclude with discussions on some of the key opportunities and challenges faced in the adoption of data analytics in smart agriculture and with an outline of a roadmap for future research in the area.

Keywords: Data analytics, Smart agriculture, Precision agriculture, Internet of things (IoT), Unmanned Aerial Vehicle (UAV)

Introduction:

Smart agriculture refers to the use of technology and data analytics to improve crop yield, reduce input costs, and increase profitability. Data analytics plays a crucial role in smart agriculture as it helps farmers to make informed decisions based on real-time data collected from sensors, drones, satellites, and other sources. Data analytics can be used to monitor crop health, predict weather patterns, optimize irrigation systems, and identify pest and disease outbreaks. With the help of data analytics, farmers can also optimize fertilizer and pesticide applications, reduce energy consumption, and minimize waste. Lastly, these practices also aim to ensure agricultural practices are sustainable and environmentally friendly. This is achieved by reducing the use of chemicals, optimizing the use of water and other resources, and limiting pollution (Agbona *et al.,* 2022). These measures will ensure that we are sustainable and able to continue to produce food in the future. Finally, the measures we take now will determine our long-term food security. Therefore, it is our responsibility to ensure the survival of our future generations by taking action now to secure our food supplies. Therefore, in order to secure our food supply, we must examine agricultural practices, increase efficiency, and promote sustainable food production. In this regard, governments should support research and development in agriculture, as well as encourage farmers to adopt new technologies and practices (Chergui and Kechadi, 2022).

Additionally, they should also invest in infrastructure, such as modern storage facilities and means of transportation, to ensure the availability of food throughout the year. The prevalence of data and data analytics in agriculture presents an exciting opportunity for farmers to increase efficiency and productivity while reducing waste and environmental impact. Inefficient farming practices are often the result of a lack of data and insights, leading to ill-informed decision-making and suboptimal outcomes. However, not all farmers have access to the same resources or training necessary to make the most of these opportunities. In order to close this gap, many universities are now offering courses in data analytics and smart agriculture, providing students with the skills and knowledge they need to drive innovation in the industry. These programs enable students to gain a comprehensive understanding of the technology and tools available, as well as develop the skills they need to apply these tools to real-world situations. By learning how data analytics can improve decision-making and increase efficiency, students are helping to drive the industry forward and improve the lives of farmers and consumers alike (Elijah *et al.*, 2018).

Smart agriculture:

Smart agriculture refers to the use of advanced technologies, such as sensors, drones, and big data analytics, to improve crop yield, reduce input costs, and minimize environmental impacts. Smart farming refers to the use of information and data management technologies in agriculture. These technologies, including software, sensors, and robotics, increase productivity and efficiency of agricultural systems. This method offers farmers tools and tactics to increase yields and the sustainability of agricultural output. Smart agricultural technology, which is spreading from other sectors (including autonomous driving), is at the core of the innovation. A farm followed the major procedures *viz*. data collection, diagnostics, decision making and actions to become a smart farm (in Figure 1) (Goel *et al.*, 2021). At the same time, people need to understand the distinction between precision agriculture and smart farming. While the first strategy makes use of cutting-edge instruments to make farming a more predictable and effective process, the technologies used in the second approach are concentrated on getting the most precise measurements.

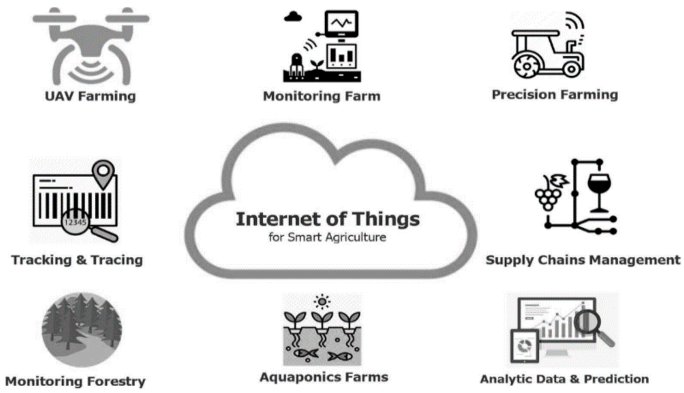

Figure 1: **An illustration of IoT applications for smart agriculture (Source: Quy *et al.*, 2022)**

1. Smart Farming Technologies:

The phrase "smart farming" refers to a variety of techniques and technology that are used to optimise agricultural processes. The following are some of the most practical and efficient smart farming tools:

- **Machine learning:** Data-driven self-adaptive technologies possess the capability to anticipate or predict variations in climate conditions, soil and water characteristics, carbon levels, the spread of diseases and pests, and other relevant factors.
- **Smart farming sensors:** Farmers can track even the smallest changes in the environment and their farms in real time through sensitive sensors.
- **Drones and satellites with cameras:**
- With the aid of these technologies, farmers can generate frequently updated maps and remotely monitor their fields without the need for physical visits.
- **Big data**: Accurate forecasting, activity planning, and the creation of more effective business models are inconceivable without big data. Making long-term judgements and acting immediately are both made possible by smart farming and big data (Quy *et al.*, 2022).
- **Internet of Things (IoT):** With IoT, you may create a single system out of all the available tools and solutions. All hardware and software have the ability to share data and take precise actions based upon patterns.

2. Advantages of Smart Agriculture:

The advantages of smart agriculture can be summarised as follows:

Better crop health monitoring	**Lesser impact on environment**	**Ensure food security in case of climate change**	**Reduce operating expenses while increasing yields**
•Utilising cutting-edge farming tools, farmers may detect crop diseases and other issues earlier.	•Systems for precision agriculture can lower carbon emissions and the usage of toxic chemicals	•More effective smart farming aids in maintaining production levels while adjusting to changing climatic conditions	•Increased yields (by 1.75%), 8% less water use, and lower energy expenditures are all achieved by smart farms.

In short, more extensive adoption of intelligent farm technologies is essential for more reasons than just increased profitability. The demands of the expanding population must also be met. The current technological advancements in the agricultural industry have the potential to drastically alter both small farms and large businesses' work processes (Ramya *et al.,* 2015). Modern farming technologies are being introduced at such a rapid rate that they are now accessible not just in developed regions but also in underdeveloped ones. The detail procedure of data analysis is summarized in Fig. 2.

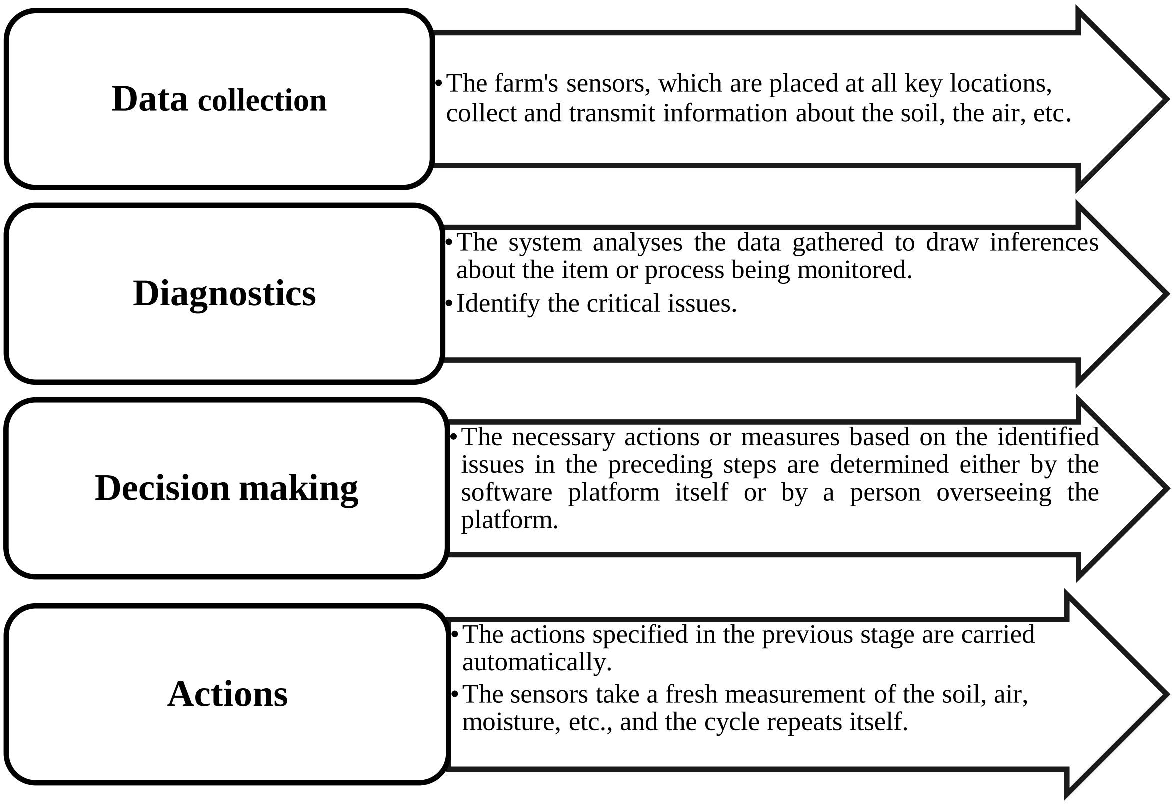

Figure 2: **The procedures used in smart agriculture on a farm**

Some examples of smart farming applications in agriculture:

Farmers have already started utilising a variety of smart agricultural technology, and their results have been amazing like

- **Livestock management and monitoring:** This technology, also known as Precision Cattle Farming (PLF), tracks multiple traits of cattle using IoT sensors and predictive analytics software. These traits are Behaviour, Feeding patterns and Health & well-being. The operation makes use of smart agricultural machinery that includes cameras, sensors, and software to monitor animal health, improve feeding regimens, and carry out real-time monitoring.
- **Smart crop management:** Farmers have typically visited the fields to assess the condition of their crops. However, this strategy is simply unworkable for major agricultural operations if you have to spend hours each day inspecting your field. IoT sensors and drones are used to monitor different factors related to crop health and soil health. AI-powered software is the innovation that enables these processes. Drones

are guided by GPS, image recognition, and numerous IoT devices in agricultural applications so they can carry out their tasks (Sinha and Dhanalakshmi, 2022).

- **Greenhouse monitoring system:** A greenhouse with a monitoring system, sometimes known as a "smart greenhouse," automatically regulates environmental conditions. Sensors, Wireless connectivity (infrastructure + cloud), and User software (a desktop and/or mobile app) are the key elements of the system. A smart greenhouse maintains an ideal micro climate and manages fertilization and irrigation. Besides this, it provides data on potential plant diseases.
- **Smart farm management software:** The goal of smart farming software is to assist with numerous facets of farm management. In essence, it serves as a hub for historical and current data and information about the facility that farmers use to organise, track, and evaluate their operations. The software may include information like weather records, animal monitoring data, farming equipment condition status, ideal and historical planting schedule *etc.* Together, this data enables farmer to handle everything with a single app. They are capable of managing not just the farm but also the finances and human resources (Mohapatra and Rath, 2022; Mohapatra *et al.*, 2023).
- **Autonomous ground vehicles:** The position and speed of the vehicle are programmed by AI and location tracking software with map data. Therefore, all that is required is GPS and equipment for managing machinery (cameras and sensors). The technology for autonomous driving is now available in tractors and other agricultural equipment. It has enabled autonomous farming and decreased the demand for human labour.

Overview of data analytics:

Data analytics is the process of gathering data from various sources, securitizing the raw data, analyzing it, and drawing inferences that help in decision-making. The data is collected based on the hypothesis and objective of the study i.e. experimental data, observational data, reference data etc. Experimental data is collected by researchers through proper planning and conducting an experiment based on the objective of study. Generally, there are two type of experiments, one is absolute experiment in which researcher is interested to know the value of a particular characteristics and another is comparative experiments in which researcher is interested to compare the characteristics under study. Comparison between the yields of two varieties of a crop in an experiment is an example of comparative experiments. However, observational data is collected by making observations. In other words, everything that can be heard or seen is noted. The majority of the data in surveys is almost certainly observational. The observational data can be obtained through remote sensing and conventional data collection methods like simple random sampling, stratified random sampling, multistage sampling, judgmental sampling etc. In sample surveys, data can be collected through various methods depending on the cost of survey and precision required i.e. direct personal interview, telephonic surveys, mail based surveys, questionnaire and schedule based surveys etc. While collecting data through surveys, a proper plan of work with supervision is crucial for getting quality data. Any carelessness at any stage will aid in more sampling error.

In conventional data collection methods, it is impractical to thoroughly survey the vast area for a number of different variables, whereas remote sensing (RS) technologies are perfectly capable of doing so. Remote sensing data has drawn the attention of researchers over the years for the acquisition of information about an object without making physical contact with the object. Precision agriculture and remote sensing are thus developing day by day as they are more efficient and eco-friendly. Advancements in remote sensing data acquisition, processing, and interpretation of ground-based, airborne, and satellite observations has made it feasible to integrate remote sensing technologies with precision crop management systems (Waheed *et al.*, 2006). There are numerous types of satellite data depending upon spatial resolution (ranging from meter to kilometres), technique (active/passive, radiometer/scatterometer), spectral range, and viewing geometry (Oza *et al.*, 2008). Once data is collected, it is cleaned to ensure that there is no mistake and redundancy in data. It will help to fix the problem before data is processed for data analysis. The basic steps in cleaning of data includes removal of duplicate observations, fix structural errors, outlier detection, missing data handling and validation. However, the steps in this process cannot be outlined in a single, unambiguous manner because the procedures will differ from dataset to dataset (Fig. 3).

Figure 3: **Flowchart of Data Analytics**

The cleaned data is then subjected to appropriate statistical analysis to draw valid conclusion about the population. The broad objective of data analysis is to look into variation in the population and the factors that contribute to it. The analysis and simplification of remote sensing data frequently involves the use of specialized methods like geostatistics, image analysis, artificial intelligence (Liaghat and Balasundram, 2010). However, Remote Sensing cannot capture all types of agricultural information. Furthermore, the information gleaned from remote sensing data is more insightful when combined with ground data. The final step in data analysis is to interpret the findings to determine how well the data answered the research question and what recommendations are made in light of the data in decision-making.

Data analytics in smart agriculture:

Data analytics plays a crucial role in smart agriculture, which refers to the use of technology to enhance and optimize agricultural practices. By leveraging data analytics tools and techniques, farmers and agribusinesses can gain valuable insights into their operations and make data-driven decisions to improve yields, reduce costs, and increase efficiency. Here are some ways data analytics can be applied in smart agriculture:

- **Predictive analytics:** Farmers can use data analytics to forecast crop yields, weather patterns, and pest infestations. By analysing historical data and real-time sensor data, farmers can make more accurate predictions and take pre-emptive actions to prevent crop loss.
- **Precision farming:** Precision farming involves using data analytics to optimize crop production by tailoring farming practices to specific areas of the farm. By analysing soil and moisture data, farmers can adjust irrigation, fertilizer application, and seed planting to maximize crop yields and minimize waste.
- **Livestock management:** Livestock farmers can use data analytics to monitor animal health and behaviour, as well as track feed consumption and growth rates. This information can help farmers make more informed decisions about breeding, feeding, and veterinary care.
- **Supply chain management:** Data analytics can be used to optimize the supply chain in agriculture, from seed production to distribution. By analysing data on demand, transportation, and inventory levels, agribusinesses can minimize waste and ensure timely delivery of products.

Overall, data analytics can help farmers and agribusinesses make more informed decisions, optimize production, and reduce costs. As technology continues to advance, the role of data analytics in smart agriculture is likely to become even more important. Data analytics is a rapidly evolving field that encompasses a wide range of methods and techniques for processing, analysing, and interpreting data. In recent years, there have been several trends that have emerged in data analytics, each of which has the potential to transform the way organizations approach data-driven decision-making. One major trend in data analytics is the increasing use of machine learning and artificial intelligence (AI) techniques. These methods enable organizations to analyse vast amounts of data and extract insights that might otherwise be difficult or impossible to identify. Machine learning algorithms can be trained to recognize patterns and anomalies in data, making it possible to automate many aspects of data analysis and decision-making. Another trend in data analytics is the growing importance of data visualization. Data visualization tools enable organizations to present complex data sets in a more intuitive and easily digestible format, making it easier for decision-makers to identify trends and patterns. Visualization tools can also be used to explore data in new ways, uncovering insights that might have been missed using traditional methods. Another emerging trend in data analytics is the use of big data technologies. Big data technologies are designed to handle large volumes of data, typically measured in petabytes or even exabytes. These technologies include distributed file systems, such as Hadoop and Spark, as well as data processing and storage tools such as NoSQL databases. Finally, there is an increasing focus on the ethical use of data analytics.

As organizations collect and analyse more data, there are growing concerns about privacy, security, and the potential misuse of data. As a result, many organizations are developing ethical frameworks and guidelines for the use of data analytics, with the goal of ensuring that data is used in a responsible and transparent manner. Overall, these trends are transforming the field of data analytics, enabling organizations to make more informed and data-driven decisions than ever before. As data analytics continues to evolve, it is likely that we will see further innovations and developments that will further enhance our ability to extract insights from data.

The escalation in global population has heightened the imperative for the adoption of intelligent agricultural practices. This makes food security a primary concern for most countries, along with the loss of natural resources, the lack of arable land, and the growth in weather unpredictability. The Internet of Things (IoT) and data analytics (DA) are employed in the agriculture business to increase operational effectiveness and production. The usage of IoT and DA is replacing the use of wireless sensor networks (WSN) as one of the main drivers of smart agriculture. The Internet of Things (IoT) merges a number of already-existing technologies, including cloud computing, radio frequency identification, middleware systems, and end-user applications. Elijah *et al.* (2018) have highlighted several benefits and challenges of IoT. They have presented the IoT ecosystem and depicted the of IoT and DA enabling smart agriculture. They have also highlighted future trends and the opportunities of IoT and DA. The most current developments are covered in-depth in a report by Sinha and Dhanalakshmi (2022). Their survey's objective is to assist prospective researchers in identifying pertinent IoT issues and choosing the best solutions depending on the application needs. They have also emphasised the importance of data analytics and the Internet of Things.

The three primary pillars of smart agriculture consist of research, innovation, and space technologies, which are considered fundamental for national development. Space technologies play a crucial role in enhancing soil quality, reducing water waste in irrigation, and providing farmers with valuable agricultural knowledge. Geospatial data collected from various sources, including terrestrial, aquatic, and aerial sensors, satellites, and surveillance tools, is extensively analyzed and utilized for smart farming and crop protection. Innovations in technology include the integration of drones in agriculture, precise gene editing in plants, epigenetics, big data, the Internet of Things (IoT), efficient utilization of renewable energy sources like smart wind and solar energy, as well as the application of artificial intelligence in robotics and large-scale desalination technology. Many of these innovations are already being implemented in industrialized countries. However, the adoption of digital farming in rural areas will be particularly beneficial for emerging economies, as agriculture plays a significant role in their development. With an estimated 85% of the world's population projected to reside in developing nations by 2030, these countries require data-driven technological advancements to boost their GDP and ensure food security for their populations. Researchers, such as Goel *et al.* (2021) and Ramya *et al.* (2015), have explored the use of data and analytics to predict and mitigate the impacts of extreme weather events on global finance and address the economic dimensions of climate change, including the challenge of global food insecurity caused by climate change. They have also developed improved automated prediction methods and scalable meteorological data analysis and forecasting systems using frameworks such as Hadoop.

Real-time estimates:

Real-time estimates refer to estimates or predictions that are updated and provided in real-time, meaning they are available instantly or with very little delay. Real-time estimates are useful in many contexts, such as in finance, weather forecasting, traffic management, and industrial processes. Real-time estimates are made possible through the use of advanced technologies such as sensors, machine learning algorithms, and data analytics. These technologies enable the collection and analysis of large amounts of data in real-time, allowing for quick and accurate predictions. Real-time estimates are particularly valuable in situations where timely decision-making is critical, such as in emergency response scenarios or in financial trading. They can also help businesses and organizations optimize their operations, reduce costs, and improve efficiency. Overall, real-time estimates are an important tool for decision-makers in a wide range of industries, enabling them to make informed decisions based on up-to-date information. Real-time estimates in agriculture can refer to the use of various technologies and techniques to gather and analyse data in real-time to improve farming efficiency and productivity. Some examples of real-time estimates in agriculture include:

- **Weather and climate monitoring:** Real-time weather and climate data can be used to help farmers make decisions about planting, irrigation, and harvesting. This can be done through various sensors and weather stations that collect data and provide real-time updates to farmers.
- **Soil monitoring:** Real-time soil monitoring can help farmers understand soil health and nutrient levels, allowing them to make informed decisions about fertilization and other farming practices.
- **Crop monitoring:** Crop monitoring can involve the use of drones, satellites, or other sensors to provide real-time information about crop health, growth, and yield. This can help farmers identify problems early on and take corrective action before it's too late.
- **Livestock monitoring:** Real-time monitoring of livestock can help farmers keep track of animal health and behaviour, allowing them to identify potential problems and take action before they become more serious.

Overall, real-time estimates in agriculture can help farmers make more informed decisions, reduce waste, and increase productivity, ultimately leading to more sustainable and profitable farming practices.

1. Generation of real time crop yield estimates:

Real-time crop yield estimates in agriculture can be achieved through the use of various technologies such as satellite imagery, drones, and sensors. These technologies can collect data on various factors that affect crop growth and development, such as soil moisture, temperature, and nutrient levels. This data can be used to estimate crop yields in real-time. One approach to real-time crop yield estimation is to use machine learning algorithms to analysed the data collected by these technologies. Machine learning algorithms can use historical data to make predictions about future crop yields based on the current environmental conditions. For example, if the soil moisture and nutrient levels are optimal, and the temperature is within a certain range, the algorithm may predict a higher crop yield. Another approach is to use sensors and other devices to directly measure the growth and development of crops. For example, a sensor may be used to measure the height of corn plants, which can be used to estimate the yield of the crop. This data can be collected and analysed in real-time to provide an estimate of the crop yield. Real-time crop yield estimation has the potential to revolutionize agriculture by allowing farmers to make more informed decisions about planting, fertilizing, and harvesting crops. By providing accurate and timely information on crop yields, farmers can optimize their production and reduce waste, ultimately leading to higher profits and more sustainable farming practices. A hypothetical work flow process involved in crop yield monitoring process in smart agriculture has been elucidated in Fig. 4.

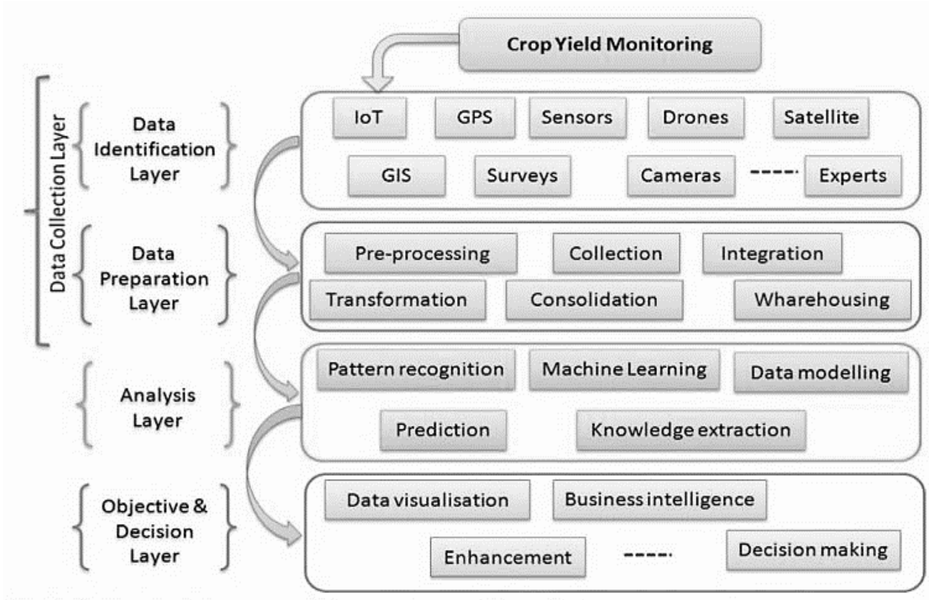

Figure 4: Process Flow of Crop Yield Monitoring in Smart Agriculture
(Source: Chergui and Kechadi, 2022)

2. Real time soil monitoring:

Real-time soil monitoring is a process of collecting and analysing soil data in real-time using various technologies and sensors. Real-time soil monitoring systems can provide farmers with up-to-the-minute information about soil health, moisture levels, nutrient levels, and other soil characteristics, allowing them to make informed decisions about fertilization, irrigation, and other farming practices.

Some examples of technologies used for real-time soil monitoring include:

- **Soil sensors**: Soil sensors can be placed in the field to measure soil moisture, temperature, and other characteristics. This information can be transmitted in real-time to a central system for analysis.
- **Wireless networks:** Wireless networks can be used to transmit data from soil sensors and other monitoring systems to a central system for analysis.
- **Satellite imagery:** Satellite imagery can be used to monitor changes in soil moisture levels and other characteristics over time, providing farmers with valuable insights into soil health and fertility.
- **Automated irrigation systems:** Automated irrigation systems can be programmed to deliver water based on real-time soil moisture data, ensuring that crops receive the optimal amount of water without wasting resources.

Overall, real-time soil monitoring can help farmers optimize their use of resources, improve crop yields, and reduce environmental impact. By providing farmers with real-time data and insights, real-time soil monitoring can help farmers make more informed decisions about fertilization, irrigation, and other practices, leading to more sustainable and profitable farming practices.

3. Real time livestock monitoring:

Real-time livestock monitoring is a process of collecting and analyzing data on livestock behavior and health in real-time using various technologies and sensors. Real-time monitoring can help farmers identify potential health problems, track animal behavior, and improve overall livestock management.

Some examples of technologies used for real-time livestock monitoring include:

- **Sensors:** Sensors can be attached to livestock to monitor vital signs such as heart rate, body temperature, and activity levels. This information can be transmitted wirelessly to a central system for analysis.
- **RFID tags:** RFID tags can be used to track livestock movements and monitor feed intake. This information can be used to identify potential health problems and improve feeding and management practices.
- **Cameras:** Cameras can be used to monitor livestock behaviour and detect signs of distress or illness. This information can be transmitted to a central system for analysis.

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- **Wearable technology:** Wearable technology such as GPS trackers can be used to monitor livestock movements and detect unusual behaviour or signs of stress.

Real-time livestock monitoring can help farmers detect potential health problems early, improve feeding and management practices, and optimize livestock production. By providing farmers with real-time data and insights, real-time livestock monitoring can help farmers make more informed decisions about animal health and welfare, leading to more sustainable and profitable farming practices.

4. Real time weather monitoring:

Real-time weather and climate monitoring is a process of collecting and analysing weather and climate data in real-time using various technologies and sensors. Real-time monitoring can help farmers make informed decisions about planting, irrigation, and harvesting, as well as help scientists study weather and climate patterns over time.

Some examples of technologies used for real-time weather and climate monitoring include:

- **Weather stations:** Weather stations can be used to collect data on temperature, humidity, wind speed, and other weather parameters. This information can be transmitted wirelessly to a central system for analysis.
- **Satellites:** Satellites can be used to monitor weather patterns over large areas, providing real-time data on cloud cover, precipitation, and other weather parameters.
- **Doppler radar:** Doppler radar can be used to detect and track severe weather events such as thunderstorms and tornadoes, allowing farmers and emergency responders to take timely action.
- **Climate models:** Climate models can be used to simulate and predict future weather patterns based on historical data and current trends.

Real-time weather and climate monitoring can help farmers make more informed decisions about planting, irrigation, and other practices, leading to more sustainable and efficient farming practices. By providing scientists with real-time data and insights, real-time weather and climate monitoring can also help improve our understanding of weather and climate patterns over time, leading to better predictions and preparation for future weather events

Challenges of data collection & analysis:

Smart Agriculture arose as a result of the democratization of digital devices, as well as advancements in artificial intelligence and data science. Smart agriculture pioneered innovative methods for increasing farm productivity and efficiency while respecting the environment. Recent and sophisticated digital technologies and data science have enabled the collection and analysis of huge amounts of agricultural datasets to assist farmers, agronomists, and professionals in understanding and making better judgments about farming activities.

1. Data collection:

Data collection is the process of gathering data for decision-making, strategic planning, research, and other purposes. It's a crucial part of data analytics and research projects. Effective data collection provides the information that's needed to answer questions, analyse performance or other outcomes, and predict future trends, actions, and scenarios. For research in science, Agricultural science, medicine, higher education and other fields, data collection is often a more specialized process, in which researchers create and implement measures to collect specific sets of data. In both the business and research contexts, though, the collected data must be accurate to ensure that analytics findings and research results are valid.

2. Data analysis:

Data analysis refers to the process of transforming, cleaning, and modelling raw data in order to extract useful insights and information from it. The goal of data analysis is to make sense of complex data sets, identify patterns and trends, and inform decision-making. Any organization may face a number of challenges in collecting consistent and quality data. To develop methods to improve data collection practices, it is necessary to first identify barriers to consistent data collection. Government departments, agencies and service providers with responsibility for data collection should consider these challenges and improvement opportunities as part of implementation planning.

3. Common challenges in data collection and analysis:

Some of the challenges often faced when collecting data include the following:

- **Poor data quality:** Raw data often contains errors, inconsistencies, and other issues that can impact its reliability. To address this, data profiling is commonly employed to identify and rectify problems in the acquired data. Without ensuring the quality and accuracy of the input data, the resulting analysis may not be trustworthy. This is particularly critical when the analysis is used to inform decision-making, as relying on flawed data can lead to serious negative consequences.
- **Collecting meaningful and real-time data:** It might be challenging to sift through all the data and find the insights that are most required. Decision-making can be significantly harmed by outdated data. Decision-makers can be sure that any decisions they make are based on complete and accurate information by using real-time reports and notifications.
- **Deciding what data to collect:** This is a crucial decision that must be made both for the initial collection of raw data and when users gather data for analytics apps. Unneeded data collection increases process time, expense, and complexity. The usefulness of a data set can be limited and analytics outcomes might be impacted by leaving out useful data.
- **Dealing with big data:** Big data settings frequently contain a mix of structured, unstructured, and semi-structured data in significant quantities. Because of this, the earliest stages of data collecting and processing are more difficult. Additionally, for particular

analytics applications, data scientists frequently need to filter collections of raw data stored in a data lake.

- **Low response:** Lack of responses or willing participants in research investigations calls into question the reliability of the information gathered.
- **Data volume:** It can be intimidating and challenging to manage a lot of data. To do this, it may be necessary to use specialised software and methods for handling, analysing, and interpreting data.
- **Data complexity:** Data can come in a variety of sorts, formats, and sources and be complicated and heterogeneous. Such data analysis may call for a variety of knowledge and abilities in data administration, statistical analysis, and machine learning.
- **Data privacy and security:** Data security and privacy are crucial considerations in data analysis. Access to sensitive information must be restricted to authorised individuals in order to maintain security.
- **Interpretation and communication:** Data analysis alone won't help; stakeholders also need to be adequately informed of insights. This necessitates the capacity to recognise essential facts and convey them in a direct and succinct manner.
- **Time and resource constraints**: It can take a lot of time and resources to analyse data. Organisations may experience staffing or financial limitations that prevent them from doing thorough analysis.
- **Bias and ethics:** Biases and ethical issues may affect data analysis. It is critical to be aware of these problems and take action to address them, such as making sure diverse representation is included in data gathering and analysis.
- **Data quantity:** It can be difficult to gather enough information to draw conclusions that are statistically significant. Sometimes there might not be enough data available, or gathering the data might be expensive or complicated.
- **Confusion or anxiety:** Even if they are aware of the advantages of automation, users may experience anxiety or confusion when migrating from conventional data processing techniques. Nobody likes change, especially when the current method of doing things is convenient and familiar to them.

Applications of data analytics in smart agriculture:

Smart farming encompasses the utilization of advanced agricultural technology to enhance and sustain production. It encompasses a range of technologies, including high-resolution satellite data, Global Positioning Systems (GPS), Geographic Information Systems (GIS), field sensors, Artificial Intelligence (AI), and automated machinery. Additionally, emerging technologies such as Unmanned Aerial Vehicles (UAVs), the Internet of Things (IoT), and cloud computing are anticipated to contribute to this progress, introducing a fusion of robotics, computer science, and IoT in farming practices. Big data holds promise as a potential technology for assessing and managing farm-level decisions, enabling the identification and rectification of inefficient practices to boost farm productivity. To address the challenges posed by increasing food demand and climate change, policymakers and industry leaders are turning to technological advancements such as IoT, big data, analytics, and cloud computing for support. Data analytics can be applied to many aspects of smart agriculture to improve the efficiency, productivity, and sustainability of farming practices. Here are some applications of data analytics in smart agriculture

- **Crop management:** Data analytics can be used to monitor crop growth, identify potential issues such as nutrient deficiencies or disease outbreaks, and optimize irrigation and fertilization practices.
- **Precision agriculture:** Precision agriculture involves using data analytics to tailor farming practices to individual plants or small areas of land, based on data such as soil moisture, temperature, and nutrient levels. This can help optimize yields while minimizing waste.
- **Livestock management:** Data analytics can be used to monitor the health and behaviour of livestock, predict potential health issues, and optimize feeding and breeding practices.
- **Supply chain management:** Data analytics can be used to track and optimize the supply chain for agricultural products, from farm to table. This can help improve efficiency, reduce waste, and ensure product safety and quality.
- **Weather forecasting:** Accurate weather forecasting is essential for effective agricultural planning and management. Data analytics can be used to analyze weather data and provide more accurate and timely forecasts.
- **Soil analysis:** Data analytics can be used to analyze soil samples and provide insights into soil quality, nutrient levels, and potential contaminants. This can help farmers make more informed decisions about fertilization and land management practices.
- **Pest control:** Data analytics can be used to monitor pest populations and predict potential outbreaks, allowing farmers to take proactive measures to prevent crop damage.

Overall, data analytics has the potential to revolutionize agriculture by providing farmers with the tools they need to make informed decisions, optimize their practices, and improve their yields and profitability.

Opportunities and future prospects of data analytics in smart agriculture:

In the agriculture, the impact of data analytics has been so extensive that it is challenging to identify all of its implications and even more challenging to predict what changes this could bring. With the advancement in smart measurements and data analysis, it has become reliable to assess the trend in agricultural related data and to forecast production, demand/supply in agricultural systems. Incorporating data analytics is instrumental in estimating production levels, resource usage, and the environmental impact within agricultural systems. It also plays a pivotal role in gauging the disparity between agricultural production and consumption, a critical factor in making decisions to ensure food security. It gives real-time insights into production, demand and supply of agricultural commodities by integrating information and technologies. As a result, data science, remote sensing data, machine learning and big data analytics are becoming increasingly promising in agriculture. Remote sensing technology, which involves using satellites and other sensors to gather information about the Earth's surface, can provide valuable data on crop health and growth patterns. This data can be combined with machine learning algorithms to predict crop yields, detect nutrient deficiencies or disease outbreaks, and make more informed decisions about crop management. A representation of the Data management workflow is mentioned in Figure 5.

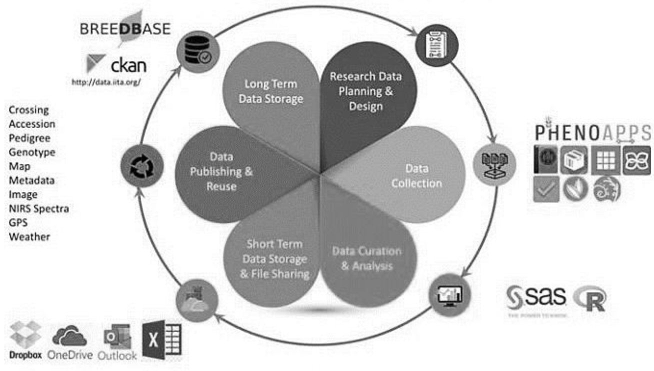

Figure 5: Data management Workflow in Smart Agriculture
(Source: Agbona *et al.*, 2022)

Conclusion:

Data analytics can help in increasing the production in the future by combining the time series data of previous and current years and can extract insights of data using appropriate algorithms. Data analytics also aids farmers in better comprehending environmental trends and consequently they can better plan for challenges and embrace opportunities without wasting resources. Before the advent of data analytics, farmers were unable to predict the early warning signs of failing crops; as a result, it was too late to take any action. Scientists can use data analytics to look for disease indicators in plants and predict future harvests to determine if crops are at risk from illness. Future agriculture will be heavily reliant on technologies like robotics, sensors, aerial photography, and GPS. Robotic systems, modern machinery and precision agriculture will make agriculture more effective, safe, and environmentally friendly.

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PULSES CONTRIBUTION TO FOOD AND NUTRITIONAL SECURITY IN INDIA

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Abstract:

Pulses are a vital protein source for India's largely vegetarian population. Although India is the world's largest pulse cultivator, it contributes only 6-7% to total food grain production. Pulses have the unique ability to fix atmospheric nitrogen, reducing their nitrogen needs. In India, pulses, often called "the poor man's meat" due to their protein content, hold a unique position. India has the highest number of malnourished individuals globally, and pulses have suffered due to the dominance of cereals. Pulses play a significant role in the agricultural systems of many developing nations in Asia, Africa, and Latin America. In South Asia, they cover 15% of cultivated land and are primarily grown on less fertile and marginal plots alongside cereals and oilseeds. Primarily India, contributes 90% of the world's pulse production, accounting for 24% globally. Notably, pulses are environmentally beneficial due to their nitrogen-fixing properties and are vital for ensuring food and nutrition security, especially for low-income populations. Agricultural policies are crucial in addressing nutritional challenges and potential solutions.

Keywords: Pulses, food security, nutrition, production

Introduction:

Food security means every individual has the physical, economic, and social means to access safe and nutritionally rich food that aligns with their dietary preferences, promoting an active and healthy life (FAO, 2001). Pulses are a vital global food crop, renowned for their high protein content. With protein levels averaging around 20 to 25 per cent, pulses surpass cereals, which typically contain 5 to 10 per cent protein (Singh, 2017). Moreover, pulses encompass a rich array of essential nutrients, including calcium, iron, and lysine, bolstering the body's defenses against vitamin and mineral deficiencies as well as diseases. This significance extends from the consumer's plate to the production system. Pulses, despite occupying only 10 to 15 per cent of arable land area, wield substantial influence on the value of agricultural production due to their premium prices. They play a pivotal role in diverse cuisines globally, from Mediterranean hummus to English baked beans and South Asian dal. In many nations, pulses are deeply embedded in cultural heritage. For instance, in Nepal, *Kwati*, a soup composed of nine pulse varieties, takes center stage during major festivals and plays a crucial role in the diets of expectant mothers. In South Asia, over 80% of pulse production is used for food consumption, while in developed countries, food use is less than 40%. Pulses are consumed in various forms such as dal, soup, snacks, and sweets. The demand for processed pulse foods has been rising due to urbanization, lifestyle changes, and an increase in two-earner households. Per capita pulse availability has increased in India, Nepal, and Sri Lanka since the mid-2000s, with a marginal decline in Bangladesh and Pakistan (Pingali and Rao, 2017). In India, per capita availability increased from 13 kg/person/annum in 1990 to 19.3 kg/person/annum in 2017, despite a historical decline in availability (Rao, 2019). Pulses exclude crops harvested while still green, like green peas or beans used mainly for oil extraction or sowing purposes. They serve as a crucial protein source, particularly for vegetarians and individuals with limited access to meat, fish, or dairy. Even for meat-eaters, pulses offer a healthier option, aiding in reducing dietary fat intake while maintaining zero cholesterol. Additionally, they provide dietary fiber, and a plethora of vitamins and minerals, including iron and zinc. Pound for pound, pulses offer a highly economical protein source when compared to meats or other alternatives. The nitrogen-fixing capabilities of pulses enhance soil fertility, thereby boosting and extending farmland productivity. In many regions, farmers employ the practice of intercropping, planting legumes alongside other crops, to enhance yields and foster soil biodiversity.

India holds the largest share in pulse production (25%), acreage (33%), and consumption (27%). In the 2014-15 period, India produced approximately 17 million tons of pulses, and an additional 4-5 million tons were imported to meet domestic demand (Verma *et al.*, 2019). However, the following year, 2015-16, witnessed a slight decline in indigenous pulse production, leading to higher prices and restricted availability. This deficit highlighted the importance of pulses in Indian agriculture. To address these challenges, various technological and policy interventions were implemented. These included establishing 150 seed hubs and 12 breeder seed production centers, raising the minimum support price (MSP) for pulses, ensuring procurement at MSP, and maintaining buffer stocks to control market prices. These interventions resulted in a remarkable increase in pulse production, reaching 22.95 million tons in 2016-17 and 25.23 million tons in 2017-18 (Singh and Praharaj, 2018). Pulse cultivation in India is cost-effective and resource-efficient, particularly when compared to animal protein. They are protein-rich, budget-friendly, and can be intercropped with other crops. Pulses are primarily rainfed, reducing the need for intensive irrigation. They thrive in areas left after fulfilling cereal or cash crop demands, offering good returns. Additionally, pulses enhance soil quality, fit well in mixed cropping systems, support crop rotations and dry farming, and provide green pods for vegetables and nutritious cattle fodder.

Pulses are an affordable source of protein and essential minerals

In many nations, the cost of meat, dairy, and fish is relatively high, placing them beyond the financial means of a significant portion of the population, particularly those with limited economic resources. Consequently, these communities rely heavily on plant-based foods to fulfil their protein requirements as shown in Table 1. The insufficiency of both the quantity and quality of protein and energy often leads to malnutrition issues, such as stunting and wasting.

Furthermore, iron deficiency is a prevalent micronutrient deficiency worldwide, particularly among individuals lacking access to well-rounded diets (Oppenheimer, 2001). These challenges are further exacerbated as the global population is rapidly expanding, necessitating a corresponding increase in agricultural production to meet the escalating demand for food. However, this heightened agricultural production must be sustainable to address environmental concerns. Pulses play a crucial role in this context. They can be cultivated as cash crops, meant for sale in markets, or grown as a source of food for smallholder farming communities, either alone or in rotation with other crops. Pulses serve as a vital and affordable source of protein, especially for smallholder farmers who consume a portion of their agricultural yield. Remarkably, the protein derived from pulses is notably more cost-effective in comparison to animal-based foods. In some regions, pulse-based protein costs considerably less than protein from milk. Additionally, the absorption of iron from pulses and the overall protein quality in the diet is enhanced when pulses are consumed alongside cereals and foods rich in vitamin C (Fidler *et al.*, 2004).

Table 1: Protein, fibre range and dietary fibre in the seed of some pulses (Ofuya and Akhidu, 2005)

Pulse crop	Protein (%) range (average)	Total fibre range (%)	Dietary fibre (%)
Chickpea (*Cicer arietinum* L.)	19.1-31.2 (22.2)	60.1-61.2	25.6
Pigeonpea (*Cajanus cajan* (L.) Millsp.)	17.9-31.0 (21.0)	57.3-58.7	15.0
Mungbean (*Vigna radiata* (L.) R. Wilczek)	24.5	53.3-58.7	15.2
Urdbean (*Vigna mungo* (L.) Hepper)	24.0	-	-
Lentil (*Lens culinaris* Medikus)	25.1	-	11.7
Cowpea (*Vigna unguiculata* (L.) Walp.)	20.0-34.2 (24.0)	-	-
Frenchbean (*Phaseolus vulgaris* L.)	15.2-36.1 (23.9)	56.3-60.5	25.4
Pea (*Pisum sativum* L.)	14.2-36.1 (23.1)	-	16.7

Minimizing food wastage footprint

Food waste stands as a primary challenge in the realm of food security. Alarmingly, approximately one-third of the food produced for human consumption on a global scale is either lost or wasted (FAO, 2013). These losses and wastages permeate the entire agricultural supply chain. In developing nations, the majority of losses occur during production and transportation, while in more developed countries, a significant portion of food is squandered during the consumption phase (Gustavsson *et al.*, 2010). Pulses offer a promising solution in the context of reducing food waste and promoting household food security. Their shelf-stable nature means that they are highly resilient to spoilage, resulting in minimal food waste at the consumption stage. This quality makes pulses a compelling choice to help ensure the availability of food within households.

Suitability of certain pulses for marginal areas

Certain pulses exhibit remarkable resilience to drought conditions, making them well-suited for cultivation in arid regions with limited and often unpredictable annual rainfall ranging from 300 to 450 mm. These are areas where other crops may struggle or yield meagre harvests. Additionally, drought-resistant pulse varieties, particularly those with deep root systems like pigeon peas, offer the dual benefit of enhancing food security and nutrition for farmers in these challenging environments while also contributing to groundwater availability for companion crops when employed in intercropping systems (Sekiya and Yano, 2004). For individuals residing in dry regions, where achieving food security remains a significant challenge, the sustainable intensification of their agricultural systems is attainable through the cultivation of locally adapted drought-resistant pulses. Nevertheless, the realization of this potential relies on the implementation of well-structured policies and programs. These initiatives should not only promote the marketing of pulses within local trade systems but also encourage the adoption of modern consumption patterns to boost both the production and consumption of these invaluable drought-resistant pulses.

Extended shelf life of pulses

When adequately stored, pulses maintain their edibility for multiple years. Farmers have acquired the knowledge of preserving pulse seeds with low moisture content in dry storage locations while discarding those seeds that may have fallen victim to insect infestations or spoilage. Furthermore, pulses demonstrate orthodox seed storage behaviour, signifying their ability to germinate even after prolonged storage. In certain scenarios, farmers can preserve their pulse stocks and subsequently use them for planting in upcoming cropping seasons.

Approaches to guarantee optimal fertilizer utilization in the cultivation of pulses:

1) Subsidized supply of DAP and SSP at sowing time to meet the high phosphorus requirement.
2) Apply 15-20 kg N and 40 kg P_2O_5 per hectare at sowing.
3) Use phosphorus fertilizer for the first and second crops in a cropping system, reserving the third (pulse) crop for its residual effect
4) Apply 20 kg K_2O per hectare along with NP in K-deficient areas.
5) Use sulfur-containing sources like SSP, gypsum, or ammonium sulfate as basal or before planting for higher sulfur use efficiency.
6) Apply 20 kg S per hectare in addition to the recommended dose of NP at sowing.
7) Integrate FYM/compost/biogas slurry at 2.5 tonnes per hectare with 50% recommended fertilizer dose and Rhizobium inoculation to save 50% of chemical fertilizers, especially in low-fertility and paddy soils.
8) Inoculate seeds with a mixture of gur, gum arabica, and culture for Rhizobium inoculation, then dry them before sowing.
9) In acid soils, treat Rhizobium-inoculated seeds with finely powdered lime ($CaCO_3$) for 5 minutes to make uniform pellets.

10) Use micro-nutrients (Zn, B, Mo, and Fe) to improve productivity and address specific deficiencies.
11) Apply a foliar spray of $ZnSO_4$ with lime for Zn deficiency, sodium molybdate for Mo deficiency and B or borax for boron deficiency.
12) Apply 1% $FeSO_4$ for iron deficiency.
13) Lime acid soils before pulse cultivation.
14) Provide two post-sowing irrigations (at branching and flowering) to enhance fertilizer utilization.
15) Ensure effective weed control, especially between 4 to 6 weeks after sowing, to prevent yield reduction in pulse crops.

Major research achievements in pulses within the National Agricultural Research System have focused on developing short-duration, high-yielding, insect-pest and disease-resistant varieties that are compatible with different climates. Over 500 such varieties have been developed, released, and notified at the central and state levels for various agro ecological regions. Notable short-duration varieties have been developed in various pulse crops, including:

Chickpea: Pusa 372, JG 11, Pusa 547, Vijay, Rajas, KPG 59, IPC 2006-77, JSC 55, JSC 56, KAK 2, Shubhra, Ujjawal, and JGK1.

Lentil: HUL 57, Moitree, IPL 81, IPL 316, and JL 3.

Pigeon pea: UPAS 120 and Pusa 992.

Fieldpea: Adarsh, Ambika, DDR 23, Prakash, Vikas, IPFD 10-12, and more.

Green gram: Samrat, IPM 2-3, IPM 2-14, Virat, Kanika, HUM 16, and others.

Black gram: Pant U 35, Shekhar 2, and Azad Urid 3.

Additionally, there are extra-large seeded kabuli chickpea varieties like MNK 1, PKV Kabuli 4-1, and Phule G 0512, large-seeded lentil variety IPL 406, green-seeded field pea variety IPFD 10-12, green-seeded black gram varieties Shekhar 1 and Shekhar 2, and machine-harvestable chickpea varieties like HC 5, NBeG 47, and GBM 2. These developments aim to increase farmers' income and cater to market demand.

Niches for pulses expansion in India

Bringing a pulses revolution to eastern India: The vast availability of natural resources and fertile lands offer ample scope to promote pulses cultivation in eastern India, the selection of crops and varieties is likely to play a major role in realizing a pulses revolution in this region.

Bringing additional area under pulses through intercropping and sequential cropping: Possible to have a pigeon pea-wheat crop rotation, which is very much required for diversifying cereal-based cropping systems in northern India

Enhancing pulses cultivation in peninsular India: Short duration and diseases resistant varieties along with matching production technologies with mungbean and urdbean production if appropriately sown after harvest of paddy in *rabi* season

Pulses in organic farming: Pulses have good potential to diversify cropping systems in organic farms

Pulse-based cropping systems in India

Pulses play a vital role in subsistence farming in India, being integrated into various major cropping systems across the country. Significant intercropping systems include pigeon pea with sorghum, groundnut, mung bean, urdbean, and cotton in the central and south zones. In the northwestern and north-eastern plain zones, pigeon pea is intercropped with maize or sorghum during the rainy season. During the post-rainy season, chickpea or lentil is intercropped with mustard, sunflower, or linseed in various zones. Peninsular India predominantly cultivates pigeon pea, mungbean, and urdbean, along with chickpea, soybean, horse gram, cowpea, and other arid legumes. Pigeon pea-wheat cropping systems are prevalent in northern India. Short-duration mungbean and urdbean varieties are grown as sole crops or intercropped with compatible crops during spring/summer seasons. For example, short-duration mungbean is followed by wheat in Punjab and parts of Haryana, while it is mixed with pearl millet or sesame during the rainy season in Rajasthan. In central India, chickpea is grown under rainfed conditions, either as a mono-crop or intercropped with linseed and safflower. Various intercropping systems involving pulses, oilseeds, and millets are popular in this region. There is significant potential to expand pulse cultivation in rice fallow areas across the peninsular region. Similarly, promoting summer cultivation of mungbean in wheat-based cropping systems in northern India can enhance pulse production. To sustain and improve crop productivity and soil health, pulses should be integrated into rice-based cropping systems in different rice-growing areas, including delta regions of major rivers like Krishna, Kaveri, and Godavari.

Strategies for value addition and pulse processing

Modern value chains exhibit characteristics like vertical coordination, supply base consolidation, agro-industrial processing, and the implementation of standards across the chain. Each value chain is distinct, comprising a unique combination of links. Figure 1 illustrates the essential links in the generic pulse value chain in South Asia. Farmers, the initial producers of pulses, typically sell their produce to cooperatives, local traders, or processing companies. Ultimately, the pulses reach consumers. The primary actors in this process are the various market players. However, there are other significant participants, such as shops, which supply fertilizers and agrochemical inputs for pulse production.

a) Create a comprehensive catalogue of value addition and processing technologies from various research institutes and publish them in vernacular languages for wider dissemination.
b) Develop cost-effective dal supplements/substitutes to reduce pressure on pulse production.
c) Promote export-oriented crop cultivation and milling, focusing on diversification and modernization of post-harvest technology. Highlight varieties with export potential.
d) Establish cost-effective processing plants at key pulse production areas to ease transportation for farmers.
e) Offer human resource development programs on scientific storage and food preservation for value addition.

f) Ensure accessibility to affordable containers and chemicals for processing, potentially exploring cost-effective import options.

g) Provide incentives and support for pulse farmers, including the formation of Self Help Groups (SHGs) in potential pulse regions.

h) Enhance farmer's knowledge of modern pulse production techniques and promote technology transfer.

i) Encourage both traditional and high-tech, environmentally friendly processing methods.

j) Enforce high hygienic standards in the food processing industry.

k) Improve coordination between State Departments of Agriculture, marketing, mandi boards, and the Food Ministry at the state level to enable small farmers to process their produce locally.

l) Provide storage bins and post-harvest equipment to pulse growers to enhance the durability of their produce and support value-added by-products.

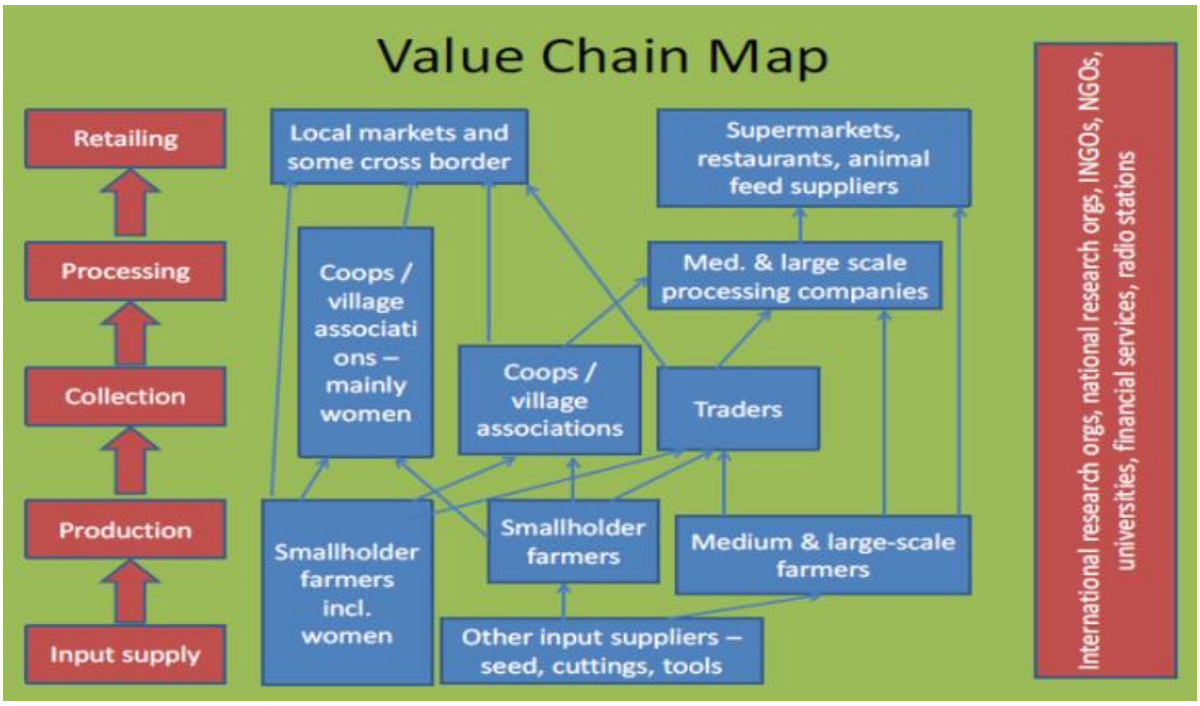

Figure 1: Generic Pulses Value chain links (Cuddeford, 2014)

Scientific guidelines for improving pulse production (Joshi and Rao, 2016)

1. *Advance Yield Enhancement in Emerging Nations*: Focus on increasing pulse yields in developing countries through innovative agricultural practices.

2. *Boost Research Funding for Biotic and Abiotic Challenges*: Allocate increased research funding to address both biotic and abiotic constraints affecting pulse production.

3. *Promote Short-Duration Varieties Complementing Current Cropping Strategies*: Encourage the adoption of suitable short-duration pulse varieties that align with existing cropping patterns.

4. *Distribute Improved Cultivar Seeds*: Facilitate access to seeds from improved cultivars that have already been introduced and proven effective.

5. *Expand Pulse Farming to Untapped Regions*: Promote pulse cultivation in areas not traditionally farmed, such as fallow rice fields in regions like Bangladesh and India.
6. *Encourage Intercropping with Cereals and Oilseeds*: Advocate for the intercropping of pulse crops alongside cereals and oilseeds to enhance overall agricultural sustainability.
7. *Provide Incentives for Pulse Cultivation*: Implement incentives akin to those for cereal crops to stimulate pulse production.
8. *Incorporate Nutritional Security alongside Food Security*: Ensure that governmental strategies consider both nutritional security and food security in pulse production.
9. *Utilize Buffer stocking and Policy Measures*: Employ strategies like buffer stocking to mitigate the price volatility of pulses and other policy measures.
10. *Enhance Value Chain Processes and Products*: Improve processes and products within the pulse value chains, with a focus on catering to the requirements of urban consumers.
11. *Engage the Commercial Sector in Marketing Processed Pulse Products*: Encourage the commercial sector to actively participate in the marketing of processed pulse products, contributing to increased availability and consumption.

Future research prospects on pulses in India (Chaudhari and Jha, 2017)

The Indian Council of Agricultural Research (ICAR) has identified key research areas to enhance pulse crop production, disseminate advanced agricultural techniques, and achieve increased yields. These research thrusts include:

a. *Development of Short-Duration, Photo-Thermo-Insensitive Pulse Varieties*: Focus on creating pulse varieties with shorter growth durations that are less sensitive to photoperiod and temperature variations, tailored to diverse agro ecologies.
b. *Climate-Resilient Pulse Varieties*: Develop pulse varieties that exhibit resilience to climatic stressors such as high temperatures and winter drought conditions.
c. *Enhanced Plant Architecture in Major Pulse Crops*: Improve the structural attributes of major pulse crops like chickpea, pigeon pea, urdbean, mungbean, lentil, and field pea to optimize their adaptability to new ecological niches.
d. *Genetic Approaches for Pest Resistance*: Explore genetic methods, including intragenics, cisgenics, and transgenics, to combat pod borers in chickpea and pigeonpea, as well as Mungbean Yellow Mosaic Virus (MYMV) in mungbean and urdbean.
e. *Advancements in Agronomic Practices*: Develop and promote sound agronomic practices, encompassing raised bed/ridge planting systems, post-emergence weed management, efficient input utilization, and novel cropping systems.
f. *Resource Usage and Conservation Technology*: Develop technology for judicious resource usage and conservation, focusing on practices like conservation tillage, residue management, and efficient input utilization within conservation agriculture.
g. *Nutritional Enhancement and Promotion*: Improve the nutritional value of pulses through biofortification and promote them as healthy food choices to address dietary needs effectively.

Future demand for pulses

Given the population growth rate in India and evolving food preferences, pulses have become crucial for meeting the protein needs of the population and ensuring food and nutritional security. With the current consumption rates and anticipated growth in the future, it is projected that India will require 32 million tons of pulses by 2030 and 39 million tons by 2050. Achieving these targets demands an annual production capacity growth rate of 2.2%, necessitating significant advancements in research, technology generation, dissemination, commercialization, and capacity building. Taking into account land availability, population growth, and technological advancements, five-year projections have been established. These projections indicate that productivity needs to increase by an average of approximately 80 kg/ha over each previous five-year period to attain targeted productivity of 950 kg/ha by the end of 2025 and 1335 kg/ha by the end of 2050. These estimates are made with the assumption that it will be feasible to expand the pulse cultivation area by approximately 4 million hectares. To meet the anticipated demand of 32 million tonnes of pulses by the year 2030, as outlined in the Vision 2030 document developed by the Indian Institute of Pulses Research in Kanpur, it is imperative to achieve a growth rate of 4.2%. Much like the situation with cereals, there is substantial room for improvement in pulses productivity. However, achieving this improvement will necessitate a fundamental shift in various areas, including research, technology development, and the widespread adoption of advanced crop management practices. It also involves promoting the commercialization of pulses and enhancing the capabilities of key stakeholders in cutting-edge research areas. A pivotal aspect in boosting productivity will be the genetic enhancement of seeds to increase yield and improve quality.

Conclusion:

The demand for pulses is expected to grow by 2% annually due to population growth and direct demand increase, which is four times the past decade's domestic production growth. This imbalance led to stock depletion and reduced exports. To meet domestic demand, we must raise production or rely on imports. In the short term, imports can help, but long-term solutions require investment in irrigation, quality seeds, research, water, and infrastructure. Policy initiatives are crucial for maintaining the production-demand balance. Government support, increased MSP, and recent production growth have helped, but stabilizing market prices below MSP is needed for the area, production, and net return stability. Promoting sustainable agriculture is vital for food security and environmental preservation. It offers resource-poor farmers fair prices, rural development, nutritious food, and employment. To support these farmers, diverse pulse cultivation methods with nutrient management are essential. Policies should encourage short-duration pulse varieties as intercrops or in fallow areas and develop disease-resistant, nitrogen-fixing varieties. Farmer readiness for organic pulse production requires collaboration between research, extension services, and farmer engagement. Public awareness campaigns are crucial. Implementing crop-specific strategies, like intercropping after rice or maize, can boost pulse production. Subsidies, access to loans, and crop insurance can lower risks for farmers, promoting sustainable agriculture and better nutrient management for the nation.

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ENDOPHYIC FUNGI: A POTENTIAL SOURCE OF AGRICULTURE APPLICATION

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Abstract:

This chapter focuses on entophytic fungi, which directly enhance plant growth, as a relatively new area of study. Current rates of population growth require the development of new agricultural strategies to feed the world human and livestock. The widespread usage of agricultural pesticides has a negative impact on both human and animal health as well as the environment. Because of this, using endophytic fungus provides a biological option for boosting agricultural output in a long-term manner. Endophytic fungi that live in symbiotic relationship with their host plant can enhance plant growth and lessen the negative impacts of biotic and abiotic stressors. Growing access to nutrients, hormone production in plants, and faster water uptake are a few of the strategies that endophytic fungus uses to encourage plant growth.

Keywords: Endophytic fungi, Plant growth, Agriculture, Plant disease

Introduction

Agriculture production and global food security face significant difficulties. The world population is predicted to exceed 9 billion by 2050, necessitating a 70% increase in food production above current levels to ensure food security (FAO, 2023). Plant diseases reduce production both quantitatively and qualitatively, resulting in huge financial losses and, on occasion, catastrophic social effects (Bergamin Filho *et al.*, 2018; Savary *et al.*, 2019; Goss *et al.*, 2014; Yoshida *et al.*, 2013). Globally, plant illnesses can result in losses of up to 16% (Oerke, 2006), and studies have already shown that infections and, more specifically, conducted cultivations, can cause losses (Savary *et al.*, 2019; Ficke *et al.*, 2018). Scientific techniques to the study of plant-fungal interactions are becoming more popular in modern agriculture, with the goal of ensuring global food security and zero malnutrition (Sharma *et al*,. 2021). Biological techniques to address food demand pressure, food poverty, and future food shortages (Sahu and Mishra, 2021). Farmers have used various methods to increase food production since antiquity, including the use of agrochemicals, which are not sustainable owing to harmful effects on the environment (Glick *et al.*, 2001). The potential for pathogen-caused losses is undeniable, and their magnitude varies based on climatic variables, culture, and the aggressiveness of the causal agent (Ficke *et al.,* 2018).

According to this concept, reducing these threats to the ecosystem and investigating potential endophytic bacteria can aid in achieving a stable environment and growing pathogen-free plants for increased crop output (Akanmu *et al.*, 2021) Endophytic microbe research and investigation as bio inoculants have opened numerous potential as a substitute for synthetic pesticides in modern agricultural systems (Orozco-Mosqueda *et al.,* 2021). Nonetheless, information on endophytic fungi antibiosis activity via biocontrol agent synthesis can be studied in integrated plant disease management.

Literally, the endosphere refers to discrete areas within plant internal tissue, and endophytic bacteria are the microorganisms that live there (Dubey *et al.,* 2020). Most intriguingly, microbial endophytes form associations with host plants that are mutualistic or antagonistic depending on how genetically similar or different they are. Plant growth-promoting endophytes are the advantageous varieties with specific plant growth-promoting (PGP) characteristics, such as phytohormone synthesis, nutrition acquisition, secretion of BCAs, and stress induction mechanism (Adeleke *et al.,* 2021).

Endophytic fungi

Endophytic fungi are found in the interior tissues of nearly all living plants and play a role in the creation of a number of advantageous features. As a result, they are well known for promoting plant growth, improving fitness, and boosting resistance to a variety of abiotic and biotic challenges. Internal plant tissues of healthy root, stem, petiole, leaves, twigs, bark, fruit, flowers and seeds can be colonized by these endophytes (Park *et al.,* 2012; Sanz-Ros *et al.*, 2015; Verma *et al.,* 2011; Fouda *et al.*, 2015; Parsa *et al.,* 2016), without causing any apparent harm or pathogenic infection to their host plants. Given the prevalence of endophytes in practically all known plant species, fungal endophytes are one of the many components of biomass that are dynamically being transformed to adapt to ecological changes and host physiology (Aly *et al.*, 2011). Endophytic fungal species are thought to number over a million in total around the world and they constitute a huge genetic resource for biotechnology (Ganley *et al.,* 2004). The complex interactions that the fungal endophytes displayed with the host phytopathogens suggested that their efficacy was either brought about by the production of natural substances, secondary metabolites, or intermediates in the biosynthetic pathway of those metabolites, which were activated in response to pathogen attack (Pusztahelyi *et al.*, 2015). This demonstrates that these endophytes, in addition to the typical metabolites produced under normal/natural settings, are capable of creating a variety of mysterious compounds when triggered under certain selective interaction situations (Kumara *et al.,* 2014)

Endosymbiotic relationship of endophytic fungi

Depending on their colonization and release of biocontrol agents, endophytic fungi and their host plants were intended to contribute to plant development and disease control (Reshma *et* *al.*, 2019). The majority of endophytic microbiomes in the plant endosphere have been shown to affect how plants respond to environmental stimuli and regulate plant diseases (Yu *et al.*, 2019). The need to clarify how endophytic microorganisms can be manipulated in agricultural biotechnology for plant health sustainability and integration in crop breeding has been highlighted by recent studies (Zhang *et al.*, 2020). Some endophytic fungi living below ground can quickly change their morphology to become endophytes because of their close proximity to the root endosphere, depending on the position of the plant organ. The establishment of endophytic microbial communities has been demonstrated to be caused by the dynamic nature, colonization, and infiltration of endophytic fungi from the external root environment into the internal tissue of plants (Yan *et al.*, 2019). Depending on the genes they have that are engaged in metabolic pathways, endophytic bacteria either directly or indirectly promote plant growth and maintain plant health (Baghel *et al.*, 2020).

The ability of endophytic microorganisms to colonize plant tissues, create exopolysaccharide and hydrogen cyanide, and activate novel genes involved in secretion systems and secondary metabolite secretions are all factors that contribute to their biocontrol potential (Singh *et al.*, 2021). Research efforts toward utilizing endophytic fungi's bioactive secondary metabolites as biopesticides and incorporating them into plant disease control remain fundamental because endophytic fungi are underutilized in the control of plant diseases. This will help mitigate the effect of applying synthetic pesticides to plants on plant growth for improved crop production. Therefore, this review updated the special qualities of endophytic fungi and the processes requiring their functions in phytopathogen defense in plants.

Growth promotion of plants

Endophytic fungi that live in multiple plant compartments generally encourage plant growth through a variety of direct and indirect ways (Adeleke and Babalola, 2022). In the direct mechanism, endophytes control different plant hormones like cytokinin, ethylene, and auxins, improve soil nutrient availability, including siderophore production, phosphorus and iron solubilization, and nitrogen fixation. In the indirect mechanism, however, the endophytes protect the plants by secreting enzymes, antibiotics, hydrogen cyanide, and volatile compounds that inhibit the activities of pathogens and induce systemic resistance (Segaran and Sathiavelu, 2019). Plant growth, disease tolerance and management, and carbon sequestration are all improved by endophytic microorganisms (Wang *et al.*, 2022).

According to Suebrasri *et al.*, 2020, endophytic fungi including *Daldinia eschscholtzii, Diaporthe phaseolorum, Macrophomina phaseolina, Trichoderma koningii,* and *T. erinaceum* produce enzymes such as protease, xylanase, amylase, and cellulase and indole-3-acetic acid from Sunchocke and medicinal plants. It is intriguing to notice that *M. phaseolina*, a notorious plant disease, can be advantageous to plants, as a result, it may be investigated for additional plant advantageous activities. Numerous biotic and abiotic factors can have an impact on the microbial networking in the root endosphere areas (Adeleke and Babalola, 2021a). Less research has been done in phytopathogen management compared to studies on fungal isolation from plant settings that can support plant development and health (Bilal *et al.*, 2018).

Researchers have been able to determine the functional features of endophytes that colonize plant roots by examining the associations that exist among them (Vélez *et al.,* 2017). The rhizosphere is thought of as a subset of root endophytes since it is simple for them to colonize the area by infiltrating the plant roots from the external soil environment (Ghafari *et al.,* 2019). Numerous useful endophytes have been discovered in a variety of plant species under various climatic and geographic conditions with bioprospecting in agriculture (Jia *et al.,* 2016). They can be separated out and identified through direct observation or methods that depend on the culture. With the use of a light and electron microscope, direct observation allowed for the direct visualization of fungi in plant tissues, which reflected endophytic fungi and those that could not be cultivated on standard growth conditions (Nazir and Rahman, 2018).

Endophytic fungi colonize the interior of both monocotyledonous and dicotyledonous plants, aid in the development of resistance, and foster the growth of plants in a variety of different situations (Waqas *et al.,* 2012). Despite this, the majority of endophytes only colonize the root, creating a system that defends the plant's other sections (Adeleke *et al.,* 2021). The host plant's physical and chemical barriers actively favour induced resistance to plant pathogens, which is a preventive mechanism brought on by both abiotic and biotic causes (Wani *et al.,* 2016).

In order to activate an innate defense against future disease threats, these chemicals cause exchangeable signals in the host plant. Typically, certain drugs that promote particular gene expression, metabolic changes, and protein synthesis cause an induced response. The plant's metabolic rate and modification in the plant's suitability as a host have resulted in a decrease in disease levels (Latz *et al.,* 2018). As was already established, biotic and abiotic stimuli can both locally and systemically cause host responses. Priming is the term used to describe the process through which a plant's defenses against diseases are activated (Martinez-Medina *et al.,* 2016). The ability of cellular defensive responses against no self to be mobilized is most frequently associated with plant-induced resistance.

There are numerous ways to increase plant physiological immunity, but growth-stimulating organisms against stress may be the most crucial (Attia *et al.,* 2021; Aldinary *et al.,* 2021; Hashem *et al.,* 2022). Additionally, it has been noted that endophyte-derived molecules are potent biostimulants of growth, physiological immunity, and yield because they increase tolerance to environmental stress by activating the antioxidant system and enhance nutrient availability and uptake from the soil (Oleńska *et al.,* 2020; Hamid *et al.,* 2021; Ali *et al.,* 2022; Rakkammal *et al.,* 2022). Endophytes are microorganisms that naturally flourish within plants and create enhanced, growth-stimulating, and antibacterial substances (Iqbal and Ansari, 2020; Chaturvedi *et al.,* 2022; Sharaf *et al.,* 2022). By modifying osmolytes and enzyme activities, *Aspergillus* has been used as a biostimulant to improve the chlorophyll levels and morphological growth characteristics in a variety of stressed crops (Asaf *et al.,* 2018; Arif *et al.,* 2021).

Therefore, one of the most significant biological aspects in enhancing agricultural output was the use of endophytes to stimulate plants' artificial immunity (Adeleke and Babalola, 2021; Sturz *et al.*, 2000; Collinge *et al.*, 2019; Attia *et al.*, 2022). By improving plant health and fostering resistance, endophytic fungi can provide essential chemicals that mitigate the damaging effects of fungal disease (Attia *et al.*, 2022).

Table 1: Endophytic fungi applied for the growth promotion of plants

Endophyte	Host	Patent Application	Reference
Acremonium sp.	*Panax notoginseng*	Root and seed development of different plants including *Radix, Ginseng*, *Oryza sativa L.*, *Semen Maydis*, *Semen Tritici aestivi*, *Rhizoma Paridis*, Rhizoma	Du, 2016
Alternaria alternata	*Acanthopanax senticosus*	Seedling-stage growth	Wang *et al.*, 2018
Alternaria sp.	*Hippophae* sp.	Drought resistance on turf grass.	Zhao *et al.*, 2015
Alternaria sp.	*Aleurites montana*	Phosphorus uptake	Hong *et al.*, 2015
Alternaria tenuissima	*Panax ginseng*	Growth of corn plant.	Tao *et al.*, 2011
Aspergillus sp.	*Casuarina* sp. rhizosphere	Photosynthesis	Hong *et al.*, 2013
Aspergillus sp.	*Casuarina* sp. rhizosphere	Nutrient element absorption	Hong *et al.*, 2013
Aspergillus sp.	*Casuarina* sp. rhizosphere	Biomass growth.	Xie *et al.*, 2013
Botryosphaeria sp.	Root of *Schima superba*	Seedling height and ground diameter under a low-phosphorus environment.	Li *et al.*, 2019
Byssochlamys spectabilis	*Rhizoma bletillae*	Seedling growth	Li *et al.*, 2019
Cercosporella Sacc.	*Rumex gmelini* Turcz	Seedling growth	Ding *et al.*, 2017
Chaetomium globosum	*Salvia miltiorrhiza*	Radix root biomass, plant height, crown diameter	Zheng *et al.*, 2017
Chaetomium nigricolor	*Bletilla striata*	Seedling growth.	Huang *et al.*, 2019
Cladosporium tenuissimum	*Salvia miltiorrhiza*	Synthesis of effective components in the root system	Chen *et al.*, 2019

Claviceps sp.	*Dendrobium officinale*	Growth and yield	Li *et al.,* 2015
Colletotrichum sp.	*Abies* sp. roots	Photosynthesis	Xu *et al.,* 2014
Colletotrichum sp./*Fusarium* sp.	*Acacia* sp.	Nutrient absorption	Lin *et al.,* 2016
Coniothyrium sp.	*Aleurites* sp.	Nutrient element absorption in wood oil tree.	Wu *et al.,* 2015
Cylindrocarpon sp.	fir plant	Growth of fir.	Lin *et al.,* 2014
Darksidea sp.	*Stipa capillata* root	Rooting and growth of maize.	Bi *et al.,* 2019
Diaporthe spectabilis	*Bletilla striata*	Seedling growth	Li *et al.,* 2019
Emericella foeniculicola	*Salvia miltiorrhizae*	Seedling growth	Wei *et al.,* 2014
Epichloë bromicola	*Coix lacryma-jobi*	Seedling growth	Qin *et al.,* 2016
Nectria sp.	*Dendrobium officinale*	Yield	Li *et al.,* 2015
Neotyphodium sp.	perennial ryegrass	Beneficial properties for plant.	Spangenberg *et al.,* 2013
Paecilomyces sp.	Not disclosed	Phosphorus absorption in fir.	Xie *et al.,* 2014
Penicillium sp.	*Acacia confusa*	Plant biomass growth of Taiwan *Acacia* plant underlow-phosphorus environment.	Xie *et al.,* 2016
Penicillium sp.	*Eucalyptus*	Phosphorus absorption	Hong *et al.,* 2011
Penicillium sp.	*Aleurites montana*	Root growth of *A. montana* in a low-phosphorous environment.	Xie *et al.,* 2015
Trichoderma sp. *Fusarium* sp.	*Acacia* sp.	Increase in the height and ground diameter	Zhou *et al.,* 2016
Tulasnella calospora	Roots of *Paphiopedilum*	Growth of aseptic seedlings	Huang *et al.,* 2019
Xylaria striata	*Oryza meyeriana*	Plant growth.	Zhang *et al.,* 2013
Zasmidium sp.	mangrove	Growth and development	Lan *et al.,* 2017

Fungal endophytes and their effects on fungal pathogens

Fungal diseases harm plants, lower yield and quality, and result in postharvest losses, which can result in some of the most severe crop damage. Some fungi that cause disease also release mycotoxins that are harmful to people and animals (Mousa and Raizada, 2013). In order to prevent fungal diseases, synthetic chemical fungicides have become a staple in agriculture. However, like other pesticides, fungicides can have negative nontarget effects on the environment (Gamboa Gaitán *et al.,* 2005; Mancini and Romanazzi, 2014; Druille *et al.,* 2013; Wilkes *et al.,* 2020; Vázquez *et al.*, 2021). For instance, frequent use of fungicides has an effect on mutualist fungi like arbuscular mycorrhizae, whose loss can significantly reduce plant fitness. Fungicides can also target pests while selectively harming unintended beneficial bacteria (Reiff *et al.,* 2021). In place of chemical fungicides, biocontrol fungi employed against pathogenic fungi reduce the frequency of pathogens while preserving mutualistic fungi. Endophytes that function as biocontrol agents can lessen the negative impacts of chemical fungicides on the environment (Kiss *et al.,* 2004), such biocontrol agents can preserve or even improve soil health, increase sustainability in the agricultural industry, and help with integrated pest management techniques. Applying a variety of pest management techniques may also help manage or prevent chemical pesticide resistance. Extensive research is being done on the secondary metabolites that endophytes produce in an effort to find organic compounds that can be used as agrochemicals (Becker and Stadler, 2021; Deshmukh *et al.,* 2020).

Various chemicals have been extracted and isolated from a few taxonomic groups of fungi using top-down methods (Becker and Stadler, 2021). The exceptional diversity of bioactive metabolites that have been isolated from species in this order, such as glucosides, azaphilones, terpenoids, non-ribosomal peptides, cytochalasans, benzenoids, macrolide polyketides, and lactones, is highlighted by a recent review of compounds produced by Xylariales (Becker and Stadler, 2021). Other investigations take a different tack in identifying the precise antifungal substances that might manage plant infections. In these investigations, a host plant species' fungal endophytic diversity is described, and endophyte cultures are chosen for dual culture assays to determine whether they are antagonistic to recognized diseases of the host plant (Chutulo and Chalannavar, 2018; Zanudin *et al.,* 2020; Azuddin *et al.,* 2021; Abaya *et al.,* 2021; Anwaar *et al.,* 2021) .

The ability of the endophytic fungi to outgrow the pathogenic fungus or the existence of inhibitory zones between the endophytic and pathogenic fungi influence antagonism against pathogens (Zanudin *et al.,* 2020; Azuddin *et al.,* 2021; Miles *et al.,* 2012; McMullin *et al.,* 2019; Tanney *et al.,* 2016). Cultures exhibiting anti-pathogen activity are subjected to chemical extraction and analysis using mass spectrometry and liquid chromatography (Becker and Stadler, 2021; Talukdar and Tayung, 2021). These studies' findings consistently demonstrate that disease antagonists are a natural component of the plant microbiome and assist in the identification of prospective endophyte species that can be further researched for their potential for biocontrol (Peters *et al.,* 2020; Qin *et al.,* 2021). But frequently, the method by which these endophytes help their host is unclear or poorly understood (Chutulo and Chalannava, 2018). By triggering a systemic response after endophytic colonization, endophytes can also improve the host plant's resistance to fungal infections (González-Coloma *et al.,* 2016; Hartley *et al.,* 2015). Researchers have examined the antifungal properties of substances made by some endophytes to determine how well they work against a variety of harmful fungus and whether they can improve the fitness of the host plant (Chutulo and Chalannava, 2018).

The plant starts to use cell wall deposits as a defensive tactic to fortify cell walls and prevent them from being penetrated (González-Coloma *et al.*, 2016). Endophytes have means to gain access to these stronger cells, such as exoenzymes, but the deposits may stop pathogens from doing the same (González-Coloma *et al.,* 2016). Through transcriptional reprogramming, endophytes can also act as priming stimuli that trigger plant defense responses. One method for doing this is by controlling the expression of downstream defense-related genes such those implicated in the salicylic acid, jasmonic acid, and ethylene signaling pathways (Tian *et al.*, 2020; Panda *et al.*, 2019; Martínez-Arias *et al.,* 2021; Morán-Diez *et al.,* 2021).

The rate of photosynthesis (*Sclerotinia sclerotiorum*), chlorophyll content of plant cells, density of trichomes and stomata on plant tissues (*Beauveria bassiana*), antioxidant enzyme activity, callose deposition, cell lignification, and phytoalexin accumulation (*Diaporthe liquidambaris*) have all been linked to colonization by endophytes and subsequent metabolite secretion (Qin *et al.,* 2021; Tian *et al.,* 2020; Zhang *et al.,* 2020). Along with these defense mechanisms, harmful fungi and endophytes may also be excluded through competition (Hartley *et al.,* 2015).

Endophytes that colonize and occupy the same potential niche can generally suppress the establishment of pathogens through a process known as competitive exclusion. In the absence of the aforementioned defense systems, this type of protection is still possible. *Colletotrichum acutatum* and *Sclerotium rolfsii*, two plant diseases, are inhibited by fungi from the genus *Daldinia* (Suebrasri *et al.,* 2020; Khruengsai *et al.,* 2021). *Zingiber officinale*, ginger, and Stemona tuberosa were used as sources for *Daldinia eschscholtzii*, which was discovered to produce 60 distinct compounds, the most abundant of which were elemicin, ethyl sorbate, methyl geranate, trans-sabinene hydrate, benzaldehyde dimethyl acetal, and 3,5-dimethyl-4- heptanone (Khruengsai *et al.,* 2021). According to reports, *Colletotrichum gloeosporoides*, *C. nymphaeae*, and *C. musae* are all susceptible to the antifungal elemicin (Khruengsai *et al.,* 2021). Numerous species of endophytes and plant pathogens belonging to the genus Fusarium can prevent the growth of other fungal infections (Toghueo, 2020). Less attention has been paid to the antifungal capabilities of these compounds and their use in agricultural systems, despite the fact that several research have examined fusarium metabolites for their potential use as pharmaceutical antimicrobial agents (Toghueo, 2020).

Rhizoctonia solani and *Fusarium oxysporum* growth was inhibited by a crude extract of *F. proliferatum* that was obtained from the medicinal plant *Cissus quadrangularis.* (Singh *et al.*, 1998). The crude extract was found to include phenolics, terpenoids, and unsaturated alkenes after further investigation (Singh *et al.*, 1998). After being purified, it was shown that *Fusarium chlamydosporum* chitinase lysed the cell walls of the germ tubes and urediniospores of the rust species *Puccinia arachidis*, which hindered urediniospore germination (Mathivanan *et al.*, 1998). There are several species of endophytes from the genera *Diaporthe, Gliocladium, Aspergillus, Colletotrichum, Lecanicillium, Phyllosticta,* and *Trichoderma* being studied for their secondary metabolites' antifungal activities. When added to infected soils in solution, the soybean-isolated fungi *Trichoderma asperellum, T. atroviride*, and *T. longibrachiatum* reduced the pathogen *Rhizoctonia solani* ability to infect seeds.

There are several species of endophytes from the genera *Aspergillus, Colletotrichum, Diaporthe, Gliocladium, Lecanicillium, Phyllosticta,* and *Trichoderma* being studied for their secondary metabolites' antifungal activities. When added to infected soils in solution, the soybean-isolated fungi *Trichoderma asperellum, T. atroviride*, and *T. longibrachiatum* reduced the pathogen *Rhizoctonia solani* ability to infect seeds by 64, 60, and 55%, respectively (Sallam *et al.,* 2021). The hydrolytic enzymes pectinase and chitinase, both of which are capable of dissolving cell wall components, were created by the *Trichoderma* species (Sallam *et al.,* 2021). The *Trichoderma* species also produced IAA, which has a significant impact on plant growth, and siderophores, which decrease the availability of iron to pathogenic fungus (Sallam *et al.*, 2021). In dual culture assays, *Trichoderma erinaceum* isolated from ginger and Stemona root was found to suppress *Sclerotium rolfsii*, the causative agent of southern stem rot disease, by 64%, and to lessen infection by 58% (Suebrasri et al ., 2020). The growth of the infections *Penicillium avelaneum, P. notatum,* and *Aspergillus terreus* was found to be at least 80% inhibited by extracts from *Aspergillus neoniger*, which was isolated from the medicinal plant *Ficus carica* (Abdou *et al.,* 2021). Aurasperone A and D were found to be generated by *A. neoniger* by high-performance liquid chromatography and nuclear magnetic resonance spectroscopy (Abdou *et al.,* 2021).

Mellein and neoaspergillic acid, two well-known antifungals, were found to be present in an extract from an *Aspergillus* species that was isolated from the plant *Bethencourtia palmensis* (Morales-Sánchez *et al.,* 2021). At an effective dose, extracts prevented the growth of *Alternaria alternata*, *Botrytis cinerea*, and *F. oxysporum* in culture (Morales-Sánchez *et al.,* 2021). Similar to *R. solani*, cultures of *Lecanicillium lecanii* and *Gliocladium catenulatum* produced chitinase that could prevent *R. solani* mycelia development and conidial germination as well as *F. oxysporum* hyphal growth, conidial germination, and sclerotial germination (Nguyen *et al.*, 2015). If camptothecin from fungi and plants has the same antifungal characteristics, more research is needed to confirm this. Watermelon, Citrullus lanatus, was used to isolate *Trichoderma harzianum, Fusarium solani f. sp. cucurbitae, Macrophomina phaseolina, T. lentiforme,* and fungal endophytes (González *et al.*, 2020). *Fusarium oxysporum f. sp. niveum, Fusarium oxysporum f. sp. melonis, Neocosmospora falciformis, Monosporascus cannonballus* and *N. keratoplastica* were investigated for their antagonistic properties against 14 soil-borne route (González *et al.,* 2020).

In vitro testing on melon and watermelon plants revealed a reduction in disease occurrence of up to 67%, while dual culture assays with *Trichoderma harzianum* and *T. lentiforme* demonstrated the greatest rates of pathogen growth inhibition of up to 93% (González *et al.*, 2020). The examined plant diseases were observed to be inhibited by the *Trichoderma* species via a variety of mechanisms of action. These fungi produced substances that broke down the cell walls of the harmful fungal hyphae, outcompeted the pathogens for resources and space, and directly parasitized the pathogens with invading hyphae (González *et al.*, 2020). Another study discovered that the Indian medicinal plant *Houttuynia cordata's Colletotrichum coccodes* and *Phyllosticta capitalensis* inhibited the growth of the opportunistic human pathogen *Candida albicans* (Talukdar and Tayung, 2021). It was discovered that *Colletotrichum coccodes* produces the antibacterial compounds geranylgeraniol, farnesol, and squalene (Talukdar and Tayung, 2021). It was discovered that the organism *Phyllosticta capitalensis* produces the antioxidant and antibacterial chemical 1-octacosanol (Talukdar and Tayung, 2021). *Diaporthe caatingaensis* isolated from the medicinal plant *Buchanania axillaris* was found to produce camptothecin, a molecule more commonly derived from plants, that has anticancer, antibacterial and antifungal properties (Dhakshinamoorthy *et al.*, 2021; Feng *et al.*, 2019).

Table 2: Phytopathogens affected by endophytic fungi based on mechanisms related to biological control

Endophytic Fungi	Plants	Targets	References
Cladosporium tenuissimum	-	*Uromyces appendiculatus*	Assante *et al.*, 2004
Trichoderma viride, T. harzianum, T. stromaticum, T. virens	-	*Rhizopus stolonifer*	Bomfim *et al.*, 2010
Trichoderma viride	-	*Rhizoctonia solani*	Mathivanan *et al.*, 2005
Trichoderma viride, T. koningii	-	*Verticillium dahliae*	Martins-Corder and Melo, 1998
Heteroconium chaetospira	*Brassica oleracea*	*Verticillium dahliae*	Narisawa *et al.*, 2002
Diaporthe helianthi	*Leuhea divaricata*	*Moniliophthora perniciosa*	Bernardi-Wenzel *et al.*, 2008
Trichoderma viride	-	*Penicillium digitatum*	Borrás and Aguilar, 1990
Trichoderma viride	-	*Phytophthora nicotianae*	Stefanova *et al.*, 1999
Fusarium oxysporum sensu lato	*Solanum lycopersicum*	*Phytophthora infestans and P. capsici*	Kim *et al.*, 2007

Xylaria sp.	*Ginkgo biloba*	*Penicillium expansum and Aspergillus niger*	Liu *et al.*, 2008
Colletotrichum gloeosporioides and Clonostachys rosea	*Theobroma cacao*	*Phythophthora sp. and Moniliophthora roreri*	Mejí, 2008
Fusarium solani sensu lato	*Vitis labrusca*	*Botrytis sp.*	Brum, 2008
Aspergillus, Penicillium and Trichoderma sp.	*Eucalyptus benthamii*	*Botrytis cinerea*	Sbravatti Junior *et al.*, 2013
Trichophyton sp., Chrysosporium sp., Candida pseudotropicalis, and Candida tropicalis	*Symphytum officinale*	*Sclerotinia sclerotiorum*	Rocha *et al.*, 2009
Alternaria alternata	*C. officinalis*	*Alternaria arborescens*	Zhao *et al.*, 2020
Gliocladium catenulatum	*Theobroma cacao*	*Crinipellis perniciosa*	Rubini *et al.*, 2005
Diaporthe terebinthifolii	*Schinus terebinthifolius*	*Phyllosticta citricarpa*	Tonial, 2008
Ramularia pratensis, Phoma aliena and Fusarium acuminatum	*Vitis riparia*	*Botrytis cinerea*	Kusari *et al.*, 2014
Aspergillus insulicola and A. melleus	*Sesuvium portulacastrum*	*Pythium aphanidermatum*	Karunasinghe *et al.*, 2020
Phyllosticta fallopiae	*Cornus officinalis*	*Alternaria alternata, A. arborescens, Botryosphaeria dothidea and Colletotrichum gloeosporioides*	Zhao *et al.*, 2020
Alternaria tenuissima	*C. officinalis*	*Alternaria alternata*	Zhao *et al.*, 2020
Colletotrichum gloeosporioides	*C. officinalis*	*Alternaria alternata*	Zhao *et al.*, 2020

Botryosphaeria dothidea	*C. officinalis*	*Alternaria alternata, A. arborescens, Botryosphaeria dothidea and Colletotrichum gloeosporioides*	Zhao *et al.,* 2020
Botryosphaeria berengeriana	*C. officinalis*	*Botryosphaeria dothidea*	Zhao *et al.,* 2020
Alternaria sp., Botryosphaeria ribis, Phoma medicaginis, Bionectria ochroleuca, Aureobasidium pullulans and Chaetomium spirochaete	*Vitis vinifera*	*Botrytis cinerea*	Cosoveanu *et al.,* 2014

In dual culture experiments, it was discovered that *Aspergillus terreus*, an endophyte isolated from the seed of the rubber tree *Hevea brasiliensis,* significantly reduced the growth of the diseases *Rigidoporus microporus* and *Corynespora cassiicola* (Mahendran *et al.,* 2021). Sterilized rubber tree wood treated with liquid culture of *A. terreus* effectively prevented the development of *R. microsporus* in a dipped stick inhibition assay (Mahendran *et al.,* 2021). Additionally, sterilized leaves placed onto cultures of *Corynespora cassiicola* after being cut with a scalpel and soaked in liquid *A. terreus* culture exhibited significantly lower rates of infection in comparison to the control (Mahendran *et al.,* 2021). The antifungal abilities of endophytic fungi, however, are the subject of conflicting studies. *Diaporthe*, a speciose genus that contains several saprotrophs, pathogens, and endophytes, is one example of this.210 membered lactones with antifungal activity against several plant pathogenic fungi, including *Aspergillus niger, Botrytis cinerea, Cochliobolus heterostrophus, Fusarium avenaceum, F. moniliforme*, *Ophiostoma minus*, and *Penicillium islandicum*, were produced by *Diaporthe* sp., an isolated stem endophyte of *Azadirachta* (Chutulo and Chalannavar, 2018; Wu *et al.,* 2008). 8R-acetoxymultiplolide a shown the best antifungal efficacy against the aforementioned plant pathogens, while it had low antifungal action against *Candida albicans* (Tan *et al.,* 2007). Non-pathogenic Additionally, *Penicillium* spp. have demonstrated antifungal activities in *A. indica*, but the chemicals responsible (Chutulo and Chalannavar, 2018). Fungal endophytes may display comparable host specificity as fungal infections, which means the advantageous antagonistic effects exhibited in one host species may not be present in another. To fully understand the antifungal mode of action employed by various fungal endophytes, more research is necessary.

This will help researchers better understand which species are producers of antifungal substances that can be isolated and utilized topically as opposed to possible biocontrol inoculants.

Conclusion:

The literature on endophytic fungi's role in enhancing plant growth is compiled in this review. Endophytes peculiar to different plants protect them from phytopathogens and promote their growth through different mechanisms. The importance of this treatment might boost chances for the germination of seeds that are unable to do so under regular circumstances. This protection was conferred on the plants to enhance crop productivity and consequently food security. The predictive functional analysis of well-known genes involved in the synthesis of phytohormones, secretion systems, biocontrol, and the synthesis of cellular components, metabolic pathways, and secondary metabolites from endophytic microbes is aided by the combined application of culture-dependent and culture-independent techniques. Utilizing the benefits of endophytic fungi, which can encourage the accumulation of secondary metabolites initially produced by plants, is the most beneficial application. Additionally, it might be shown that this fungus can take the place of chemical fungicides. Therefore, the utilization of endophytic fungus demonstrates that such organisms are an effective tool for research and businesses in the areas of biocontrol, biostimulation, and biofertilization.

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MICRO-IRRIGATION IN CEREALS: PROBLEMS AND PROSPECTS

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Abstract:

Agriculture is the primary consumer of global freshwater resources, accounting for approximately 70% of total usage and up to 95% in some developing nations. Despite this, the efficiency and sustainability of water use in agricultural production could be significantly improved. This is crucial as water availability has a profound impact on crop yield. Cereal crops, which form a significant portion of the human diet, are particularly affected. Cereals such as wheat, maize, rice and to a lesser extent, millet and sorghum, are fundamental food sources on which billions of people globally rely. To meet future demand, annual cereal production will need to rise from the current 2.1 billion tons to 3 billion tons. Therefore, optimizing water usage in agriculture is not only essential for conserving our precious water resources but also for ensuring food security. Various irrigation techniques, including flood, furrow and micro-irrigation, are employed in cereal-based systems, with them flood irrigation being the most prevalent. However, conventional irrigation practices are becoming increasingly unsustainable. Surface irrigation, the predominant method used in many regions, results in less than half of the water released, being utilized by crops. The remainder is lost through conveyance, application, runoff and evaporation. Micro-irrigation techniques, such as drip and sprinkler systems are essential for the effective distribution and application of water in crop cultivation. These methods significantly reduce losses during conveyance and distribution, leading to improved water use efficiency. Drip irrigation, in particular, offers the highest potential for efficient water and fertilizer usage through fertigation. However, the adoption of micro-irrigation faces numerous obstacles including energy shortages, lack of awareness, affordability issues and declining farm incomes and landholdings. Despite these challenges, micro-irrigation systems can enhance water and crop productivity while conserving water, energy and labour costs compared to traditional methods. With the backing of various policies and schemes like PMKSY from central and state governments, farmers are expected to adopt micro-irrigation on a wider scale.

Introduction:

By 2050, the global population is projected to rise to 9.15 billion, up from the current 7.79 billion. A significant portion of this population (24.5%) will be in South Asia, with India alone accounting for 17.9% of the global total. If we take into account the importance of cereals in human nutrition, it's estimated that annual production will need to increase from today's 2.1 billion tons to 3 billion tons (Diouf, 2009). Key staples such as wheat, maize, rice and to a lesser extent, millet and sorghum, will continue to be vital for feeding billions worldwide. Increasing agricultural production in a sustainable manner to meet the rising food demand, particularly in the face of dwindling water resources, poses a significant challenge to scientists in the current climate scenario. Despite occupying only 2.4% of the world's total land area, India is home to 18% of the global population, making it South Asia's largest geographical region with over 72% of the area's inhabitants. However, India only possesses 4% of the world's freshwater resources. This disparity is further highlighted by the fact that India receives an average annual precipitation of 4,000 billion cubic metres, which serves as the primary source of fresh water in the country.

In 1951, India's per capita annual water availability was approximately 3000 m^3, but due to population growth and increased water usage in other economic sectors, this figure has dropped to 1458 m^3 per capita. The agricultural sector is the largest consumer of water in India, accounting for over 85% of the country's water usage. This consumption is expected to rise further due to population growth and future food demands. Rice and wheat, the main staple foods in India, are predominantly produced under irrigated conditions. Traditional irrigation methods used for cereal production in India have low water use efficiency. However, modern irrigation techniques such as drip and sprinkler systems can enhance water use efficiency and boost both water and crop productivity.

Water use by different sectors in India

Presently, food production is the largest consumer of freshwater resources, accounting for 70% of usage, while household use and industry account for 10% and 20% respectively (Thakur *et al.*, 2007). Each year, the agriculture sector alone uses up to 70% of the available freshwater (FAO, 2014). A breakdown of global water utilization by sector is depicted in Fig. 1.

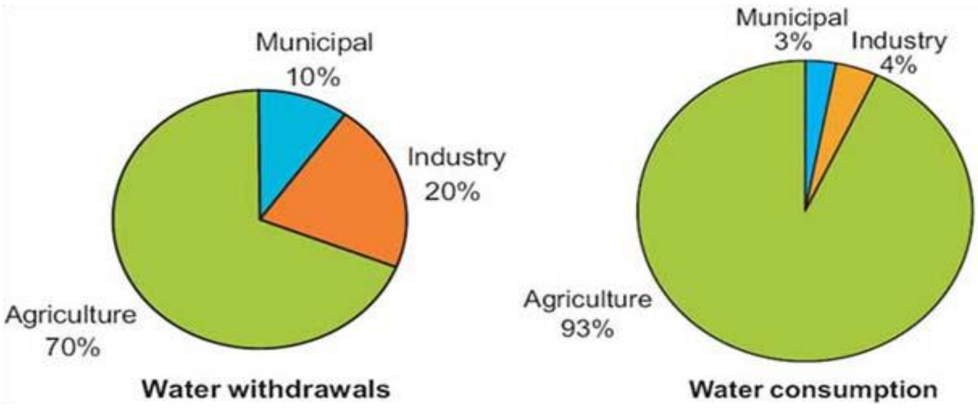

Figure 1: Sectorwise breakdown of global water utilization

Future trends in water use

According to projections (Fischer *et al.*, 2007), the demand for irrigation water (IW) is expected to rise by 50% in developing regions and 16% in developed regions between 2000 and 2080. Concurrently, the growing expansion of other economic sectors is leading to an increased and further escalating demand for water. This trend is creating heightened competition for agricultural water resources and widening the gap between the demand and supply of irrigation water in agriculture. The future water demand from various economic sectors, including urban centers, industries and infrastructure, is projected to be significantly high in both the 2030 and 2050 scenarios (Table 1).

By 2050, it is projected that the total water demand across all sectors in India will reach 1180 BCM, exceeding the country's total utilizable water resources (NCIWRD, 2015). As a result, the proportion of water allocated to agriculture is expected to decrease to 68% (Table 1). This implies that the cereal systems, which are responsible for a significant portion of food production, will have to operate with less water and potentially lower quality water. Therefore, it's crucial to enhance the productivity of these cereal systems through precise irrigation management while also safeguarding groundwater resources.

Table 1: Current and projected future water demand by different sectors of the economy of India

	Water demand (billion cubic meters; BCM)					
	Standing sub-committee of the Ministry of Water Resources			**National commission on integrated water resources development**		
Sector of economy	**2010**	**2025**	**2050**	**2010**	**2025**	**2050**
Agriculture	688	910	1072	557	611	807
Domestic	56	73	102	43	62	111
Industry	12	23	63	37	67	81
Others	57	87	210	73	103	181
Total	**813**	**1093**	**1447**	**710**	**843**	**1180**

Cereals in Indian agriculture

A cereal refers to any grass that is grown for its edible grain, which consists of the endosperm, germ and bran. This term can also be applied to the grain itself, often referred to as "cereal grain". These grain crops are cultivated in vast quantities and supply more food energy globally than any other crop type, making them staple crops. In developing countries, cereals remain the primary source of food consumption. In India, the key cereals include wheat, paddy, sorghum, bajra, barley and maize. As per the Indian Ministry of Agriculture's data for 2020-21, the production of major cereals such as rice stood at 118.43 million tonnes, wheat at 107.59 million tonnes, sorghum at 4.73 million tonnes, maize at 28.64 million tonnes, bajra at 10.29

million tonnes and Nutri cereals at 47.48 million tonnes. While most millets are grown in rainfed conditions, wheat, rice and maize have the highest percentage of irrigated areas compared to other cereals.

Farmers employ various irrigation methods for cereal-based systems, with flood irrigation being the most prevalent (Fig. 2) (Jat *et al.,* 2019; Sidhu *et al.,* 2019). Flood irrigation, a traditional practice in India, provides protective irrigation to crops. However, this conventional system has a significantly lower irrigation efficiency compared to modern methods. For instance, irrigated rice production necessitates approximately 2500 litres of water to yield 1 kg of grains. Due to its cultivation techniques, rice farming results in substantial water loss through evapotranspiration and soil percolation (Bouman, 2009). This intensive utilization of water resources for the rice-wheat production system has led to severe groundwater depletion in the Indo-Gangetic plains (IGP) of South Asia, particularly in north-west India (Humphreys *et al.,* 2010; Perveen *et al.,* 2012).

Table 2: Present status of area, production and per cent irrigated area of cereals in India

Crop	Area (m ha)	Production (m t)	Irrigated Area (%)
Rice	43.78	118.43	62.7
Wheat	31.45	107.59	95.3
Sorghum	4.71	4.73	10.1
Bajra	7.52	10.29	9.4
Maize	9.72	28.64	26.28
Nutri-cereals	24.02	47.48	17.41

Source: Agricultural Research Data Book 2022

The sustainable utilization of water resources and the enhancement of water efficiency in irrigated agriculture are pressing issues. Effective water use can be achieved by increasing beneficial uses, minimizing water losses and boosting water productivity (Pereira *et al.*, 2012). Micro-irrigation stands out as a crucial strategy for ensuring the sustainability of irrigated agriculture. It can significantly reduce water usage while improving both the quantity and quality of the yield. The implementation of micro-irrigation has the potential to result in higher yield and increased water productivity (Çetin and Üzen, 2016).

Modern irrigation methods address the shortcomings of traditional techniques, thereby promoting efficient water usage. These contemporary methods encompass two primary systems:

- Sprinkler irrigation system
- Drip irrigation system

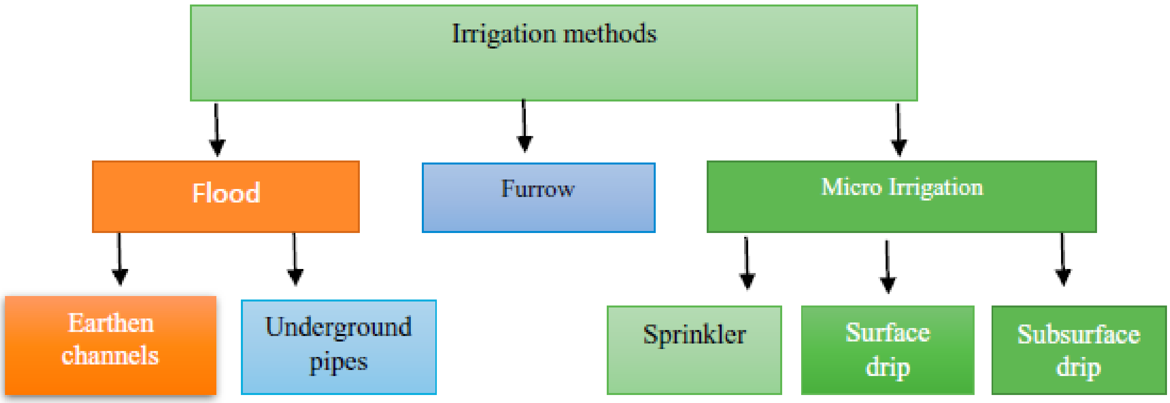

Figure 2: Methods of irrigation in cereals

Micro-irrigation development in India: Current status

Micro Irrigation (MI) in India has been promoted through subsidies provided by both central and state governments. As of 2017, MI covers approximately 8.7 million hectares, which represents only about 13% of the potential area. The states of Maharashtra, Andhra Pradesh, Telangana, Karnataka and Gujarat collectively account for about 85% of the total area under drip irrigation (Table 2). In terms of sprinkler systems, Rajasthan and Haryana lead the way. However, states like Madhya Pradesh, Punjab and Haryana are significantly underutilizing their potential, despite having groundwater development exceeding 100%.

Table 3: Irrigation efficiency of different irrigation methods

Irrigation Methods	Irrigation efficiency
Wild flooding	20-25%
Border flooding	50-60%
Check and basin flooding	60-65%
Furrow irrigation	65-70%
Sprinkler irrigation	70-85%
Drip irrigation	85-95%

Sprinkler irrigation system

Sprinkler irrigation is a method of watering that simulates natural rainfall. It utilizes a network of pipes, typically powered by a pump, to distribute water. The water is sprayed into the air using sprinklers, where it fragments into small droplets that fall to the ground, similar to rain. The sprinklers, pump supply system and operational conditions must be carefully designed to ensure uniform water application.

Table 4: State-wise area covered under Micro irrigation (Drip and Sprinkler) in India (as of 31.03.2021) (In Hectare)

States/UT	Drip	Sprinkler	Total
Andhra Pradesh	1388126	519165	1907291
Arunachal Pradesh	4017	3494	7511
Assam	4208	16217	20425
Bihar	13763	106979	120742
Chhattisgarh	31311	331283	362594
Goa	1386	1346	2732
Gujarat	865959	764933	1630892
Haryana	40018	600461	640479
Himachal Pradesh	7934	6403	14337
Jammu & Kashmir	1779	280	2059
Jharkhand	25686	17713	43399
Karnataka	788981	1304281	2093262
Kerala	24168	9096	33264
Madhya Pradesh	330335	258600	588935
Maharashtra	1349979	576325	1926304
Manipur	358	7039	7397
Meghalaya	308	307	615
Mizoram	5551	1744	7295
Nagaland	3589	6210	9799
Odisha	29425	115396	144821
Punjab	36416	14055	50471
Rajasthan	287619	1730876	2018495
Sikkim	6667	7943	14610
Tamil Nadu	805282	348010	1153292
Telangana	203279	74871	278150
Tripura	444	1651	2095
Uttar Pradesh	41273	227897	269170
Uttarakhand	12737	10300	23037
West Bengal	10347	92984	103331
India	**6320945**	**7155859**	**13476804**

Agricultural Research Data Book 2022

A typical sprinkler irrigation system consists of the following components:

Pump unit: Sprinkler irrigation systems function by dispersing water across the fields in a manner that simulates rainfall. The water is propelled under pressure to the fields.

Mainline and sub-mainlines: The mainline is responsible for transporting water from the source and distributing it to the submains. These submains then carry the water to the lateral lines, which subsequently supply water to the sprinklers.

Sprinkler's head: Sprinkler heads are designed to evenly distribute water across the field, minimizing runoff or excessive loss due to deep percolation. There are various types of sprinklers available, which can be categorized as either rotating or fixed type.

Sprinkler irrigation in cereal production offers its own set of challenges and opportunities. Here, we'll discuss the problems and prospects associated with sprinkler irrigation in cereals:

Problems of sprinkler irrigation in cereals:

- **Uniform water distribution:** Sprinkler systems may encounter challenges in ensuring consistent water distribution, which can lead to the risk of overwatering in specific areas while causing drought stress in others. These issues have the potential to impact the quality and yield of cereal crops. Effective system design and efficient management play a vital role in achieving the best results in cereal production.
- **Evaporation and wind drift:** In times of elevated temperatures and strong winds, sprinkler systems may experience challenges with water loss and reduced irrigation effectiveness due to the increased likelihood of water droplets evaporating and being carried away by the wind. This susceptibility can negatively impact the growth and yield of cereal crops. To prevent this, careful consideration of system design and management is crucial for optimal crop production.
- **Energy consumption:** Sprinkler systems commonly result in substantial energy usage and operational expenditures, given their necessity for high-pressure pumps to facilitate water dispersion. These associated costs are notable and need to be managed effectively.
- **Disease and pest susceptibility**: In the realm of cereal crops, the surplus moisture generated by sprinkler systems can foster a microenvironment favorable to the proliferation of specific diseases and pests. Excessive moisture on foliage and plant surfaces can elevate the occurrence of fungal diseases and pests, thereby requiring supplementary pest control methods and potentially escalating the usage of pesticides. Such actions can carry both environmental and economic consequences.
- **Cereal sensitivity to saline water**: Cereals including wheat, rice, and maize, are recognized for their susceptibility to saline water when sprinkler systems are utilized for irrigation. The utilization of saline water via sprinklers can result in detrimental consequences for cereal crops, given the detrimental impact of high salt levels on their growth and well-being. Therefore, it is imperative to exercise meticulous control over the water source and its quality when employing a sprinkler system for cereals. This precaution is essential to avert potential complications associated with salinity and uphold the highest possible crop productivity.

- **Soil erosion risk:** Within cereal farming, the vigorous force of water droplets produced by sprinkler systems has the potential to displace soil particles, thereby elevating the chances of soil erosion. To counter this risk, it is imperative to implement effective soil conservation practices when employing sprinkler irrigation for cereal crops.
- **High initial costs:** Small-scale and marginal cereal growers encounter difficulties in embracing sprinkler systems, primarily because of the significant initial capital outlay required. Scarce financial means create obstacles in meeting the expenses associated with equipment procurement and installation. Consequently, the availability of subsidies, loans, or support initiatives is pivotal in facilitating broader accessibility to sprinkler technology for these farmers.

Prospects of sprinkler irrigation in cereals:

- **Frost protection:** Sprinkler irrigation plays a pivotal role in protecting cereal crops against frost-related harm. The application of water creates a protective layer of ice, serving as a shield that safeguards the plants from the effects of low temperatures. This safeguarding measure helps maintain the health of the crops and preserves their potential for yielding a productive harvest.
- **Mitigating heat stress:** Sprinkler irrigation assumes a pivotal role in mitigating heat stress for cereal crops in hot and arid regions. This technique efficiently lowers the temperature around the crop canopy, generating a microenvironment that provides protection against extreme heat. The alleviation of heat stress not only promotes the well-being of the crops but also results in an overall enhancement of cereal productivity. It ensures that crops can thrive even in demanding, high-temperature conditions.
- **Ease of installation:** Sprinkler systems have the benefit of being uncomplicated to set up, making them accessible to a broad spectrum of cereal farmers and various agricultural scenarios. This simplicity in installation facilitates their broad acceptance and utilization in cereal farming.
- **Adaptability to various cereals:** Sprinkler systems are adaptable to cater to the distinct water requirements of various cereal crops, offering flexibility in the management of irrigation.
- **Drought resilience:** Sprinkler systems serve as a crucial element in enhancing the drought resistance of cereal crops. During periods of short-term drought, these systems offer swift relief through timely irrigation, ensuring the prompt delivery of moisture. This capability enables cereal crops to endure and rebound from drought stress, safeguarding their yields and contributing to food security.
- **Versatile soil compatibility:** Sprinkler irrigation showcases its versatility by adeptly adapting to different soil types, particularly excelling on sandy soils through its efficient water distribution. Nevertheless, it may not be the most suitable choice for heavy clay

soils and rice cultivation, where more specialized water management approaches are often necessary.

- **Slope adaptability and water efficiency:** Sprinkler irrigation systems display remarkable adaptability and can be deployed on farms with varying slopes, including both uniform and undulating terrain. This adaptability is conducive to water conservation, effectively extending the irrigated area for cereal crops. Furthermore, the precise regulation of water application makes sprinkler systems well-suited for light and frequent irrigation, leading to a substantial enhancement in water distribution efficiency.
- **Government support:** Numerous governments offer financial support and incentives to encourage the adoption of sprinkler irrigation in the agricultural sector, rendering it an appealing choice for farmers.

When contemplating the adoption of sprinkler irrigation for cereal production, it is vital to take into account particular factors such as the type of crop, local climatic conditions, and the availability of resources. While this method provides benefits like safeguarding against frost, alleviating heat stress, and simplicity of installation, it is equally imperative to address concerns related to uniform water distribution, energy usage, and maintenance to ensure its effective utilization. Farmers should conduct a thorough evaluation to ascertain whether this irrigation approach aligns with their individual requirements and the prevailing conditions.

Drip irrigation system

Drip irrigation, also known as trickle system of irrigation, involves the slow application of water (2-20 litres per hour) in the form of continuous drops, tiny streams or miniature sprays through mechanical devices known as emitters. These are located near the root zone of plants. This modern drip technology was pioneered by Simcha Blass in Israel. The operating pressure for drip irrigation is 2.5 kg cm^{-2} and it requires high maintenance skills. Unlike surface and sprinkler irrigation which waters the entire soil profile, drip irrigation delivers water directly to the plants, moistening only the soil area where roots grow. This method typically applies water more frequently (usually every 1-3 days), maintaining a high moisture level in the soil where plants can flourish. Compared to furrow irrigation without residue, grain yields of maize and wheat under drip irrigation with a residue retention system increased significantly by 13.7% and 23.1% respectively, while saving 88 mm and 168 mm of water through surface drip irrigation with residue retention (Sandhu *et al.*, 2019). The water savings achieved with drip irrigation are due to reductions in deep percolation, surface runoff and soil evaporation.

Components of drip irrigation

Pump: To lift the water from the source of supply.

Head unit: To maintain the required pressure for circulation of water.

Central distribution system: Connected to the main water supply, which regulates water pressure and quantity.

Fertilizer tank: To supply soluble plant nutrients along with irrigation water.

Filter: To remove materials suspended in water.

Main supply pipe: To deliver the desired discharge.

Sub-main/or laterals: Connected in a parallel way to the main.

Dripper: To control the release of the desired quantity of water.

Types of drip irrigation

1. **Surface drip irrigation system:** Surface drip irrigation is a prevalent method that utilizes a wide variety of drip emitter devices.

- Lateral lines, which are supplied from a field main, are positioned on the surface.
- This method is highly favoured for crops that are spaced widely apart.
- The installation, inspection, alteration and cleaning of emitters is straightforward.
- It may interfere with farming operations.

2. **Sub-surface drip irrigation system:** Sub-surface irrigation (SDI) is a more advanced, and consequently, more costly and less common method. It utilizes thin plastic tubes approximately 2 cm in diameter. These tubes are buried in the soil at a depth of between 20 and 50 cm, sufficiently deep to avoid disruption from regular tillage or traffic.

- Laterals are positioned beneath the soil surface.
- There's no need for installation and removal.
- It minimally interferes with farming operations.
- It has a longer economic lifespan.

Drip irrigation in cereals, while less common compared to other irrigation methods, has its own set of problems and prospects. Here, we'll explore the issues and potential benefits of using drip irrigation in cereal production:

Problems of drip irrigation in cereals:

- **Challenges in drip irrigation implementation for cereals:** The setup and execution of drip irrigation systems in cereal farming can be intricate and demanding, often necessitating meticulous preparation, technical proficiency, and a significant initial financial outlay.
- **Incompatibility with certain cereal crops:** Drip irrigation may not be universally applicable to all cereal crops, as the water delivery technique and system design must correspond to the precise needs of each crop. Drip irrigation is not well-suited for rice cultivation due to the substantial water demands of rice crops and the necessity for intermittent inundation in rice fields.
- **Challenges of drip irrigation for closely spaced cereal crops:** Drip irrigation can pose challenges when applied to closely planted cereal crops, such as wheat or barley, owing to the compact plant spacing. This proximity not only hinders the even dispersion of water but also adds complexity to the setup and oversight of drip systems, which could potentially affect the growth and yield of cereal crops.

- **Initial investment cost:** The installation of drip irrigation systems entails substantial upfront costs, encompassing expenses for drip lines, emitters, filters, pumps, and control systems. For small-scale or resource-constrained cereal farmers, this initial investment can present a formidable barrier to the adoption of this technology.
- **Clogging:** In the sphere of cereal cultivation, drip emitters are vulnerable to blockages when the water carries impurities, sediments, or organic materials. To ensure a continuous water supply to the crops, it is essential to implement diligent and routine maintenance procedures. This includes the regular cleaning of filters and emitters to prevent clogging problems.
- **Risk of pest and disease spread**: In cereal farming, especially when employing drip irrigation, there exists a potential danger of creating a humid microenvironment around the base of the plants. This microenvironment can facilitate the growth of particular pests and diseases, particularly in areas with elevated humidity.
- **Impact of water quality on cereal drip systems**: In cereal cultivation with drip irrigation systems, the quality of water plays a crucial role. Subpar water quality, characterized by elevated salt levels or chemical contaminants, can profoundly disrupt the effectiveness of drip systems, leading to clogs in emitters and issues related to salinity.
- **Energy consumption:** Drip irrigation frequently relies on pumps to pressurize and distribute water, potentially resulting in energy expenses. This could pose a challenge in regions with restricted access to electricity.
- **Skill and knowledge requirements:** The correct setup and handling of drip irrigation systems demand technical knowledge. Farmers should receive training in system design, operation, and maintenance to ensure its effective use.

Prospects of drip irrigation in cereals:

- **Water efficiency:** Drip irrigation is renowned for its exceptional water efficiency in cereal farming, as it precisely delivers water to the root zone, minimizing losses from evaporation and runoff. This efficiency holds particular significance in regions with limited water resources, where it maximizes water utilization for cereal crops, thereby promoting sustainability and higher yields.
- **Improved cereals yields:** Accurate water application can lead to amplified yields and improved crop quality, concurrently mitigating water stress on plants. Consequently, this can culminate in a more dependable and foreseeable harvest.
- **Optimal nutrient management:** Drip irrigation systems provide the benefit of directly delivering fertilizers to the root zone in cereal cultivation. This enhances the precision of nutrient management while reducing the chances of nutrient leaching and runoff. This focused approach guarantees the efficient utilization of nutrients, supporting robust cereal growth and mitigating environmental repercussions.

- **Adaptability to various cereals:** Drip irrigation's versatility extends across various cereal crops, allowing for tailoring to fulfill the specific water requirements of cereals such as wheat, rice, maize, barley, and others. This adaptability highlights its appropriateness for a wide array of cereal farming, enabling precise water management for each crop type.
- **Reduced weed growth:** Drip irrigation, with its accurate water delivery, contributes to weed control by keeping the inter-row spaces drier. This focused method aids in reducing weed competition, ultimately improving the general well-being and productivity of cereal crops.
- **Environmental benefits:** The efficient management of water and the reduction of chemical runoff linked to drip irrigation can yield substantial environmental benefits for cereal production. These advantages include decreased soil erosion and improved water quality in the adjacent ecosystems, which in turn enhances the overall sustainability of cereal farming practices.
- **Climate resilience:** Drip irrigation is an invaluable tool for bolstering the resilience of cereal crops during drought and water stress episodes. This technology stands as a vital resource for advancing climate-resilient cereal agriculture, protecting crop yields, and securing food production in light of fluctuating climate conditions.
- **Government support:** Numerous governments provide financial support and incentives to promote the adoption of drip irrigation as part of their water conservation and agricultural advancement programs.

For the successful integration of drip irrigation in cereal production, it is essential to address challenges while leveraging opportunities. The provision of training, extension services, and financial assistance for small-scale farmers can significantly contribute to the broader adoption of this technology, ultimately leading to more sustainable and productive cereal cultivation.

Conclusion:

In conclusion, micro-irrigation presents a promising solution for the cultivation of cereals, offering both challenges and opportunities. While the initial costs and technical knowledge required may pose hurdles, the long-term benefits in terms of water and nutrient conservation, increased crop productivity and reduced greenhouse gas emissions cannot be overlooked. The adoption of micro-irrigation could lead to significant water savings, particularly in cereal crops that occupy a substantial portion of India’s arable land. Furthermore, integrating micro-irrigation with other on-farm water-saving strategies could enhance soil and water conservation. Despite the challenges, the prospects of micro-irrigation in cereals are bright, positioning it as a potential game-changer for sustainable agriculture in the future.

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TRICHODERMA AS BIOCONTROL AGENT AGAINST PESTS

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Abstract:

Trichoderma, a widely studied fungal genus, has gained prominence as a potent biocontrol agent against various pests. This versatile microorganism exhibits multifaceted mechanisms of action, including mycoparasitism, antibiosis, and induced systemic resistance, making it effective against a diverse range of plant pathogens and insect pests. It's ability to outcompete and inhibit the growth of harmful microorganisms in the soil and on plant surfaces contributes to its biocontrol potential. Moreover, it stimulates the host plant's natural defense mechanisms, enhancing its resistance to pests. Its ecological safety and minimal environmental impact make Trichoderma an attractive choice for sustainable pest management. As the demand for environmentally friendly pest control methods grows, trichoderma emerges as a promising biocontrol agent that not only reduces the reliance on chemical pesticides but also promotes healthier, more resilient agricultural ecosystems. Extensive research and application of Trichoderma in integrated pest management practices hold the potential to revolutionize pest control in agriculture and enhance crop productivity while minimizing environmental risks.

Keywords: Trichoderma, biocontrol agent, pests, Entomopathogenic fungi

Introduction:

In agriculture, *Trichoderma* spp. is an effective biocontrol agent for insects, nematodes, and fungal diseases thereby promoting plant growth. Strains of *Trichoderma* are widely used as a substitute in place of chemical pesticides to tackle many plant pathogens. It is a filamentous-fungi, avirulent, saprophytic and opportunistic plant symbionts, inhabiting mainly the soil. These are economically important due to their production of secondary metabolites of great use in medicine, biotechnology, and agriculture. *Trichoderma viridae* can be easily mass multiplied on household waste, vegetable waste and other wastes. It not only increases the fertility of soil, but also eco-friendly and do not affect the other beneficial microorganisms (Mridula Khandelwal *et al.*, 2012). Trichoderma spp. offer additional advantages to the agriculture such as increase in plants photosynthetic capability and yields, efficient absorption of nutrients and abiotic stress tolerance (Sood *et al.*, 2020).

Mode of Action:

Trichoderma (Entomopathogenic fungi) infect insects by direct penetration of the cuticle. The infection process initiates with the adhesion of spores to insect integument. In this process, two types of proteins are produced such as hydrophobins and adhesins where layers breakdown during the sporulation of spores and enabling the fungal pathogen to the insect's cuticle and recognise the host respectively (Skinner *et al.*, 2014, Wang and Leger, 2007). Spore germination occurs in the presence of carbon and energy sources on the insect's cuticle at sufficient humidity and temperature. The optimum temperature for the growth and germination of this fungi is 20-30^{o}C. (Skinner *et al.,* 2014). Thereafter, appressoria develops, causing intense mechanical pressure on the cuticle and produce lytic enzymes such as proteolytic, lipolytic and chitinolytic where disintegrates the insect's body shells (Lacey *et al.,* 2015). After penetrating the insect body cavity (haemocoel), fungal hyphae begin to proliferate and form secondary hyphae that remain in the host tissues thereby nutrient deficiency occurs. In this process, the fungi produce secondary metabolites that cause paralysis and disrupt the insect immune responses (Donzelli and Krasnoff, 2016). Although the complete infection process is relatively long but first symptom often appears about 7 days after infection. Initially the insect's body becomes soft and then stiff due to fluid absorption by the fungus. The hyphae of the fungus develop from the cadaver of the host through holes in its body (mouth hole, anus) and through intersegmental areas and then infective spores are produced, which allows the fungus to spread and infect other individuals (Skinner *et al.,* 2014).

Direct effect on pests

It acts as an entomopathogen like parasitism, production of insecticidal secondary metabolites, repellent and antifeedant compounds.

Indirect effect on pests

It acts as an mycoparasite or as plant-endophyte which activate the systemic plant defensive responses, attraction of natural enemies or the parasitism of insect symbiotic microorganisms.

Combinations:

T. asperellun strains provided improved biocontrol results of insects by combination with the entomopathogenic fungi *Beauveria bassiana*. Maize seeds coated with this combination produced 90% mortality of Asian corn borer larvae (*Ostrinia furnacalis*, the most important pest of maize in China) and reduced more than 80% the damage of plants compared to an insect infestation treatment (Batool *et al.,* 2020). Ahmad Nawaz *et al.* (2020) reported that the combination of *Trichoderma spp*. and *B. thuringiensis* showed a synergistic/ additive effect and gave better control of brinjal insect pests. Single formulation provided also significant population reductions of brinjal insect pests.

Conclusion:

Compared to chemical control, although Trichoderma have shown similar or even higher efficiency than fungicides and pesticides in specific conditions (Table 1), the total replacement of fungicides by Trichoderma is far. Compared to other biocontrol agents, Trichoderma offer additional benefits such as increase in plants photosynthetic capacity and grow promotion.

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MULBERRY PESTS AND THEIR MANAGEMENT

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Abstract:

Mulberry, the food plant of silkworm is prone to attack by number of pests comprising largely with insects and few non-insect species. They cause reduction in mulberry leaf yield besides deteriorating its nutritional value and make unfit for feeding silkworm. Feeding pest affected leaves to silkworm often results in adverse impact on its growth and cocoon yield. Therefore, proper management strategies need to be adopted to keep mulberry garden free from the pests for sustainable production of silk. Chemical pest management practice is invariably preferred by the farmers as it yields visible result. But spray of highly toxic or long persisting insecticides is not recommended for mulbe rry garden due to their residual toxic effects to the silkworms and health hazards to the farmers on continuous use. Therefore, adoption of IPM strategies with emphasis on non-chemical methods like use of botanical formulations, natural enemies of mulberry pests, traps, water jetting etc., are advocated. In recent past, the pest status in mulberry ecosystem is changed due to advent of high yielding mulberry varieties, more use of agronomical inputs clubbed with climate change. Therefore, thorough updated knowledge on the pests invading mulberry garden including their descriptions, mode of damage to plants, symptoms, seasons favouring their multiplications, alternate host plants, effective natural enemies, suitable IPM practices is essential.

Keywords: Pest, sap suckers, defoliators, borers, integrated pest management

Introduction:

Sericulture is an emerging agro based enterprise for small and marginal holding farmers having less capital investment. Mulberry belonging to the genus Morus is extensively grown in south India where most of the sericulture industry is concentrated. Mulberry (*Morus alba* L.), the main food source of silkworm (*Bombyx mori* L.) is a perennial plant, since mulberry leaf is available throughout the year, it makes the plant prone to various disease and pests. Pest cause leaf yield loss either by depletion of nutritive value or defoliation. Feeding these inferior quality leaf adversely affects the silkworm growth and finally the silk industry. Therefore, regular agronomical practices viz. manuring, irrigation, weeding, pest, and disease management *etc*., are imperative in moriculture in order to improve the production of quality mulberry leaf. The expression of 'Pest' is used very broadly to insects, other invertebrates like nematodes, mites, snails etc. and vertebrates like rats, birds, jackals, squirrels etc., that cause significant and economic damage to crops. An insect reaches the status of pest when its number increases and inflicts significant damage. An insect may become a pest under one set of conditions and not so under others and similarly, an insect can be considered as a pest in one place and not in another. In any crop ecosystem, if a pest can be controlled at a cost less than the expected market value of the potential increase in yield, the pest species can be considered as economic or controllable pest. This is also referred to as "the economic threshold" (ETL) for deciding this an arbitrary limit can be fixed, such as the size of the population responsible for a 5 per cent loss in yield and this level is called as the pest status. Therefore, if an insect causes a loss of < 5 per cent of the yield the infestation is negligible. Insects which normally cause a loss ranging from 5 to 10 per cent are said to be minor pests and those which cause a loss of more than10 percent are said to be major pest and damaging species. Though mulberry hosts hundreds of insect species. The important pests are Mealy bug, Leaf roller, Bihar hairy caterpillar, Wingless grasshopper, Jassid, Thrips, Cutworm, Whitefly, Scale insect, Stem borer, May-June beetle and Termites. Majority of them are found throughout the year due to short life cycle. The pests cause reduction in leaf yield (10-20%) and/or quality.

Classification of mulberry pests

Based on the phylum or class, mulberry pests are classified into two major categories called insect and non-insect pests. Insect pests are predominant in mulberry ecosystem whereas only few non-insect species like mites, snails, slugs, nematodes and millipedes are reported to be causing damage to mulberry plants occasionally.

Based on their mode of feeding Mulberry pests are divided into three groups namely,

1.Sap suckers: mealybug, jassid, thrips and whitefly.

2.Leaf eaters: leafroller, Bihar hairy caterpillar, cutworm and wingless grasshopper.

3.Root/shoot feeders: stem borer, May-June beetle and termites.

A) Sap suckers: The insects, which suck the juice from the leaf, are called as sap suckers. They are smaller insects compared to leaf eaters. They affect the leaf quality greatly. Besides, they also inject toxic substances into the plant causing deformities. The major sap sucker pests attacking mulberry are Mealy bug, Thrips, Jassids and White fly.

1) Pink mealybug, *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae)

Occurrence Throughout the year and the incidence is maximum in summer months (March to August). Their population is negligible during rainy season.

Alternate host plants They are highly polyphagous and so far, more than 350 host plants have been recorded in the world. Important host plants are hibiscus, beans, pumpkin, croton, chrysanthemum, citrus, grapevine, guava, coffee, sugarcane, soybean, mango, pigeon pea, maize, cotton, teak etc.

Symptoms of pest attack:

- The leaves are wrinkled, thickened, dark green and become yellowish prematurely.

- The nymphs feed by sucking the sap from tender leaves and stem portion. Hence the affected apical shoots show bunchy appearance due to curling of leaves, shortening of internodes and thickening of stem. This symptom is popularly known as 'Tukra' in India.
- A heavy, black sooty mould also develops on attacked plants due to heavy deposition of honeydew produced by mealy bug.
- The leaf yield is greatly reduced and leaf is low in nutritive value.
- Leaf yield loss was reported to be 4,500 kg/yr.

Pink mealybug

C. montrouzieri feeding on pink mealybug

Management (Integrated Pest Management)

- Clipping and destruction (by burning) of pest attacked parts.
- Clip-off the healthy apical parts in the entire garden along with 2 to 3 leaves when the silkworms are under IV moult. Such parts can be used for resumption of feeding (one or two feeds) to silkworms after IV moult. This will reduce spread of tukra.
- Do not grow alternate host plants of the mealybug in the vicinity of mulberry gardens.
- After each leaf harvest, remove the left-over leaves to prevent further attack.
- Spray 0.05% Dimethoate (36 % EC) 12-15 days after pruning. Safe period to silkworm is 20-25 days. During summer second dose of 0.2% DDVP (76% EC) 10 days after first spray is essential to avoid recurrence of the pest during growing phase of mulberry plants. Safe period is 15-17 days.
- Spray 0.5% of 0.03% neem-based insecticide (Azadirachtin) 30 days after pruning. Safe period: 10 days.
- Biological Release of biological predator *Cryptolaemus montrouzieri* @ 250 or *Scymnus coccivora* @ 500 adults/acre in two equal splits during Oct.-Nov. and Jan.-Feb to feed on the mealy bugs to decrease infestation.

2) Papaya mealybug, Paracoccus marginatus Williams and Granara de Willink (Hemiptera: Pseudococcidae)

Occurrence Occurs throughout the year, but severity is more in summer months.

Alternate host plants the pest is polyphagous in nature having wider host range and reported to infest more than 80 host plants of about 25 genera including economically important crops viz., papaya, tapioca, jatropha, hibiscus, avocado, citrus, cotton, tomato, egg plant, pepper, beans, peas, sweet potato, mango, cherry, pomegranate, *Plumeria* etc.

Symptoms of pest attack

- It has piercing-sucking mouth parts and feeding on phloem sap of mulberry both from stem and leaf resulting in loss of moisture and decline in nutritional values.
- The symptoms appear on the leaves as chlorosis (yellowing), deformation (curling), pre mature drop, stunted growth followed by death of plants.
- Growth of dense black sooty mould on leaves over the honeydew excreted by the pest reduces the photosynthetic efficiency of the plants as well as pollutes entire mulberry garden in case of severe infestation.

Papaya mealybug

Affected garden

Management practices

- Clipping off the infested twigs and leaves and burning during early stage of infestation is the best method of eradication of the pest.
- All crop residues in the infested garden harbouring mealybug populations should be removed and burnt.
- Water jetting involves physical force which hits on the infested plant parts to dislodge and washout the insects so that the mulberry garden is kept free from the population of papaya mealybug.
- As soon as the pest is noticed, release exotic parasitoid, *Acerophagus papayae* or *Pseudleptomastix mexicana* @ 250 parasitoids / acre of mulberry garden. These parasitoids are most effective in controlling papaya mealybug successfully rather than spray of chemical insecticides.

3) Thrips: *Pseudodendrothrips mori* (Niwa) (Thysanoptera: Thripidae)

Commonly called ‘thunder flies or storm flies’.

Period of occurrence: Throughout the year and severe during summer (April – May) and least in rainy season (October- November).

Alternate host plants Very few plants like Ficus, Tridax procumbens, Camellia sinensis, *Leersia hexandra* are reported as alternate hosts of *P. mori*.

Symptoms of pest attack

- Nymphs and adults are found mainly on the underside of the leaf. They pierce the epidermis of mulberry leaves using their lacerating mouthparts and extract the plant sap.

- During laceration, they secrete saliva which coagulates the sap resulting in the formation of white streaks in the early stage followed by silvery blotches which are mixed with small black spots of thrips feaces in the advanced stage.
- In acute cases serious drying of the leaf tissues results in leaf curl and these leaves shrink harden and ultimately fall.
- Stunting, leaf curling and deformation are also observed in severely affected gardens.
- Feeding thrips affected mulberry leaves to silkworm results in adverse impact on economic traits and cocoon yield.

Thrips infestation

Thrips affected mulberry plant with stunted growth

Management

- Mulberry field should be thoroughly cleaned after harvest by removing small side branches, dead leaves and weeds in order to eliminate any developmental stages of thrips on them.
- Periodical ploughing and digging of mulberry field help in exposing the thrips pupae to hot sun and natural enemies. Water jetting or sprinkler irrigation is effective in reducing thrips population. Providing frequent irrigation helps in increasing the pupal mortality in soil thereby reducing the thrips emergence.
- Spray of 0.1% Dimethoate 30% EC (3ml/litre) 15 days after pruning. Safe period is 20-25 days.
- Release of S. coccivora @ 500 adults or Chrysoperla @ 1000 eggs / acre, a week after the insecticide spray.
- In addition to the above methods a mixture of 1: 3 diesel and water may be used in insect damaging area to remove the insects.

4) Jassids: *Empoasca flavescens* Fabricius (Hemiptera: Cicadellidae)

This species of Jassid is commonly called as Leafhopper or Plant hopper

Occurrence It is considered to be a minor or occasionally serious pest of mulberry. The insect remains active throughout the year, but maximum population build up occurs during November to January, that is mostly in the winter season.

Alternate host plants Castor, tea, okra, cotton, beans, brinjal, potato *etc.*, are prone to severe attack of jassid.

Symptoms of pest attack

- Both nymphs and adults damage the plant by sucking the sap of young leaves and tender shoots.
- The pest serves as a vector for a toxic virus.
- The leaves curl upward becoming cup shaped, margins turn brown, dry and wither off prematurely
- Yellowing / drying of leaves all along the leaf margin ('hopper burn') due to injection of toxic virus.

Hopper burn symptom in leaves

Management

- Set up light traps and yellow sticky traps to destroy adult population.
- Sprinkler irrigation is effective in controlling the pest.
- Spray neem oil (3%) with fish oil rosin soap (2%). Safe period is 10-12 days.
- Cultivation of cluster bean, cowpea, black gram or groundnut as intercrops in mulberry encourage to build-up natural enemies like coccinellids and spiders.
- Spray 0.1% Dimethoate 30% EC (3ml/litre). Safe period is 25 days.

5) Spiralling whitefly, Aleurodicus dispersus Russell. (Homoptera: Aleyrodidae)

Period of Occurrence March - June and October - December.

Alternate host plants Mango, custard apple, apple, papaya, banana, sweet potato, cassava, avocado, guava, citrus, capsicum, brinjal, tomato, pepper, rose, hibiscus, coconut, etc.

Symptoms of pest attack:

- Majority of the feeding damage is done by the first three nymphal stages.
- The pest infests the lower surface of leaves resulting in chlorosis (paleness), yellowing and upward curling of the leaves.
- The honeydew produced by these insects will fall on the upper surface of the lower leaves which becomes a medium for developing sooty mould fungus, *Capnodium sp.*
- This in turn, interferes with photosynthetic process by not allowing enough light to reach the cytochrome tissues of the leaves.
- The sooty mould may also increase thermal absorption and raise leaf temperature, thus causing reduced leaf efficiency and further deterioration in the nutritional quality.

- Feeding spiralling whitefly infested mulberry leaves to silkworm will affect its growth and development which leads to adverse impact on cocoon production.

Spiralling whitefly affected mulberry plant & close view

Management

- Collection and destruction of pest attacked leaves.
- Adoption of recommended practices for spacing and fertilizer dose and use of yellow sticky trap can control the infestation
- Spray of a strong jet of water in the affected mulberry garden will help to reduce the pest population below economic injury level without applying any chemical insecticides.
- Removing alternate weedy host plants like Abutilon and cassia Auriculata and other weeds from the field and neighbouring area.
- Spray of 0.05% Dimethoate (1.75 ml in 1 litre of water). z Spray of 0.5% Neem oil mixed with soap solution at 1: 2 ratios.
- Release *S. coccivora* @ 500 adults or *Chrysoperla* @ 1000 eggs / acre, a week after the insecticides spray.
- Two parasitoids namely *Encarsia quadeloupae* and *Encarsia haitiensis* are known to parasitise *A. dispersus* in India.
- An egg predator *Axinoscymnus puttarudriahi* was identified and it could also be used to destroy the pest in egg stage itself.

6) Black scale insect, *Saissetia nigra* (Nietner) (Hemiptera: Coccidae)

Occurrence Though it is a minor pest occurs throughout the year, but severe during summer months.

Alternate host plants Attacks several crops like avocado, banana, chrysanthemum, citrus, coffee, cotton, crotons, guava, mango, pomegranate *etc.*

Damage and symptoms

- Both nymphs and adults suck the plant sap from the leaf as well as apical tender stem portion.
- Feeding results in yellowing of leaves, stunted growth of plants and affected shoots start drying from the distal
- end.

- The pest excretes copious amount of honey dew on which sooty moulds develop. This restricts photosynthesis and affects the nutritional value of the leaves.
- In case of severe infestation, the black sooty moulds pollute the plants of entire garden and make the leaf unfit for feeding silkworm.
- The movement of ants can also be noticed on the infested plants.


***S. nigra* infestation on stem Heavily infested mulberry garden**

Management practices

- Scrape the stem with the help of wooden plate to dislodge the insect.
- Swabbing the affected stem with diesel oil and soap emulsion (1:3 ratio) to dislodge the insect.
- Cutting and burning of infested plant parts.
- Spray strong jet of water to washout the crawlers and clean the sooty moulds.
- Spray 0.05% Dimethoate 30% EC (1.5 ml/litre) or 0.15% DDVP 76% EC (2 ml/litre). Safe period 12 & 15 days respectively.
- *Metaphycus helvolus* (Compere) is reported as effective parasitoid of *S. nigra*.

7) Soft scale insect, *Megapulvinaria maxima* (Green) (Hemiptera: Coccidae)

Occurrence This pest occurs in mulberry garden generally from August to February while peak incidence is found in October and November. It is more prevalent in hilly regions.

Alternate host plants *M. maxima* has been recorded from plants belonging to 24 genera in 15 families. However more incidences occur in Neem and *Jatropha*.

Symptoms

- Soft scale insect infests both leaves and twigs.
- Infestation of *M. maxima* can easily be identified by the presence of white scabs on the leaves and twigs.
- Nymphs and adult females ingest the plant sap by inserting its thread like mouth part which causes depletion of nutrient value of the leaves.
- A large amount of honeydew secreted by the pest invites fungal growth and development of black sooty mould on the leaf surface which interferes with the photosynthetic activities and reduces plant vigour.

Megapulvinaria maxima

Management practices

- Prune the infested shoots and destroy by burning.
- Spray strong jet of water to washout the crawlers and clean the sooty moulds.
- Spray 0.05% Dimethoate 30% EC (1.5 ml/litre) or 0.15% DDVP 76% EC(2 ml/litre). Safe periods 12 & 15 days respectively.
- Releases of predators like coccinellids and *Chrysoperla* control this coccid effectively.

B. Defoliators These insect pests possess the mouthparts especially adapted to biting and chewing of various plant parts mainly leaf and shoot tissues. These pests make shot holes in leaves, skeletonize them or defoliate the entire plants. Some common biting and chewing insect pests of mulberry are caterpillars, beetles and grasshoppers.

8) Leaf webber, *Diaphania pulverulentalis* Hampson (Lepidoptera: Pyralidae)

Occurrence The infestation is observed on the onset of monsoon i.e., from June and lasts up to February. Peak period of infestation is November to February.

Alternate host plants Mustard, turnip, radish, red beet, bean, soyabean.

Symptoms of pest attack and extent of damage

- The target area of the leaf webber is the apical portion of the mulberry shoot.
- The young caterpillar binds the leaflets together by silky secretion and settles inside and devours the soft green tissues of the leaf surface.
- Grown up caterpillars feed voraciously on tender leaves and its faeces can be seen over the leaves below the infested shoot.
- As this pest devour/ damage the apical shoot portion, growth of plants is affected which leads to adverse impact on leaf production.

Leaf webber on mulberry

Management practices

- Clip off infested portion along with the larva into polythene bag and destroy by burning or dipping in 0.5% soap solution (5 g of soap in 1 litre of water).
- Collect and burn the dry leaves to destroy pupae.
- Install light traps @ 1-2 trap/acre to attract adult moths and destroy them.
- Plant dry sticks in all the sides of the garden to attract birds which feed on the larvae.
- Deep ploughing exposes pupae to sunlight and natural enemies.
- Flood irrigation help to kill pupae.
- Spray 0.076% DDVP 76% EC (1 ml /litre) 12 to 15 days after pruning or leaf harvest safe period is 15 days.
- Release *Trichogramma chilonis* egg parasitoid from fifth day after chemical spray @ 1 Trichocard /acre / week for 4 weeks.
- Release of larval parasitoid *Bracon brevicornis* @ 200 adult wasps.
- Release pupal parasitoid *Tetrastichus howardii* @ 1 pouch /ac.
- After the release of these parasitoids, no insecticides should be sprayed in the garden.

9) Cutworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae)

Occurrence The cutworm incidence occurs from August to February, mainly in winter season.

Alternate host plants Cutworm is a polyphagous pest with a wide host range. Important host plants include tobacco, tomato, castor, beet root, carrot, cauliflower, capsicum, potato, radish, cotton, soyabean, cabbage, chickpea, sunflower, mustard, okra, maize, sorghum etc.

Damage and symptoms

- The caterpillars attack shoots of young mulberry plants and cut them, hence the name cutworm.
- The cut portion of the shoot dries up and falls off.
- They also feed on mulberry leaves voraciously.
- In heavily infested mulberry gardens, the plants are seen without branches and sometimes with dried leaves.

Different stages of *S. litura*

Management practices

- Collection and destruction of egg masses and gregarious early instar larvae.

- Digging up of soil around mulberry plants after pruning and dusting of 5-10% BHC around the base of the plant reduce the incidence by killing the lurking caterpillars. (Safety period of 45 days).
- Deep polughing of the field to expose the various stages of the pest
- Spraying 0.025 per cent parathion also controls the pests effectively (with a safe period of 8 days).
- Install light traps to attract and kill the adult moths.
- Use Spodolure, a pheromone trap @2 lures/acre twice at an interval of 15 days from 25th day after pruning to attract and kill male moths.
- Spray 0.15% DDVP 76% EC (2 ml/litre) during evening hours, 20 days after pruning Safe period is 15 days.
- *S. litura* is known to be attacked by many natural enemies at various life stages. Release of the egg parasitoid, *T. chilonis* is most promising.

10) Bihar hairy caterpillar, *Spilosoma obliqua* Walker (Lepidoptera: Arctiidae)

Occurrence Incidence of Bihar hairy caterpillar, S. obliqua in mulberry starts with the onset of monsoon. It occurs throughout the year in certain pockets. Peak infestation is seen during March to April and July to November.

Alternate host plants It is a polyphagous pest with a wide host range. Important host plants include amaranthus, cowpea, jatropha, groundnut, jute, sunflower, castor, cotton, green gram, bengal gram, maize, sun hemp etc.

Damage and symptoms

Gregarious young caterpillars feed upon the chlorophyll layer mostly on the under surface and skeletonize the leaves. However, late age caterpillars are voracious feeders, consume entire leaf and cause loss by way of defoliation. In severe cases, only stems are left behind

Spilosoma obliqua

Management practices

- Collect the egg masses, caterpillars, affected leaves and destroy them by dipping in 0.5% soap solution or by burning.
- Deep ploughing and flood irrigation to kill pupae in the soil.
- Install light traps to attract and kill the adult moths.

- To check the migration of caterpillars, prepare trench all around the mulberry plot. Keep poisonous baits inside the trench. (Preparation of baits: Dissolve 2kg of jaggery in 1 litre of water, add 20-25 kg of saw dust or wheat bran + 3 litre of water. To this add 250ml of nuvacron, mix well and allow it to ferment for 1 day)
- Spray of 0.1% Dimethoate 30 % EC (safe period 20 days) or 0.15% DDVP76% EC 20 days after pruning (safeperiod15 days).
- Release pupal parasitoid *Tetrastichus howardii* @ 1 pouch /ac.
- Release *T. chilonis* @ 1 trichocard per week after the spray of insecticide. Donot spray any insecticide after the release of parasitoids.

11) Tussock caterpillar, *Euproctis fraterna* (Moore) (Lepidoptera: Lymantriidae)

Occurrence The pest is active throughout the year but its activity is reduced in winter.

Alternate host plants It is a polyphagous pest which infests castor, cotton, sunflower, hibiscus, pear, sesame, brinjal, okra, red gram, cowpea, pomegranate, mango, chikoo, Ber, apple, jack, cinnamon, citrus, guava, coffee, tea, cocoa, rose wood, Sal, teak, papaya, *etc*.

Damage and symptoms

The neonate caterpillars feed gregariously on the epidermal tissues of the leaves by scraping the chlorophyll content resulting in the skeletonization of leaves. Later they cause the damage by feeding on the entire leaves. There may be a complete defoliation of plants, in case of severe infestation, the branches are seen without leaves.

Different stages of E. fraterna

Defoliation by *E. fraterna*

Management practices

- Collect the caterpillars along with affected leaves and destroy by burning.
- Install light traps to attract and kill the adult moths.

- Spray of 0.1% Dimethoate 30 % EC (safe period 20 days) or 0.15% DDVP76% EC 20 days after pruning (safeperiod15 days).

12) Wingless grasshopper, *Neorthacris acuticeps nilgriensis* Uvarov (Orthoptera: Acrididae)

Occurrence Incidence of this pest coincides with onset of monsoon and continues till post monsoon periods. However, peak infestation occurs during October and declines subsequently with no occurrence from January till onset of monsoon.

Alternate host plants Sunflower, finger millet, groundnut, beans, potato *etc*.

Damage and symptoms

- Both nymphs and adults feed voraciously on sprouting buds and leaves of mulberry.
- Sometimes, they also feed on green bark of affected plants.
- Branches of plants without leaves are observed in the mulberry garden in case of severe incidence.

N. acuticeps nilgriensis

Management practices

- During early morning hours, they are less active and hence can be collected and destroyed.
- Deep ploughing immediately after the onset of monsoon to expose egg masses to sunlight and predators.
- Field sanitation by keeping mulberry garden free from weeds which serves as alternate host plants.
- Spray 0.076% DDVP 76 % EC (1 ml/litre) on mulberry foliage to kill the nymphs and adults. If infestation is severe, need second spray, 10 days after first spray Safe period is 15 days.
- While spraying, take precaution to see that they will not jump and escape to neighbouring mulberry gardens. For this, spray in concentric circle manner for few rounds so that they will be trapped in some corner.

13) May-June beetle/ cock chafer bettles: *Holotrichia serrata* Fabricius (Coleoptera: Scarabaeidae)

Occurrence Their infestation coincides with the onset of monsoon and an occasional pest to mulberry crop in south India.

Alternate host plants Neem, ber, grapes, guava, moringa, mango, *Melia azadirachta*, rose, *Acacia*, Jamun, fig, *Ficus religiosa*, *Ailanthus*, tamarind, *Cassia fistula*, groundnut, maize, jowar, potato, bajra, sweet potato, tapioca, chilly, sugarcane, tobacco, coffee *etc*.

Damage and symptoms

- The early hatched grubs initially feed on organic matter and later start feeding on roots or rootlets thereby causing damage to the host plants. The adult beetles are observed feeding on the foliage.
- During night time, adult beetles enter mulberry garden in swarms and feed voraciously on the foliage, leaving only the stem portion.
- It appears as cow grazing and lot of small black faecal pellets appear below the plants.
- It is a serious pest on Bannur and Malavally areas of Karnataka, Udumalpete of Tamil Nadu and Marayoor of Kerala.

Holotrichia serrata

Management practices

- After first monsoon keep a vigil for adult beetles in the mulberry garden. Collect them and destroy by putting in kerosene solution.
- Installation of light trap and collection of adult beetles during night in kerosene mixed water.
- Tying up of few fresh neem branches (with leaves) to mulberry plants indifferent parts of the garden to attract the adults followed by their collection and destruction.
- Ploughing just before monsoon helps in exposure of various stages of the pest to natural enemies.
- Spray 0.2% DDVP 76% EC (2.5 ml/litre) with a safe period of 15 days preferably during evening hours.
- Drench the soil with 0.2 % Chlorpyriphos 20% EC to kill the grubs.

14) Green weevil, *Myllocerus viridanus* (Fabricius) (Coleoptera: Curculionidae)

Occurrence The weevils are found throughout the year but, more prevalent during summer season.

Alternate host plants Groundnut, bhendi, finger millet, brinjal, maize, sorghum, *etc.*

Damage and symptoms

Adults feed on leaves and buds whereas the grubs feed on the underground parts of plant. In case of severe attack plants wilt and dry up. Irregular serrated margin on the leaves are observed from the feeding by adults.


Weevil damage on mulberry

Management practices

- Ploughing helps in exposing all the life stages of weevils to scorching sun and natural enemies mainly the birds.
- Flood irrigation immediately after digging or ploughing helps in killing the eggs, grubs and the pupae.
- Apply Neem cake @ 500 kg/ha at the time of pruning of mulberry plants.
- Soil drenching with Chlorpyriphos 20%EC (2ml/litre) at the root zone help in reducing their population as well as damage.
- As many weeds serve as alternate hostplants mulberry garden should be kept weed free.

C. Borers The root/shoot feeders vary in size. They have prolonged life cycle. These pests are capable of boring into plant parts and destroy the tissues. Tunnelling by the borers may kill branches but rarely whole trees due to interruption of nutrient and water transport. Borers infestation is very difficult to identify at initial stage as they typically leave only tiny sized entrance holes and most part of their life cycle is spent inside the tunnel. The symptom is visible only when the frass comes out from the entry points or sap oozes out of the holes.

15) Mulberry longhorn beetle, *Apriona germari* Hope (Coleoptera: Cerambycidae)

Occurrence They occur throughout the year.

Alternate host plants Important alternate host plants of these beetles are fig, jack, apple *etc.*

Damage and symptoms

Apriona germari

During egg laying the stem tissues are partially damaged and hence twigs easily break due to wind. The grubs make tunnel all along the branches just beneath the bark or in the wood. All along the main gallery frass expulsion holes are visible at intervals. Severely attacked plants may die.

Management practices

- Infested shoots should be removed and destroyed by burning.
- Inject 0.1% DDVP 76% EC into the frass holes to kill the grubs.
- Swab the trunk and branches with a paste of 0.1% malathion 50% EC to avoid egg laying.

16) Stem girdler, *Sthenias grisator* (Fabricius) (Coleoptera: Cerambycidae)

Occurrence It is noticed throughout the year.

Alternate host plants Major alternate host plants are casuarina, mango, jack, crotons, grapes *etc*.

Damage and symptoms Girdling of the young or green stem and subsequent wilting are the main symptoms of infestation. Such stems get dried up which enable the grubs to tunnel into the dry wood. Such affected branches will die soon.


Adult beetle on mulberry stem


Mulberry stems attacked by *S. grisator*

Management Practices

Cutting and burning of affected branches.

Swab the trunk and branches with paste of 0.1% malathion 50% EC to avoid egg laying.

D. Soil inhabiting insect pest

17) Termites, *Odontotermes sp.* (Isoptera: Termitidae)

Occurrence They occur when rain recede or from October onwards and continues till the onset of monsoon rains.

Alternate host plants Termites are highly polyphagous insects attacking all most all the agricultural, horticultural and forest tree plants.

Damage and symptoms

Termite damage is mainly observed in rainfed gardens. In mulberry nursery and new plantation, they attack below ground portion. They feed on the bark and hardwood. Hence, cuttings dry up and no sprouting takes place. In old plantations, they first infest the dry twigs. Later they slowly move to live twigs. They form foraging galleries inside the main stem and extending below the ground. In case of pruned plants, they form a sheath around the twigs and feed on them. Thus, they affect the sprouting buds.

Termite attack on mulberry plants

Management practices

- Remove the dead and dried twigs and leaves.
- Flood irrigation help in keeping termites away.
- Locate the termite mounds if any nearby mulberry gardens and destroy by breaking mounds and kill the queen. When once the queen is killed or destroyed the colony gets abandoned by them.
- Prepare a solution of Chlorpyriphos20% EC @ 3ml/litre and pour into the mound followed by closing the mound hole with wet earth.
- In established plantation, soil drenching with 0.1% Chlorpyriphos 20% EC to be practiced.
- Treat the mulberry cuttings with 0.1%Chlorpyriphos 20 % EC solution before planting.

Conclusion:

Success of silkworm rearing mostly depends upon quality and quantity of mulberry leaves. Mulberry plant have been found attacked by some major pests. This results in severe economic losses to the sericulture farmers. Several control measures (mechanical, physical, cultural, chemical and biological) are recommended to reduce the loss caused by the pests.

Before adopting control methods, it is necessary to have knowledge on correct identification of pests based on their symptoms of attack, extent of damage and type of control methods to be selected. Mulberry ecosystem is ideal to implement biological control of pests because of its perennial nature. Moreover, the usage of high potent insecticides on a crop like mulberry is practically impossible due to their sensitivity to silkworms. Therefore, the biological method plays a significant and indispensable role in managing key pests of mulberry.

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LAC INSECT AND ASSOCIATED FAUNA

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Abstract:

Lac cultivation is an important source of income for livelihood of forest and sub-forest dwellers in different states and also generates employment for many people. Lac insects are commercially important species for resin, dye and wax production. Those secreted products are the most valuable gifts of the nature to mankind. Being the sedentary nature of lac insect, more vulnerable to be attacked by number of pests and diseases. The present chapter look into how the lac insects are associated with different fauna like insects and non-insects. Predators attack more compared to parasites and non-insects on lac insects. Among them, *Eublemma amabilis* is the one which attack and destroy more on the lac insect, cells and secreted product. Few hyper parasitoids like *Agathis*, *Perisierola sps* etc protect lac insects against natural enemies of lac insects. In this chapter, specifically focused on how the different fauna attacking host insect which can help in understanding to control those natural enemies of lac insect.

Keywords: Lac insect, predators, parasitoids, fauna, hyper parasitoids

Introduction:

Lac insects are known as solitary animals with a significant ability to produce natural resin. The natural product produced is called lac, which is composed of three main components such as lac resin, wax, and dye (Kandasamy *et al.*, 2022; Netam *et al.*, 2021). India is endowed with rich wealth of lac insect resources where 27.7% lac insect biodiversity reported from the world is found in our country under two genera i.e., *Kerria* and *Paratachardina*. Members of the genus *Kerria* (Hemiptera, Coccoidea: Tachardiidae), recorded with 29 species worldwide (Bashir *et al.*, 2021), 24 species are found in India (Garcia *et al.*, 2016) of which *K. lacca* species is most widely cultivated for commercial lac production. Lac insects are largely immobile, plant feeding for most of their life. Additionally, their ability to produce resin varies at different stages except adult males and crawlers which do not produce resin while, fertilized adult females and settlers produce resin (Thamilarasi and Sharma 2019). The cultivation of lac mainly contributes to the economic well-being of the forest and sub-forest communities in Jharkhand, chattisgarh, M.P, west Bengal, Maharashtra, odisha, A.P and NEH region. Lac is primarily produced in country India followed by Indonesia, Thailand and China. India takes the lead as the foremost global producer of lac, contributing significantly to the world's total production of 18,944 tons in the 2019-20 period. Among the states engaged in lac cultivation, Jharkhand plays a noteworthy role with 10343 tons of lac production followed by Chhattisgarh (3478 tons), Madhya Pradesh (2468 tons), Maharashtra, and West Bengal (Yogi *et al.* 2021).

The lac insect is categorized into two subspecies or strains known as Kusumi and Rangeeni, distinguished by variations in their host preference, life cycle, and the quality of lac they produce. The Rangeeni strain is identified by an uneven duration of the bivoltine and a lack of preference for kusum as a host. In contrast, the Kusumi strain is characterized by a more or less equal duration of the life cycle and a preference for kusum as a host (Vasantharaj and Ramamurthy, 1975).

Composition of lac:

Lac resin –	75%
Lac wax –	6%
Lac dye-	5-6%
Others-	12-13 %

About 1.5 lakh insects produce 1 lb of lac

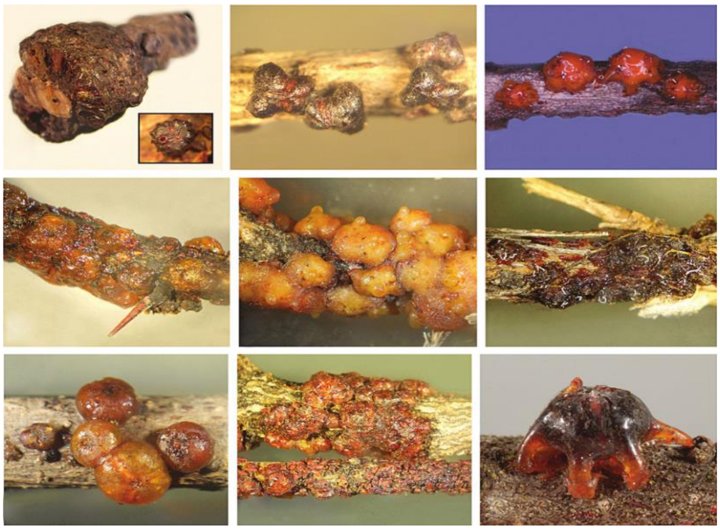

Figure 1: Some lac insects known from the World (Kondo and Gulla, 2011)

Life cycle:

Female lac insect deposits eggs within the encrustation, and upon hatching, nymphs emerge from the cell by crawling out. From an encrustation, the nymphs may continue to emerge for two to three weeks but most of the nymphs come out during the first five days. A single female can produce 300 to 1000 nymphs of which one-third of them being males. Nymphs are minute, about 0.6mm long, soft-bodied, pointed posteriorly, deep red with black eyes and three pairs of legs, antennae have a pair of long thin hairs at their apices and the posterior end of abdomen possesses small bent tube and a pair of thin hairs. As the nymphs wander along the shoots, their primary movement is directed upward towards the tender branches, where they eventually settle. The settling rate is observed to be between 44 and 103 individuals per square centimeter. Once they find a suitable spot, the nymphs anchor themselves by piercing the shoot and remain stationary thereafter. Within two days of settling, they initiate the process of resin secretion, covering their bodies. The resin glands are distributed across the cuticle except near the mouth parts, breathing pores and anus. Notably, the resinous coating expands proportionally with the insect's growth. The nymph moults thrice and becomes an adult. After the first moult, nymphs of both females and males lose their antennae, eyes and legs but the males regain them. After the second moult, nymphs of female undergo swelling without any discernible segmentation. The posterior end of insect abdomen bends upward, resulting in rounded form that occupies the entire space within the cell. Males may exhibit winged or wingless after emergence and live for three or four days only. Even at the initial stages of growth, the female and male cells are distinguishable since the former has grown up along its vertical axis resulting in spherically shaped appearance and later grows along its longitudinal axis with slipper-shaped.

The male engages in copulation with the female even while the female remains inside the cell. A copulated female grows up very fast and secrets lac abundantly and size of the insect and the cell reach several times that of the male cell. Thus, the female insects are the chief producers of lac. At the time of oviposition, the anal tubercle is withdrawn and eggs are laid inside the cell. As the eggs are laid the female shrinks in size leaving some space at the posterior half of the cell. Oviposition, period of incubation, and emergence of nymphs are all greatly influenced by temperature. Egg laying ceases when the temperature inside the lac cell falls below 17^{o}C and the nymph becomes inactive at temperatures below 20^{o}C (Mohanasundaram *et al.*, 2016)

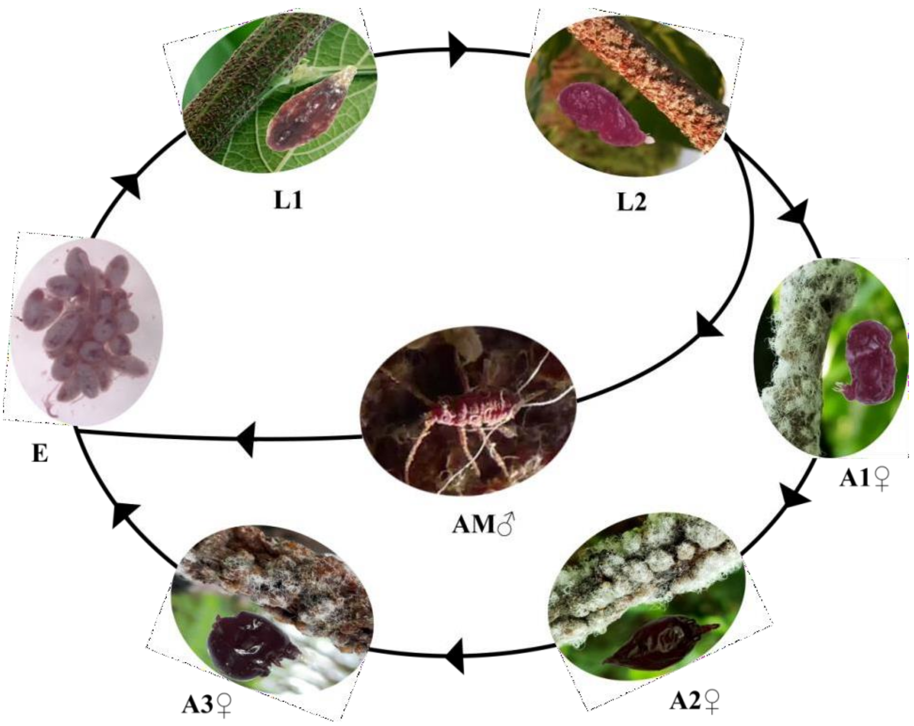

Figure 2: Life cycle of lac insects: females and males are morphologically different from each other. Showing eggs (E), early instar larvae (L1), late instar larvae (L2), early adult (A1), mid adult (A2), late adult (A3), and adult male (AM) (Bashir *et al.* 2022).

Importance:

The uses of the secretions of the insect was known to man from the prehistoric time. Cultivation of lac involves a seasonal, part-time agroforestry endeavor that can be cultivated on wild or cultivated host trees. To maximize sticklac yields, it is essential to focus on insect cultivation, carefully manage host trees, and pay attention to parasite control. Lac production in some traditional lac production catchment is decreasing due to effects of various parasites, predators and pathogens. Attack of enemy insect and diseases are the important reasons of reduction in lac production. On an average 30-40% lac crops are damaged due to attack of enemy insect (Malhotra and Katiyar,1979). There are several parasites and predators of lac insects and another set of parasites of lac predators which are intimately associated with each other in the biotic complex (Srivastava, 1980; Jaiswal, 2001).

Foes (Enemies):

Trophic level status	Order	Family	Fauna
Predators	Lepidoptera	Noctuidae	*Eublemma amabilis*
			Catablemma sumbavensis
			E. coccidiphaga
			E. cretacea
			E. roseonivea
			E. scitula
		Blastobasidae	*Pseudohypatopa pulverea*
		Cosmopterygidae	*Pyroderces falcatella*
		Heliodinidae	*Oedematopoda* sp.
			Stathmopoda theoris
		Momphidae	*Lacciferophaga yunnanea*
		Phycitidae	*Cryptoblabes ephestialis*
		Pyralidae	*Ephestia* sp.
	Blattodea	Blattellidae	*Ischonoptera fulvastrata*
			Phyllodromia sp.
			Phyllodromia humbertiana
	Neuroptera	Chrysopidae	*Chrysopa* sp.
			Chrysopa madestes
			C. lacciperda
	Coleoptera	Cucujidae	*Silvanus iyeri*
		Silvanidae	*Oryzaephilus surinamensis*
		Tenebrionidae	*Tribolium ferrugineum*

	Diptera	Syrphidae	*Episyrphus viridaureus*
			Eupeodes sp.
			Sphaerophoria sp.
		Mycetophagidae	*Berginus maindroni*
		Tephritidae	*Bactrocera*
Parasitoids	Hymenoptera	Eulophidae	*Aprostocetus purpureus*
			Mischotetrastichus sp.
			Necremnus leccarthros
		Aphelinidae	*Coccophagus tschirchii*
			C. nigropleurum
			C. scutatus
			Eurymyiocnema aphelinoides
			Marietta javensis
		Braconidae	*Aphrastobracon flavipennis*
			Bracon sp
			Bracon greeni
			Campyloneurus indicus
			Cotesia sp.
			Dolichogenidea sp.
		Cecidomyiidae	*Cecidomyid* sp.
			Dentifibula lacciferi
		Encyrtidae	*Aenasiella africa*
			Anicetus dodonia
			Atropates hautefeuilli
			Erencyrtus dewitzi
			Lyka lacca
			Parageniaspis indicus
			Tyndarichus clavicornis
			Protyndarichus submettalicus
			Tachardiobius nigricans
			Tachardiaephagus tachardiae
			Thomsonisca sp.
		Entedontidae	*Holcopelte* sp.
		Mymaridae	*Camptoptera* sp.
		Pteromalidae	*Pteromalus* sp.

		Scatopsidae	*Scatopse* sp.
		Eutorymidae	*Plutarchia indefensa*
		Halticidae	*Sphecodes* sp.
		Ichneumonidae	*Diplazon lactatorius*
		Torymidae	*Pseudotorymus* sp.
		Pteromalidae	*Pachyneuron ahlannse*
			Pachyneuron aphidis
			Pachyneuron stom
			Pteromalus pupareum

Two categories of enemies Insects and Non-insects. These are more serious causing about 40% loss. The predator moths and fly lay their eggs on the lac encrusted twigs. Upon hatching, their larvae penetrate the lac encrustation, consuming both the lac encrustations and lac insects. White lac moth (*E. amabilis)* is particularly destructive to trees, whereas, black lac moth poses a greater threat to stored lac (Sujatmoko, 2009). White lac moth is responsible for causing substantial damage to the lac insects rather than other insect enemies. It alone contributes to at least 30-35% of the overall damage caused by predators. A single white lac moth larva causes damage to 46 mature cells before pupation. It not only destroys the lac insect but also eats the lac encrustation (Rahman *et al.*, 2009). *Chrysopa* larvae suck the body fluid of the lac insect without consuming the lac itself.

Parasites are small winged insects belonging to order hymenoptera and family chalcididae. They lay their eggs in the lac cells and the grubs on hatching devour lac insects inside the cells. They cause 5-10%loss. The lac insect is vulnerable to vertebrate predators including monkeys, rats, squirrels, lizards, birds, and woodpeckers (Mohanta *et al.,* 2014). Among these, rodents cause a significant damage by gnawing on mature lac encrustations on trees or brood lac sticks tied for inoculation and resulting in the consumption of gravid females. Moreover, these animals can cause brood lac to fall to the ground, hindering the inoculation process (Singh, 2007).

Friends:

Hyper parasitoids	Bethylidae	*Perisierola* sp.	*Pseudohypatopa pulverea*
			P. pulverea
	Braconidae	*Agathis bischoffi*	*P. pulverea*
		A. coryphe	*P. pulverea*
		A. festiva	*P. pulverea*
		Apanteles angaleti	*P. pulverea*
		Apanteles fakhrulhajiae	*P. pulverea*
		A. tachardiae	*P. pulverea*
		Aphrastobracon	*Eublemma amabilis,*

		flavipennis	*E. coccidiphaga,*
		Bracon greeni	*E. amabilis, P. pulverea*
		B. hebetor	*E. amabilis, P. pulverea*
		B. tachardiae	*E. amabilis*
		Cedria paradoxa	*E. amabilis*
		Chelonus sp.	*P. pulverea*
		Chelonella cyclopyra	*P. pulverea*
		Phaneratoma buchneri	*P. pulverea*
	Cerephronidae	*Conostigmus* sp.	*Chrysopa madestes*
	Chalcidae	*Brachymeria tachardiae*	*E. amabilis, P. pulverea*
	Elasmidae	*Elasmus albomaculatus*	*P. pulverea*
		E. claripennis	*E. amabilis*
		E. colemani	*E. amabilis*
		E. indicus	*E. amabilis*
	Encyrtidae	*Anagyrus breeni*	*C. madestes*
		Cheiloneurus sp.	*C. madestes, C. lacciperda*
		Thomsonisca sp.	*Encyrtid parasitoids*
		Tyndarichus sp.	*E. amabilis* and *P. pulverea*
	Eupelmidae	*Brasema annulicaudis*	*E. amabilis*
		Eupelmus tachardiae	*E. amabilis, P. pulverea*
	Eurytomidae	*Eurytoma pallidiscapus*	Pupae of *P. pulverea*
	Ichneumonidae	*Pristomerus sulci*	*P. pulverea*
	Trichogrammatidae	*Trichogramma* sp.	*E. amabilis, P. pulverea* eggs
	Scelionidae	*Telenomus* sps.	*C. lacciperda, C. madestes*
	Perilampidae	*Perilampus* sp.	*C. lacciperda*

Management:

- Insecticides targeting the larval stage of predators of lac insects (*Chrysopa lacciperda*) like Lamda cyhalothrin, indoxacarb, carbosulfan, alphamethrin, Spinosad, fipronil, and ethonofenprox (Singh *et al.*, 2011).
- *Eublemma* predator has several natural enemies such as *Componotus Compressus* (the big black ant) and *Solenopsis Geminata* (small red ant) pick up the larvae when they come out from the egg shell and tries to enter the cells by biting at the encrustation.

- The parasite, *Bracon greeni* has is an ectoparasite of the lepidopteran, *E. amabilis* larvae.
- Brood lac should be removed as soon as the tree is sufficiently covered by the lac insects in order to prevent continuation of the life cycle of *E. amabilis* which could attack crop during swarming period.
- Use brood that is free from selected predators and parasites for each crop. Self inoculation should be avoided.
- Immerse the entire crop, excluding the portion intended for use as brood lac, in water for 2-4 days. Subsequently, remove the crop and let it dry thoroughly, mostly in the shade. Upon examination, the sticks will be revealing the absence of any living predators or parasites.
- In India, *Trichogramma achaeae, T. exiguum, T. brasiliense, T. chilonis, T. poliae, T. ostrinae* and *T. pretiosum* were highly effective against the eggs of *Eublemma amabilis* and *Pseudohypatopa pulverea*. The population of insect predators was reduced by more than 75% using the egg parasitoids.
- Delfin, a commercial formulation of *Bacillus thuringiensis* subspecies *kurstaki* was highly effective against *E. amabilis* and *P. pulverea*. The biopesticide reduced the incidence of lac insect predators and enhanced the yield of lac (*Kerria lacca*).
- Essential oils extracted from *Cymbopogon citratus* (lemongrass), *C. nardus* (citronella) and *C. martini* (palmarosa) also exhibited excellent repellent activities against these lepidopteran predators. *Cassia occidentalis*, which harboured the eggs of *Catopsilia pyranthe*, a preferred alternative host for *Trichogramma chilonis*, increased the *Trichogramma* population in the lac ecosystem when planted along with bushy lac host plants.
- The *Chrysopa* spp. infesting kusmi lac raised on *Schleichera oleosa* were trapped using light traps (Bhattacharya *et al.*, 2008).
- Use only healthy, pest-free brood lac for inoculation. Cut twigs for inoculation just before swarming to ensure the brood's health. Harvest the entire crop, as any leftovers may attract pests.
- Fumigate or submerge the stick or phunki lac to eliminate any pests. Promptly remove encrusted lac from twigs and immediately process the obtained lac into seed lac, avoiding leaving it near the inoculated lac hosts. Infected stick lac, along with predators and pests, should be eradicated (Singh, 2007).

Conclusion:

The lac insect, faces a dynamic ecosystem of predators, parasitoids, and hyperparasitoids. Predators like ladybugs and birds feed on the lac insect directly, helping to control its population. Parasitoids, such as wasps and flies, lay their eggs inside the lac insect, ultimately leading to its death. Hyperparasitoids further complicate the web, targeting the parasitoids themselves. This intricate interplay highlights the complex balance within the lac insect's ecosystem. Conservation measures and sustainable practices are crucial to ensure the lac insect survival and maintain the ecological equilibrium.

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BIODIESEL: A SUSTAINABLE FUEL FOR FUTURE GENERATIONS

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Abstract:

Biodiesel, as a sustainable alternative to fossil fuels, holds critical importance in addressing contemporary environmental challenges. Biodiesel is derived from organic sources, making it renewable and reducing our reliance on finite fossil fuel reserves and significantly lowers greenhouse gas emissions, mitigating climate change and improving air quality. Its lower sulphur content reduces harmful pollutants, and its biodegradability makes it less harmful in the event of spills. Although biodiesel necessitates certain engine modifications, its capacity to improve engine efficiency and minimize wear is remarkable. Overall, biodiesel stands as a vital and eco-friendly solution in the global effort to transition towards cleaner and more sustainable energy sources, ensuring a greener and more environmentally responsible future.

Keywords: Biodiesel; Alternative Fuel; Conventional Fuel; Environment Sustainability; Biofuels.

Introduction:

The increasing demand for alternative fuels is driven by a combination of environmental, economic, and energy security concerns. As concerns about climate change and air quality rise, there is a pressing need to reduce carbon emissions and dependence on finite oil reserves. Renewable energy technologies harness the power of nature to generate clean and sustainable electricity. Solar panels capture the sun's energy, wind turbines convert wind into power, and hydropower systems utilize the flow of water to produce electricity. These technologies offer numerous benefits, including reduced greenhouse gas emissions, energy independence, and long-term cost savings. With ongoing advancements in efficiency and affordability, renewable energy technologies are playing a pivotal role in the global transition to a greener and more environmentally responsible energy landscape. Alternative fuels, such as biofuels, hydrogen, and electric power, offer cleaner and more sustainable energy sources. Additionally, advancements in technology and government incentives have made these alternatives more accessible and affordable. As a result, businesses and individuals alike are increasingly embracing alternative fuels to mitigate their carbon footprint and secure a more sustainable energy future.

Biodiesel is a renewable and sustainable alternative to traditional diesel fuel, primarily derived from organic sources such as vegetable oils, animal fats, or recycled cooking oils. It is produced through a chemical process called transesterification, which breaks down these feedstocks into biodiesel and glycerine. Biodiesel is considered an eco-friendlier option because it produces fewer greenhouse gas emissions than conventional diesel, reduces dependence on fossil fuels, and can be used in existing diesel engines with little to no modification. Its versatility and potential to be produced from various feedstocks make it a promising component in the quest for cleaner transportation fuels, especially in efforts to mitigate climate change and reduce pollution.

Biodiesel production

The production of biodiesel involves a chemical process known as transesterification, where triglycerides (fats and oils) are converted into biodiesel and glycerol. Environmental and economic sustainability are critical considerations in biodiesel production, as the choice of feedstock, production methods, and the impact on land use can have significant effects on its overall carbon footprint and economic viability. Sustainable practices, such as using waste oils or non-food feedstocks and minimizing land-use change, are encouraged in the biodiesel industry to reduce its environmental impact.

Here are the key steps involved in biodiesel production:

- **Feedstock selection:** The first step in biodiesel production is choosing a suitable feedstock. Common feedstocks include vegetable oils (such as soybean, canola, sunflower, and palm oil), animal fats (such as tallow), and used cooking oil.

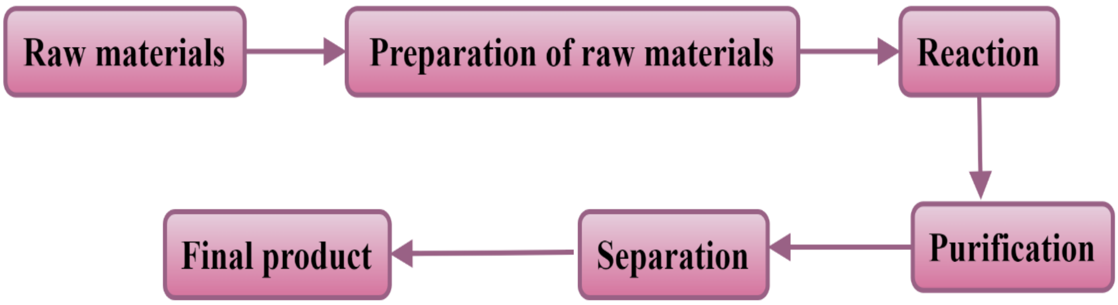
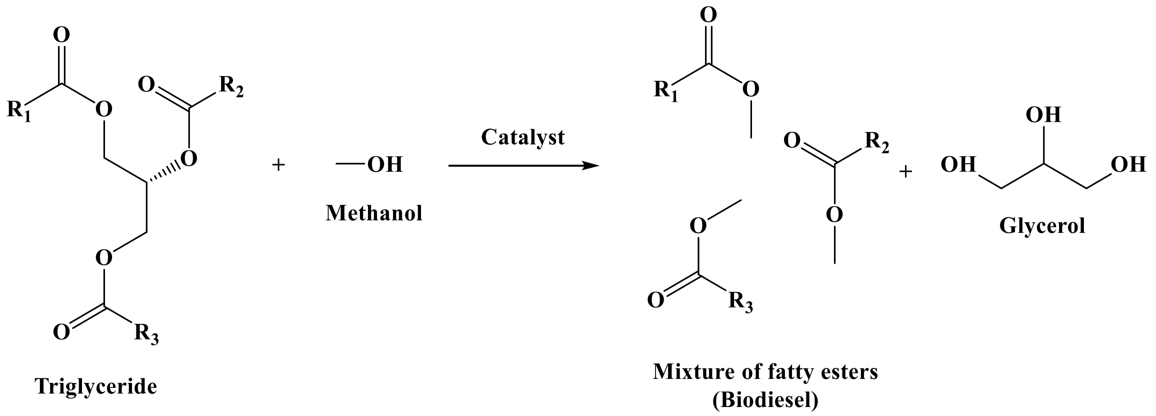


Figure 1: Biodiesel Production

- **Pretreatment:** The selected feedstock may undergo pretreatment to remove impurities, moisture, and free fatty acids. This step helps improve the efficiency of the transesterification process.
- **Transesterification:** Biodiesel production typically starts with triglycerides, which are the main components of fats and oils. Triglycerides consist of three fatty acid chains attached to a glycerol molecule. The main chemical reaction involved in biodiesel production is transesterification. In this process, the triglycerides in the feedstock are reacted with an alcohol (typically methanol or ethanol) and catalyst to speed up the reaction. The catalyst usually are acids (HCl, H_2SO_4, H_3PO_4, and sulfonic acid), alkalis (KOH, CH_3ONa, and NaOH), and enzymes (Lipase) initiates the cleavage of the fatty acids from the glycerol backbone and the formation of biodiesel. This reaction breaks the triglycerides into biodiesel (methyl or ethyl esters) and glycerol.

The general reaction equation for transesterification is as follows:

Triglyceride + Alcohol + Catalyst → Biodiesel (Methyl/ethyl Esters) + Glycerol



Scheme 1: Transesterification (Biodiesel production)

The product of transesterification is a mixture of biodiesel molecules, which are typically methyl esters of fatty acids. Biodiesel molecules have a similar structure to diesel fuel and can be used as a direct replacement or blend with conventional diesel fuel.

- **Separation and washing:** After the transesterification reaction, the mixture contains biodiesel, glycerol, unreacted alcohol, and other impurities. This mixture is typically allowed to settle, and then the glycerol layer is separated from the biodiesel layer. Glycerol is a co-product of the transesterification reaction. It is a simple polyol compound and can be used in various industrial applications. The biodiesel is washed multiple times with water to remove remaining impurities and traces of alcohol.
- **Drying:** The washed biodiesel is dried to remove any remaining water, which can lead to fuel quality issues and engine problems if not removed.
- **Biodiesel quality testing:** Quality control tests are performed to ensure that the biodiesel meets the required standards and specifications, including properties such as the determination of viscosity, acid value, moisture content, flash point, cloud point and the presence of contaminants.
- **Storage and distribution:** Once the biodiesel passes quality tests, it is stored and distributed for various applications, including blending with petroleum diesel, or using it as a standalone fuel in diesel engines.

The specific chemistry and process parameters may vary depending on the feedstock used (vegetable oils, animal fats, etc.) and the desired properties of the biodiesel. Additionally, biodiesel can be blended with conventional diesel fuel in various proportions to create biodiesel blends (e.g., B5, B20), which can be used in diesel engines without modification.

Physical and chemical properties of biodiesel:

Biodiesel, as an alternative fuel derived from organic sources, has distinct physical and chemical properties.

Physical properties:

- Appearance: Biodiesel typically appears as a clear or slightly yellowish liquid.

- Density: Biodiesel is denser than petroleum diesel, with a density around 0.88 to 0.92 grams per millilitre (g/mL).
- Cetane Number: Biodiesel has a higher cetane number, which indicates better ignition quality. This can lead to smoother engine operation and lower emissions.
- Viscosity: It has a higher viscosity compared to petroleum diesel, which can impact fuel flow and atomization in engines. This can be addressed by blending with other substances or through engine modifications.
- Flash Point: Biodiesel has a higher flash point, making it less flammable than petroleum diesel. This can be a safety advantage.

Chemical properties:

- Oxygen Content: Biodiesel contains oxygen in its chemical structure, which can lead to better combustion and reduced emissions of certain pollutants.
- Chemical Composition: Biodiesel is composed of fatty acid methyl esters (FAME), which are typically produced from triglycerides found in vegetable oils, animal fats, or recycled cooking oil.
- Sulphur Content: Biodiesel is essentially sulphur-free, resulting in lower sulphur dioxide emissions compared to conventional diesel fuels.
- Glycerine: During the transesterification process used to produce biodiesel, glycerine is produced as a byproduct. Proper glycerine separation is essential to maintain fuel quality.
- Cold-Flow Properties: Biodiesel may have issues with gelling in cold temperatures, depending on the feedstock used and the blend. Blending with petroleum diesel or adding cold flow improvers can address this.
- Biodegradability: Biodiesel is biodegradable and less harmful to the environment in case of spills or leaks.
- Corrosiveness: Biodiesel can be more corrosive to certain materials, particularly some elastomers and seals in older fuel systems. This may necessitate material compatibility adjustments in older engines.
- Storage Stability: Biodiesel can degrade over time due to oxidation, and it may be susceptible to microbial contamination if not properly stored.

Advantages of biodiesel

Biodiesel produces fewer greenhouse gas emissions compared to traditional diesel, reducing the overall carbon footprint. It also emits fewer harmful pollutants, such as sulphur and particulate matter, which contributes to better air quality. Its prospects look promising due to several key factors:

- Biodiesel is biodegradable and non-toxic, making it less harmful to the environment in case of spills or accidents.
- **Renewable resource:** Biodiesel feedstocks, such as soybean oil, canola oil, and palm oil, are renewable resources that can be replenished through sustainable farming practices.

The use of waste and recycled cooking oils for biodiesel production reduces waste and maximizes resource utilization.

- **Energy security:** Biodiesel can be produced domestically, reducing a country's dependence on imported fossil fuels, and enhancing energy security.
- **Economic opportunities:** The biodiesel industry supports jobs in agriculture, processing, and distribution, contributing to local and national economies. As demand for biodiesel grows, it can stimulate economic growth in rural areas by creating new markets for agricultural products.
- **Technological advancements:** Ongoing research and development are improving the efficiency and cost-effectiveness of biodiesel production methods. Advanced technologies like algae-based biodiesel and enzymatic transesterification hold promise for even more sustainable and scalable production.
- **Reduced price volatility:** Biodiesel prices are often more stable than those of fossil fuels, as they are less influenced by geopolitical events or fluctuations in oil markets.

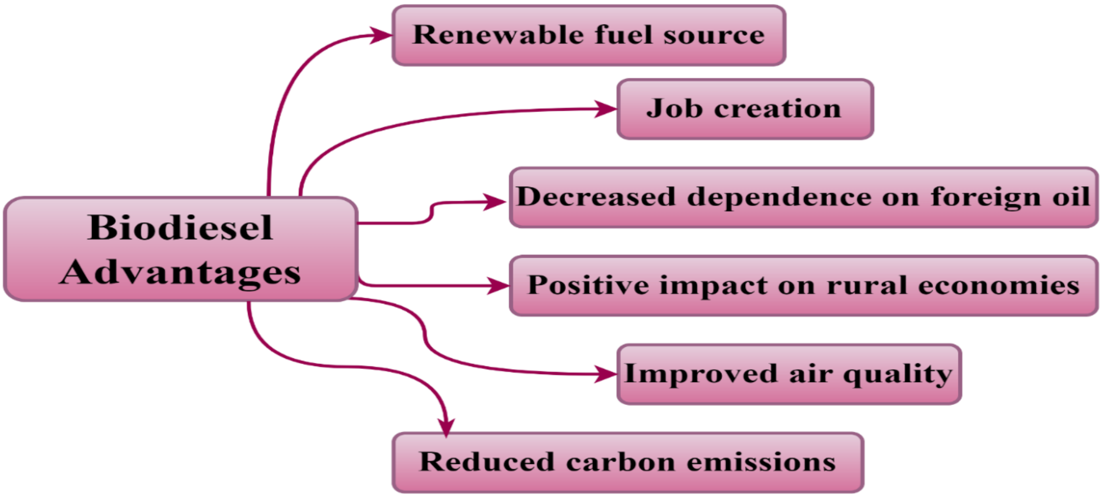


Figure 2: Biodiesel Advantages

- **Government support and regulations:** Many governments worldwide are implementing policies and incentives to promote biodiesel production and consumption, such as tax credits, mandates, and subsidies. These regulations encourage investment in biodiesel infrastructure and stimulate market growth.
- **Compatibility with existing infrastructure:** Biodiesel can be blended with petroleum diesel at various ratios (e.g., B5, B20), and most diesel engines can run on biodiesel without modification. This makes it a practical and accessible alternative.
- **Sustainable certification:** Certification programs like the Roundtable on Sustainable Palm Oil (RSPO) and the International Sustainability and Carbon Certification (ISCC) help ensure the responsible and sustainable production of biodiesel feedstocks.

Biodiesel and conventional diesel fuel (often referred to as Petro diesel) have several key differences in their properties. Here is a comparison of these two types of fuels:

Property	Biodiesel	Conventional Diesel Fuel
Source	Organic (vegetable oils, animal fats, recycled cooking oil)	Crude oil (fossil fuel)
Environmental Impact	More environmentally friendly, lower emissions	Higher greenhouse gas emissions, air pollution
Flash Point	Higher, less flammable	Lower, more flammable
Sulphur Content	Virtually sulphur-free	Contains sulphur, air pollution contributor
Cetane Number	Typically higher, better ignition quality	May have a lower cetane number, variable quality
Viscosity	Higher, may require modifications or blending	Lower, flows more easily
Lubricity	Good lubricity properties	May require additives for lubrication
Cold-Weather Performance	Gels at higher temperatures, may require blending or additives	Performs better in cold temperatures without gelling issues
Biodegradability	Biodegradable, less harmful in spills/leaks	Less biodegradable
Engine Modifications	May require minor modifications, material compatibility adjustments, and fuel system upgrades	Typically, compatible with most diesel engines without major modifications.

This table summarizes the key differences between biodiesel and conventional diesel fuel, emphasizing their sources, environmental impact, physical and chemical properties, and engine-related considerations.

Challenges

Despite the advantages, biodiesel is not without challenges. The availability and sustainability of feedstocks, land use changes, and competition with food production are some of the concerns associated with its production. Additionally, the energy balance of biodiesel, including the energy required for farming, processing, and transportation, should be considered to assess its overall environmental impact. While biodiesel offers several advantages, it also faces several challenges:

- Feedstock availability: The primary feedstocks for biodiesel production are vegetable oils and animal fats. The availability and cost of these feedstocks can fluctuate, making biodiesel production less economically competitive compared to fossil fuels when feedstock prices are high.

- Land use and competition with food production: Biodiesel production can compete with food production for land and resources. Using large swaths of agricultural land for biodiesel feedstock crops can lead to concerns about food security and deforestation.

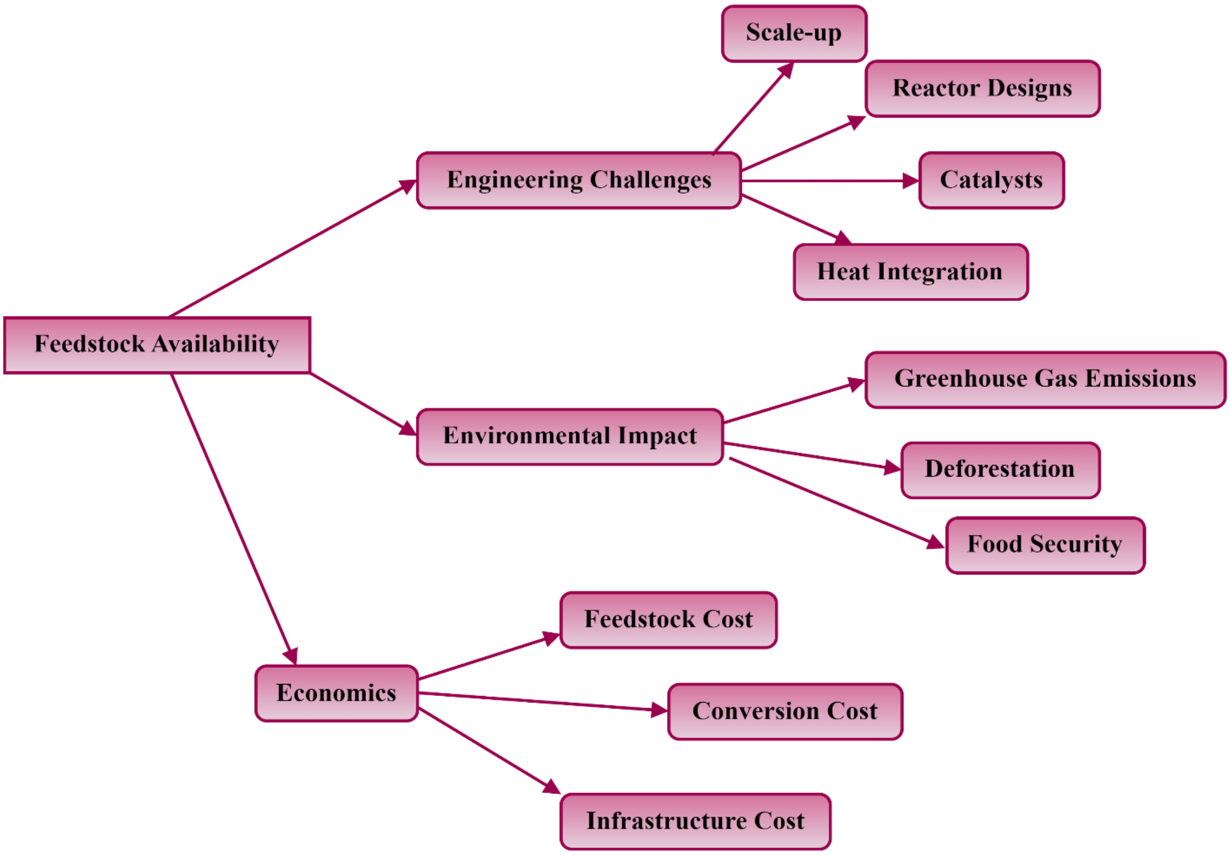


Figure 3: Challenges for Biodiesel Production

- Cold weather performance: Biodiesel has poorer cold-weather performance compared to petroleum diesel as it can transforms to gel at low temperatures, which can cause engine issues in cold climates. This requires additional processing or blending with additives to improve cold-weather performance.
- Energy intensive production: The production process for biodiesel can be energy-intensive, particularly if it involves growing and harvesting feedstock crops, as well as the conversion process itself. This can limit the overall energy efficiency and environmental benefits of biodiesel.
- Limited feedstock options: The choice of feedstocks is somewhat limited, and the selection of suitable feedstock can depend on local climate and soil conditions. Expanding the range of feedstock options can improve biodiesel's sustainability and availability.
- Engine compatibility: Biodiesel can cause compatibility issues in older diesel engines due to its different chemical properties. Engine manufacturers have developed biodiesel-compatible engines, but older vehicles may require modifications or retrofits.

- Fuel infrastructure: The infrastructure for distributing and storing biodiesel is less widespread than that for petroleum diesel. Increasing the availability of biodiesel at fuelling stations is essential for its widespread adoption.
- Quality control: Ensuring consistent biodiesel quality is crucial. Variations in feedstock and production processes can lead to varying fuel quality, which can impact engine performance and emissions.
- Environmental concerns: While biodiesel is considered more environmentally friendly than petroleum diesel in terms of greenhouse gas emissions, there are concerns about its environmental impact when it comes to land use, water usage, and potential soil degradation.
- Policy and regulatory challenges: Biodiesel production and distribution are influenced by government policies and regulations. Changes in policies, incentives, or regulations can significantly impact the biodiesel industry's growth and stability.

Efforts to address these challenges include research into alternative feedstocks, improvements in production processes, and the development of more efficient engines and infrastructure. Additionally, government incentives and renewable fuel standards can play a role in promoting biodiesel adoption.

Optimization strategies required for biodiesel use:

Biodiesel can generally be used in diesel engines with minimal modifications, but some engine adjustments and optimization strategies may be advisable to ensure optimal performance and longevity. Here are a few considerations:

- Fuel system and materials compatibility: Biodiesel has different solvent properties compared to petroleum diesel and can degrade certain rubber and plastic components in older fuel systems. Upgrading to biodiesel-resistant materials or using compatible elastomers may be necessary.
- Cold weather performance: Biodiesel can gel at colder temperatures, impacting flow and engine start-up. Blending biodiesel with winter-grade diesel or using a fuel additive can help mitigate this issue.
- Fuel filter maintenance: Biodiesel may act as a solvent and clean fuel systems. As a result, it can dislodge accumulated deposits, which might clog fuel filters. More frequent filter changes may be necessary during the transition to biodiesel.
- Fuel quality and storage: Ensure that the biodiesel used meets industry standards for quality, as poorly processed biodiesel can cause issues. Proper fuel storage and handling are also critical to maintain fuel integrity.
- Engine timing and compression ratio: Some older engines may require adjustments to optimize performance with biodiesel. Timing and compression ratio changes may be necessary for optimal power and fuel efficiency.

- Engine calibration: In some cases, modern diesel engines equipped with electronic control units (ECUs) may benefit from recalibration to achieve the best performance and emission levels with biodiesel.
- Regular maintenance: Biodiesel can have mild cleaning effects on fuel systems, which may expose underlying maintenance issues. Regularly servicing and maintaining the engine is important.
- Blending and fuel standards: Familiarize yourself with local regulations and standards for biodiesel blends. In some regions, specific biodiesel blends are mandated.

With the right precautions and adjustments, biodiesel can be a sustainable and effective alternative fuel source.

Conclusion:

Biodiesel is a promising alternative to conventional diesel fuel with numerous environmental and sustainability advantages. Derived from renewable sources like vegetable oils and animal fats, biodiesel has a lower impact on greenhouse gas emissions, reduced sulphur content, and increased biodegradability. Its higher flash point makes it safer to handle, while its better lubricity properties can benefit engine components. However, biodiesel also presents challenges, such as higher viscosity, potential cold-weather issues, and the need for engine modifications in some cases. Overall, biodiesel contributes significantly to the shift from fossil fuels to cleaner, more sustainable transportation fuels by providing a more environmentally friendly option for lowering greenhouse gas emissions and slowing down global warming.

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NON-TIMBER FOREST PRODUCTS – MARKETING AND TRADE

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Abstract:

Non-timber forest products (NTFPs) play a significant role in the sustainable management of forests and the socioeconomic well-being of local communities. In this chapter, we provide a comprehensive analysis of the marketing and trade of NTFPs, employing a rigorous research approach. This chapter examines the ecological, economic, and social dimensions of NTFPs, highlighting their importance in biodiversity conservation, income generation, and cultural preservation.

Keywords: Non-timber forest products (NTFPs), marketing, sustainable forest management, biodiversity conservation

Introduction:

Non-timber forest products (NTFPs) refer to a wide range of resources derived from forests that are not primarily harvested for timber. These products include a variety of plant and animal-based materials, such as fruits, nuts, seeds, medicinal plants, honey, resins, fibers, dyes, and handicrafts. NTFPs play a significant role in the livelihoods of many communities around the world, providing food, income, and other essential resources.

The use of NTFPs is deeply rooted in traditional knowledge and practices of indigenous and local communities. These resources have been sustainably managed and utilized for generations, often contributing to the cultural identity and well-being of these communities. Additionally, NTFPs offer important economic opportunities, particularly in rural areas where alternative income sources may be limited.

The sustainable harvest and trade of NTFPs can have several positive impacts. It can contribute to poverty alleviation, enhance food security, promote biodiversity conservation, and support sustainable forest management. Moreover, the utilization of NTFPs can provide an incentive for the conservation of forests, as the sustainable management of these resources relies on maintaining healthy and intact ecosystems.

Many countries and organizations recognize the significance of NTFPs and are taking measures to promote their sustainable utilization. This includes the development of policies and regulations that support community-based management, the establishment of certification schemes to ensure sustainable sourcing, and the facilitation of fair-trade practices to enhance market access for producers.

For example, the Convention on Biological Diversity (CBD), an international treaty signed by numerous countries, acknowledges the importance of NTFPs for the conservation of biological diversity and the sustainable use of natural resources. The CBD's objectives include the fair and equitable sharing of benefits arising from the utilization of genetic resources, which can encompass NTFPs.

NTFPs have gained recognition for their ecological, economic, and socio-cultural significance, contributing to sustainable forest management, biodiversity conservation, and livelihood improvement for communities around the world.

Scope and benefits

The scope of NTFPs is vast, encompassing a diverse array of resources with multiple uses and applications. NTFPs hold immense potential in various sectors, including food security, healthcare, pharmaceuticals, cosmetics, handicrafts, and tourism. They often serve as alternatives to traditional agricultural crops and provide income diversification opportunities for rural communities. The benefits of NTFPs can be summarized as follows:

1. **Economic benefits:** NTFPs offer income generation opportunities, particularly in marginalized and forest-dependent communities. They provide a source of livelihood for millions of people globally, contributing to poverty alleviation and economic development. The sustainable harvesting, processing, and trade of NTFPs can create employment and foster local entrepreneurship, leading to increased income and improved living standards.
2. **Environmental benefits:** The utilization of NTFPs can promote sustainable forest management practices and biodiversity conservation. NTFPs are often harvested from forests with minimal or no negative impact on tree populations, promoting the preservation of forest ecosystems. Sustainable harvesting techniques, such as selective extraction and regenerative practices, ensure the long-term viability of NTFPs and help maintain the ecological balance of forest habitats.
3. **Social and cultural benefits:** NTFPs play a crucial role in the cultural heritage and traditions of indigenous and local communities. They are deeply rooted in traditional knowledge systems and have significant social value, contributing to cultural identity and community cohesion. The sustainable management of NTFPs allows for the preservation of traditional practices, knowledge transmission, and the strengthening of cultural resilience.
4. **Health and nutrition:** Many NTFPs possess nutritional and medicinal properties, providing essential nutrients, vitamins, and minerals. Medicinal plants, for instance, contribute to traditional healthcare systems and have been used for generations to treat various ailments. NTFPs can offer accessible and affordable healthcare options, particularly in remote areas with limited access to modern medical facilities.

These products can be classified into various types based on their characteristics and uses. Here are some common categories of NTFPs:

1. **Medicinal plants:** Medicinal plants refer to plant species or parts used for their therapeutic properties in traditional and modern healthcare systems. These plants provide

remedies for various ailments and contribute to traditional medicine practices. Medicinal plants have gained global recognition for their potential in drug discovery and as sources of natural remedies.

2. **Edible fruits, nuts, and seeds:** This category includes a wide variety of wild fruits, nuts, and seeds that are consumed for their nutritional value. Examples include berries, wild almonds, Brazil nuts, and shea nuts. These resources often serve as important food sources for both local communities and wildlife.
3. **Fibers and rattans:** Forests provide a range of fibers and rattans that are used for various purposes, including weaving mats, baskets, ropes, and handicrafts. These materials have cultural significance and economic value, as they are often traded and used in local and international markets.
4. **Resins and gums:** Resins and gums obtained from trees, such as frankincense, myrrh, and gum arabic, have multiple uses. They are used in traditional medicines, cosmetics, incense, and as binding agents. These products have cultural, economic, and religious significance in various regions.
5. **Honey and bee products:** Forests provide habitats for bees, and honey and other bee products, such as beeswax and royal jelly, are considered valuable NTFPs. Beekeeping and honey production contribute to livelihoods and biodiversity conservation by supporting pollination services.

The marketing of Non-Timber Forest Products (NTFPs)

It involves strategies and approaches aimed at promoting sustainable trade, value addition, and market development of these products. Effective marketing plays a crucial role in enhancing the economic viability of NTFPs, ensuring fair returns to producers, and creating market demand. Here is an overview of the marketing concepts and approaches related to NTFPs:

1. **Market development:** Market development involves identifying and creating new market opportunities for NTFPs. This includes understanding consumer preferences, identifying niche markets, and developing marketing strategies to reach target audiences. Market research and analysis help in identifying potential markets, assessing demand, and determining product specifications. Market development efforts aim to increase the visibility and market share of NTFPs, leading to improved access and profitability for producers.
2. **Value addition:** Value addition refers to the process of enhancing the quality, processing, and packaging of NTFPs to increase their market value. This may involve improving post-harvest handling, developing processing techniques, and creating innovative product forms. Value-addition activities can help differentiate NTFPs in the market, attract higher prices, and increase consumer appeal. By adding value, NTFPs can compete with alternative products and create economic incentives for sustainable resource management.
3. **Certification and quality standards:** Certification schemes and quality standards are essential for assuring buyers and consumers about the sustainability and quality of NTFPs. Certification provides third-party verification of sustainable harvesting practices, social responsibility, and adherence to environmental standards. Certification can increase market access, build trust, and enable premium pricing for sustainably sourced NTFPs. It also helps ensure that NTFP trade aligns with environmental and social sustainability goals.
4. **Fair trade and ethical marketing:** Fair trade initiatives aim to ensure that producers receive fair prices and equitable treatment in the NTFP value chain. Fair trade certification can provide market advantages by appealing to consumers who value social and environmental justice. Ethical marketing emphasizes transparency, traceability, and sustainable sourcing practices. Ethical marketing can enhance consumer trust, brand reputation, and market competitiveness for NTFPs.

These marketing concepts and approaches are crucial for unlocking the potential of NTFPs and ensuring sustainable trade. By adopting appropriate marketing strategies, NTFP producers can access larger markets, receive fair compensation, and contribute to the conservation of forest resources.

The trading of Non-Timber Forest Products (NTFPs)

It involves the buying, selling, and exchange of these resources within local, regional, and international markets. The trading concept encompasses various aspects related to the commercialization, supply chain management, and market dynamics of NTFPs. Here is an overview of the trading concept for NTFPs:

1. **Market channels and networks:** Trading NTFPs involves establishing market channels and networks that connect producers with buyers and consumers. These channels can include local markets, cooperatives, wholesalers, retailers, and online platforms. Developing efficient and transparent market channels is crucial for ensuring fair prices, reducing intermediaries, and creating direct connections between producers and consumers.
2. **Market information and access:** Access to accurate and up-to-date market information is vital for NTFP traders. This includes information on market demand, pricing, quality standards, and trends. Market information systems, market intelligence, and networking platforms can facilitate the exchange of market information and improve market access for NTFP traders.
3. **Supply chain management:** Efficient supply chain management is essential for the trading of NTFPs. This involves activities such as collection, processing, storage, packaging, transportation, and distribution of NTFPs from the point of harvest to the end consumers. Supply chain management ensures timely delivery, quality control, and traceability of NTFPs, thereby maintaining their value and marketability.
4. **Market regulations and compliance:** Compliance with national and international regulations is crucial for NTFP trading. This includes adherence to legal frameworks, permits, certifications, and standards related to the sustainable sourcing, processing, and trade of NTFPs. Compliance ensures the legality, sustainability, and ethical sourcing of NTFPs, facilitating market access and avoiding trade barriers.
5. **Fair trade and benefit-sharing:** Fair trade principles can be applied to NTFP trading to ensure that benefits are equitably shared among producers, traders, and other stakeholders. Fair trade practices promote transparency, fair prices, social equity, and environmental sustainability in the trading of NTFPs. Fair trade certification and initiatives can create market advantages and increase the social and economic benefits for NTFP producers.

The marketing and trading of non-timber forest products (NTFPs) are closely interconnected, as they both contribute to the commercialization and value realization of these resources. Here is an overview of the relationship between marketing and trading of NTFPs:

1. **Market-oriented approach:** Marketing and trading of NTFPs involve a market-oriented approach, where the focus is on understanding consumer demand, identifying market opportunities, and developing strategies to meet those demands. Market research, market development, and value addition activities are essential components of marketing NTFPs

effectively. These activities contribute to creating market awareness, building brand reputation, and generating demand for NTFPs.

2. **Market channels and networks:** Trading of NTFPs requires the establishment of market channels and networks that connect producers with buyers and consumers. These channels can include local markets, cooperatives, wholesalers, retailers, exporters, and online platforms. Effective marketing strategies help in developing and maintaining these market channels, facilitating the smooth flow of NTFPs from producers to end consumers.
3. **Market access:** Marketing efforts play a crucial role in ensuring market access for NTFPs. By promoting the value and benefits of NTFPs, marketing activities help create market demand and attract buyers. Marketing also contributes to building trust and credibility in the market, which can enhance the market access and marketability of NTFPs. Market information, market intelligence, and networking platforms facilitate market access by providing information about market dynamics, buyer requirements, and distribution channels.
4. **Value addition and differentiation:** Marketing and trading of NTFPs are closely linked to value addition and product differentiation. Value addition involves improving the quality, processing, and packaging of NTFPs to increase their market value. This can be achieved through improved post-harvest handling, processing techniques, and innovative product forms. Marketing strategies help communicate and showcase these value-added aspects, enabling NTFPs to stand out in the market and command higher prices compared to raw or unprocessed products.
5. **Market regulations and standards:** Marketing and trading of NTFPs also involve compliance with market regulations, certifications, and quality standards. Adherence to legal frameworks, sustainability standards, and certifications helps ensure the legality, sustainability, and ethical sourcing of NTFPs. Compliance with these regulations and standards contributes to market acceptance, builds buyer confidence, and enables access to niche markets and premium prices.
6. **Fair trade and ethical marketing:** Fair trade principles and ethical marketing practices are gaining importance in the trading of NTFPs. Fair trade initiatives aim to ensure fair prices, equitable benefit-sharing, and social and environmental sustainability throughout the value chain. Ethical marketing emphasizes transparency, traceability, and responsible sourcing practices. These approaches contribute to the marketability and market reputation of NTFPs, attracting conscious consumers and supporting sustainable trade practices.

The relationship between marketing and trading of NTFPs is symbiotic, as effective marketing strategies enable successful trading, while trading activities generate market feedback and insights that inform marketing decisions. By leveraging marketing and trading synergies, NTFPs can reach wider markets, create economic opportunities for producers, and contribute to sustainable livelihoods and forest conservation.

Conclusion:

The marketing and trading of non-timber forest products (NTFPs) are closely intertwined and play a vital role in promoting the sustainable commercialization of these resources. The relationship between marketing and trading is symbiotic, as effective marketing strategies facilitate successful trading, while trading activities provide valuable insights and feedback that inform marketing decisions.

By adopting a market-oriented approach, NTFPs can be positioned to meet consumer demands and tap into market opportunities. This involves conducting market research, developing value-added products, and establishing market channels and networks. Marketing efforts contribute to creating market awareness, building brand reputation, and generating demand for NTFPs.

Market access is crucial for NTFP trading, and marketing plays a key role in facilitating market access. By effectively promoting the value and benefits of NTFPs, marketing activities attract buyers and build trust and credibility in the market. Market information and networking platforms further support market access by providing insights into market dynamics, buyer requirements, and distribution channels.

Value addition and product differentiation are essential aspects of marketing and trading NTFPs. By improving the quality, processing, and packaging of NTFPs, their market value is enhanced. Marketing strategies effectively communicate these value-added aspects, enabling NTFPs to stand out in the market and command higher prices.

Compliance with market regulations, certifications, and quality standards is essential for the marketing and trading of NTFPs. Adhering to legal frameworks and sustainability standards ensures the legality, sustainability, and ethical sourcing of NTFPs, thereby enhancing market acceptance and access to niche markets.

Additionally, fair trade principles and ethical marketing practices are gaining importance in the trading of NTFPs. Fair trade initiatives aim to ensure fair prices, equitable benefit-sharing, and social and environmental sustainability throughout the value chain. Ethical marketing practices promote transparency, traceability, and responsible sourcing, which enhance the marketability and reputation of NTFPs.

In conclusion, the effective marketing and trading of NTFPs contribute to their sustainable commercialization, market access, and economic viability. By leveraging marketing strategies, value addition, market access, and compliance with standards, NTFPs can unlock their full potential, benefiting both producers and the conservation of forest resources.

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ORGANIC FOODS

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Abstract:

From the recent research, it was observed that the organic foods are majorly consumed in worldwide for the maintainance of the health of the conusumers. Generally, organic foods are agricultural products cultivated without the synthetic preservatives, artificial colourants, inorganic herbicides. pesticides, genetic modifications, irradiations, etc. It helps to boosts the plant lifecycle in a healthy way. Organic farming is also referred to as "sustainable agriculture" which includes foods like vegetables, fruits, milk, meats and poultry, grains and cereals etc. Organic food production maintains soil quality by increasing organic matter and avoiding synthetic fertilizers. And it contributes to a healthier soil structure, enhanced water retention, and a more sustainable food production. Organic forming results in both positive (It preserves natural resources for future) and negative (Higher costs of natural fertilizers due to its nutritions) effects. In this study, we will discuss about the organic foods with its purpose, advantages, disadvantages, parameters and its comparision with the conventional foods. The standard range of each vitamin and minerals were studied based on human consumption and the required amount in the foods and its products.

Keywords: Organic Foods, Conventional Foods, Benefits, Nutritional Values, Environmental Impact.

Introduction:

Organic food is the food produced by without using any chemicals or pesticides. The food is naturally produced by the method of organic farming by using organic or naturally occuring substances, this organic subtances includes compost manure, green manure, bone meal manures, etc. Each and every organic food product undergone a specific inspection under the US Department of Agriculture. So, they implemented a program named as the National Organic Program (NOP) which is in the response of the Organic Food Production Act (1990). In order to increase the quality and healthy agricultural products, there are many new methods are available like organic farming, natural farming, biodynamic agriculture, do-nothing agriculture, eco-farming. Comparing to those methods, organic farmings are based on traditional way, so it provides a nutritious food. Organic foods include vegetables, fruits, milk, poultry, pork, beef, grains and cereals, eggs, etc. From the referred papers, it was observed that there is no evidence in humans for nutritional benefits and disease protection by consuming organic foods.

Awarness about the organic foods were determined by the labelling standards, conventional farming practices, cost and environmental implications on the methods of organic food production. Production of organic foods based on the proper organic raw materials where the cultivation of raw ingredients relies on natural fertilizers, crop rotations, and biological pest control. In order to improve the quality of the raw materials for organic food products, the cultivating soil is maintained in unique way by without addition of any fertilizers for about 3 years which helps to reduce the soil contaminations from near by lands and reduce the consequences of chemical fertilizers which are previously used in the land.

Purpose of organic foods:

- To reduce impact of chemical fertilizers in environment.
- To boosts plant lifecycle in a healthy way.
- To decrease the health problems in living organisms.
- To provides a new option to the consumers alternative to conventional foods.
- To increase the soil fertility and yield of foods.
- To supply fresh and nutritious products which can easily afford by consumers.

Advantages of organic foods:

- It enhances the physical characteristics of the soil, reducing erosion and improving water-holding capacity as well as granulation, good tilth, good aeration, and easy root penetration.
- It enhances the chemical characteristics of the soil, boosting favorable chemical interactions, reducing nutrient loss into water bodies and the environment, and increasing the availability and retention of soil nutrients.
- It lowers pollutant levels, and maintaining the health of the environment.
- By lowering the amount of residues in the product, it lessens the health risks to humans and animals.
- It aids in maintaining a sustainable level of agricultural output.
- In addition to lowering agricultural production costs, it also enhances soil health and fertility.
- It not only lowers the chance of crop failure but also saves energy for both machines and animals.
- It guarantees the best possible use of natural resources for immediate gain and contributes to their preservation for future generations.

Disadvantages of organic foods:

- The marketing of organic product production is not well organized. Many farms in India have either never used chemicals to manage or develop their land, or they have returned to organic farming due to the farmers' convictions or simple financial considerations. Even though they cultivate millions of acres of land, these thousands of farmers are not considered organic. Their production is either sold at the same price on the general market alongside produce farmed conventionally, or it is sold exclusively through select outlets and regular specialized markets based on goodwill and trustworthy labeling as organic.

- Due of the high expenses and substantial paperwork needed to obtain certification, some farmers might never choose to become certified.
- A purchase of organic fertilizers may result in higher costs than chemical fertilizers because organic manure is source and may not provide the same nutrients for plants.
- Organic farmers should receive premium prices for their food because production in this field falls, particularly in the initial few years of cultivation.
- Indian farmers are not familiar with the regulations around organic farming, processing, certifications, and transportation. So it may be difficult to handle by them.

Difference between conventional foods and organic foods:

Generally, the significance of organic farming is contingent upon its impact on environmental quality, as the careless application of pesticides taints soil and water, leading to a widespread degradation of the ecosystem. The usage of conventional agriculture has been linked to additional issues, including increased pollution and soil erosion as well as greater production-related energy costs. It goes without saying that the main benefit of conventional farming is its increased capacity to produce food. Although it is still early in the process, organic agriculture may be able to increase the amount of numerous essential elements for the consumers. The differences between conventional and organic vegetables should be done with caution, as a number of factors including, crop time, climatic condition, soil qualities, environmental factors, cooking methods and change in food's nutritional value

1. Crop time

As a result of the focus on sustainable techniques, improving soil health, using natural pest management methods, and relying heavily on organic inputs, producing organic food frequently takes longer time for producing the products. The prolonged growth cycle of organic crops depends on number of factors, including the adaption period, the use of natural fertilizers, and reliance on mechanical weed control. Organic farming strives to produce wholesome food without the use of chemicals and may take longer, but it is also more environmentally friendly. Whereas Conventional food production is characterized by faster crop growth due to the use of synthetic pesticides, fertilizers,and genetic modification. Practices like monoculture, intensive farming techniques to quicker production of products, while these methods can enhance efficiency, concerns exist regarding environmental sustainability and potential health impacts associated with synthetic inputs and genetically modified organisms.

2. Climatic condition

Generally, the production of organic food is greatly impacted by climatic circumstances, which also have an impact on pest control techniques, crop variety selection, water management techniques, and soil health. Local climates are accommodated by organic farming, which prioritizes sustainable methods. While in conventional foods, climate has a big impact on how conventional foods are produced; it shapes decisions about crop selection, water management, and pest control. Using tools like artificial pesticides and irrigation, conventional farming adjusts to local conditions. In conventional agriculture, crop yield optimization depends on local conditions and adaptation.

3. Soil qualities

Organic food production prioritizes soil quality through practices such as increasing organic matter, avoiding synthetic fertilizers, implementing crop rotation, fostering microbial diversity, and controlling erosion. These methods contribute to a healthier soil structure, enhanced water retention, and a more sustainable. In conventional foods, the food production manages soil quality through the use of synthetic fertilizers, pesticides, herbicides, and intensive tillage practices. While these methods can provide short-term benefits in terms of crop yield, they may pose challenges to long-term soil health. Issues such as nutrient imbalances, soil erosion, and impacts on microbial diversity differentiate the approach to soil quality in conventional farming.

4. Environmental factors

In organic food production, environmental factors are managed through sustainable practices such as natural pest control, the use of organic fertilizers, crop rotation for soil health, and a focus on biodiversity. Organic farming prioritizes a holistic approach that works with natural processes. In conventional food production, environmental factors are influenced by the extensive use of synthetic pesticides, fertilizers, and genetically modified organisms. This approach may lead to environmental concerns such as soil degradation, water pollution, reduced biodiversity, and increased energy consumption. The reliance on monoculture and intensive practices distinguishes conventional farming from organic methods, which prioritize sustainable and natural approaches to minimize environmental impact.

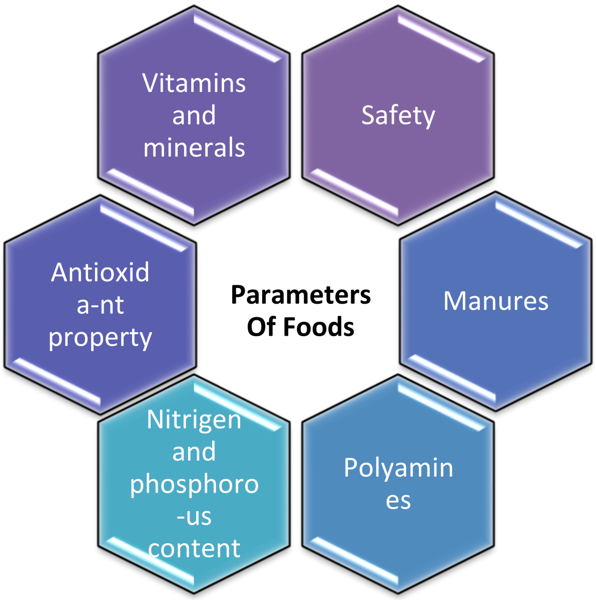
5. Cooking methods

Common cooking techniques that work with both conventional and organic foods include grilling, roasting, steaming, boiling, simmering, sautéing, stir-frying, baking, and raw preparations. In organic foods, the cooking method is not dictated by their production methods but is influenced by culinary preferences. Common cooking methods for organic foods include grilling, roasting, steaming, boiling, simmering, sautéing, stir-frying, baking, and raw preparations. These methods highlight the natural flavors and nutritional qualities of ingredients, along with the overall health benefits and its sustainability, while cooking methods for conventional foods are not inherently different from those used for organic foods. Cooking techniques are not determined by the processes used to produce the materials, but rather by culinary decisions, cultural traditions, and personal preferences.

6. Change in food's nutritional value

Organic foods may have higher levels of certain nutrients, such as vitamin C, iron, magnesium, and phosphorus. They may also contain higher levels of antioxidants, and organic milk and meat products may have increased omega-3 fatty acids. Organic foods are produced without synthetic pesticides, resulting in lower pesticide residues compared to conventional foods. However, the nutritional impact can depend on factors like crop type, soil conditions, and farming practices. In conventional foods, Genetically modified organisms (GMOs), pesticides, and synthetic fertilizers are a examples of having an impact on the nutritional value of conventional meals. The conventional foods might contain a little bit more antioxidants, omega-3 fatty acids, and nutrients than their conventional equivalents with various impacts as a consequence. Pesticide residues may be present in conventional foods, however they usually fall within acceptable safety limits**.**

Parameters of foods:



1. **Safety:**

Organic foods are considered as safety intake when compared to conventional foods. While comparing to organic foods, the conventional foods contain heavy metals like cadmium, mercury, lead, arsenic which leads to several health risks like nervous disorder, respiratory problems, development issues of fetuses, cardiovascular diseases, etc. Generally, organic foods are produced and distributed in healthy conditions, it does not require any food additives to maintain the appearance and preserving quality of food. But in conventional foods, additives are used continuously which leads to severe consequences that includes allergic reactions, digestive issues, metabolic effects (insulin sensitivity and weight gain), hyperactivity in children and long term health problems.

2. **Manures:**

In conventional foods, commonly synthetic fertilizer are used in order to increase the yield of raw materials, cost effectiveness, and to supply the excess nutrient level but still it has some risk concerns which leads to nutrient runoff, water pollution, harmful algal blooms and long term usage may affect the soil health and fertility. In organic foods, natural fertilizers are used as a manure in the food production. It provides essential nutrients and to improve the soil fertility. The manures are used in organic farming which contains nitrogen, phosphorous, potassium and micronutrients, where the nutritions are released slowly over time to reduce the risk of nutrient run off. It increases water retention and it promotes beneficial microbial activity in the growth during farming.

3. Polyamines:

Polyamines are organic compounds characterised by the presence of multiple amino groups which plays essential roles in various biological process includes cell growth, proliferation and differentiation of cells. Polyamines are not considered as additives, it is an bio molecular compounds which is naturally found in organic raw materials. Common polyamines present in the foods are spermine, spermidine and puterscine. These polyamines are naturally present in tha plant cell and involved in maintaining cellular structure and functions. In convential foods, the amount of polyamines are about 25 – 30%, where its amount gets reduced due to the addition of synthetic fertilzers. In organic foods, the amount of polyamines are about 75 – 85%, where it may increase its level by continuous addition of manure (natural fertilizres). Based on the amount of polyamines present in the foods leads to various health benefits which is one of the major need of the consumers.

4. Nitrogen and phosphorous content

Nitrogen is necessary for the growth of plants and is an important part of proteins, which are necessary for human nutrition. Sufficient levels of nitrogen in meals guarantee appropriate protein synthesis, promoting general well-being and growth. Typical sources of high nitrogen content are dairy products, nuts, seeds, legumes, and lean meats**.** In organic farming, the needed nitrogen was obtained from the organic matters from the manures used in farming while in conventional farming, they use primary baagged nitrogen fertilizers. Phosphorus is essential for many biological activities, including DNA synthesis, energy metabolism, and the development of bones and teeth. Phosphorus-rich foods include dairy products, meat, fish, nuts, and whole grains. A well-balanced diet is because of rich in phosphorus is crucial for bone health, cell function, and general metabolic activity. Generally, the standard intake of phosphorous for adult is 2.8 to 4.5mg/dL, while for children was 4 to 7mg/dL. Excess intake of phosphorous may leads to reduce the amount of calcium in the body. In coventional foods, the amount of phosphorous is higher than the standards level for humans due to the usage of the synthetic fertilizers. But in the organic foods, the amount of phosphorous is less due to the usage of natural fertilizers.

5. Antioxidant property

Antioxidants are substances that support the body in resisting free radicals, hence lowering oxidative stress and the risk of cell damage. Common sources of antioxidants include beta-carotene, vitamins C and E, and flavonoids, which are present in fruits, vegetables, and some drinks (like green tea). Consuming a range of foods high in antioxidants promotes general health and may offer some protection against chronic illnesses. Generally, foods had a antioxidant property of about 70% during consumption. But in conventional foods, the range of antioxidant property was about 52% due to the uasge of synthetic fertilizer which breaks the amine compounds present in it, while the organic foods are produced with the antioxidant compounds in the range of about 60% and the farmers are still trying to increase its range using other natural fertilizers.

6. Vitamins and minerals

Generally, both organic and conventional foods had vitamins and minerals but the amount and its effects must be varied based on the fertilizers that is being used. Minerals are inorganic substances that are essential to the body's numerous physiological functions. Among them are vital minerals like zinc, potassium, iron, and calcium, magnesium supports a variety of functions, including blood coagulation, fluid balance, and bone health. The essential minerals in organic foods are crucial for health, including calcium (leafy greens and fortified plant-based milk), iron (legumes and whole grains), magnesium (nuts and seeds, potassium in fruits and vegetables), zinc (nuts and legumes), selenium (foods grown in selenium-rich soils), copper (nuts and legumes), phosphorus (whole grains and legumes), manganese (nuts and seed), and iodine (seaweed and iodized salt).

Table 1: Common minerals present in foods

Minerals	**Examples**	**Level in Organic Foods (mEq)**	**Level in Conventional Foods (mEq)**
Calcium	Cheese, Milk, Sardines	40 – 95	15 – 45
Cholride	Seaweed, Olives	3 - 4	0.2 – 0.8
Magnesium	Leafy Greens, Cocoa Products	60 - 295	14 - 50
Chromium	Beef, Brocolli, Eggs	1 - 20	0.1 - 2
Cobalt	Beef Liver, Fish	0.5 – 0.8	0.2 – 0.3
Potassium	Legumes, Meat, Sweet Potatoes	100 - 255	29 - 85
Zinc	Cheese, Meat, Milk	9 - 11	3 - 7
Phosphorous	Beef, Nuts, Cheese	70 - 95	85 - 110
Sodium	Bread, Chips	8 - 69	0 – 0.8
Manganese	Grains, Legumes, Nuts	60 - 120	1 - 4
Iodine & Iron	Dairy, Eggs, Grains	227 - 1584	10 - 20
Molybdenum	Dairy, Leafy Greens	40 - 67	22 - 47
Copper	Cocoa, Grains, Shellfish	0 - 70	0.5 – 3

Table 2: Common vitamins present in foods

Vitamins	Examples	Level in Organic Foods (mcg)	Level in Conventional Foods (mcg)
Vitamin A	Liver, Carrot, Sweet Potato	650 - 750	350 - 400
Vitamin D	Eggs of from Catfish, Salmon	13 - 18	7 - 8
Vitamin E	Wheat Germ Oil, Sunflower Seeds	13 - 20	7 - 8
Vitamin K	Spinach, Broccoli	50 - 70	25 - 35
Vitamin C	Guavas, Red Pepper, Broccoli	65 - 75	50 - 60
Choline	Egg, Cauliflower	400 - 425	325 - 385
Thiamine (B1)	Legumes, Grains	1 – 1.5	0.4 – 0.9
Riboflavin (B2)	Dairy, Eggs, Greens	1 - 2	0.7 – 1.0
Niacin (B3)	Dairy, Eggs, Fish	10 - 15	5 – 8
Pantothenic Acid	Mushrooms, Cauliflower	4 - 6	2 - 3
Vitamin B6	Avocado, Legumes	1.3 – 1.7	0.5 – 0.9
Folic Acid/Folate	Dark Greens, Citrus Fruits	380 - 400	280 - 320
Biotin	Tomatoes, Romaine Lettuce, Carrots	20 - 30	10 - 15
Vitamin B12	Soymilk, Eggs, Poultry	2 – 2.4	0.6 – 1.5

Vitamins are organic substances required for proper metabolism, development, and general health. They are divided into two categories: fat-soluble (like vitamins A, D, E, and K) and water-soluble (like vitamin C and B-complex). Every vitamin has a distinct purpose in the body and can be acquired by eating a varied and well-balanced diet. The vitamin content in organic foods varies based on factors like soil quality and farming practices. A well-balanced diet, including a variety of nutrient-dense foods, is essential for meeting vitamin needs, and the choice between organic and conventional foods should consider individual preferences and nutritional benefits.

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ARTIFICIAL INTELLIGENCE APPROACHES IN AGRICULTURE

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Abstract:

By 2050, the worldwide population is predicted to attain more than nine billion human beings, necessitating a 70% growth in agricultural manufacturing to satisfy demand. Simplest around 10% of this more production could come from the supply of vacant lands, with the closing ninety% coming from intensification of modern production. Numerous challenges are faced in the agricultural sector, including illness, incorrect soil analysis, pest infestation, irrigation, poor drainage, and many more. Due to these difficulties, excessive pesticide use causes severe crop loss and hazardous environmental dangers. Artificial intelligence and its thorough learning capabilities have developed into a crucial strategy for addressing a range of farming-related difficulties. On this regard, one of the most pressing wishes is the software of modern technical solutions to enhance farming efficiency. Agriculture has passed through a revolution as an outcome of synthetic intelligence. This technology has blanketed crop yields towards an expansion of things inclusive of weather exchange, populace boom, labour problems, and food protection issues. The main goal of this chapter is to examine the various ways synthetic intelligence is being used in agriculture, including irrigation, weeding, and spraying, utilizing sensors and other integrated equipment. These technologies lessen the usage of water, pesticides, and herbicides, maintain soil fertility, and resource in the green use of manpower, so improving productiveness and improving best.

Keywords: Artificial Intelligence, Farming Efficiency, Irrigation, Soil Fertility.

Introduction:

Agriculture, a vital element of every nation, continues to be one of the biggest challenges currently. The united countries' FAO estimated that by 2050, the populace will exceed nine billion. Rapid population growth, reducing farmland, depleting herbal assets, irregular weather trade, and evolving market wishes are all pushing agriculture into a brand new paradigm. Artificial intelligence (AI) is a modern technique used in agriculture. The use of AI-based tools and technologies has elevated agriculture to a new level. The fact of today is that human labour is being empowered by artificial intelligence. Artificial intelligence has quickly adapted in agriculture with its different ways. The current scenario requires attending to more efficient farming methods using technical breakthroughs and solutions. By improving the quality of crops, use of technology like artificial intelligence will enable farmers to accomplish more with less. Manpower was one of the key components of farming prior to the industrial revolution. Today, a variety of approaches are utilized, including field management, disease detection, crop readiness assessment, determining the best fertilizer to apply based on the soil, and many more. Currently, Microsoft Corporation in India is working with 175 farmers in Andhra Pradesh to provide a variety of services.

Crop manufacturing has notably progressed of this generation, as has real-time tracking, harvesting, processing, and advertising (Yang *et al.,* 2007). In the agro-based totally region, the today's technologies of automatic systems the usage of agricultural robots and drones has made a full-size contribution. We will broaden smart farming strategies by way of the use of artificial intelligence to lessen farmer losses and provide them with excessive yields. Synthetic intelligence platforms can acquire massive amounts of data from authorities and public websites, in addition to actual-time monitoring of various records thru IoT, which could then be correctly analyzed to help farmers in addressing most of the unsure problems they face in the agriculture region. In a fast - changing world quickly, here are some of the greatest new technologies that farmers may use to help them produce all the food we need. Although increasing population and climate change will present enormous challenges, the use of artificial intelligence in farming can lessen their effects and make smart farming considerably more resilient to the issues that farmers endure.

Key technologies of agricultural IoT:

i. **Sensor perception technology:** Physical property sensors, biosensors, and micro electro-mechanical sensors are the three types of sensors usually working in agriculture (You and Tang, 2013). Micro electro-mechanical sensors, a novel technology with exceptional attributes including low power consumption and good reliability, are used in biosensors to transfer information depending on the reaction to the outside world (Li *et al.,* 2015). The fluorescence emission effect and spectrophotometry are two optical sensing processes that are used for soil inspection and chlorophyll content assessment (Li *et al.,* 2017). Crop planting and transplantation, pesticide spraying and terrain monitoring, soil structure analysis, and other applications use photoelectric sensors. The electrochemical method may be used to examine the chemical makeup of soil, crop growth and development, among other things. It is based on the electrochemical characteristics of the chemicals in solution and their changing laws (Adamchuk *et al.,* 2004).

ii. **Wireless communication technology:** A major element of agricultural IoT is data transmission, and WSN is one of the most significant methods of data transfer. When transferring agricultural IoT data, communication technology should not be chosen at random, but rather according to the project's specific requirements. In one study, a ZigBee and the CC2530 protocol stack were used to build transceiver hardware and wireless networked sensor nodes for an agricultural irrigation system (Xu *et al.,* 2012; Zhang *et al.,* 2011). Future agricultural sensor networking will primarily focus on LPWAN (represented by LoRa and NBIoT), which will be augmented by 4G and 5G to support the transfer of large data like agricultural images and audio recordings.

iii. **Information processing technology:** The ultimate objective of data processing is to collect and analyze the data that has been collected. Many production data are collected in the process of agricultural production monitoring, and they have the qualities of being real-time, dynamic, and immense. Cloud computing is mostly utilized for data processing, and it may successfully handle the problem of huge agricultural production data storage, calculation, and processing. Many new cloud service platforms are capable of storing, finding, and interpreting large amounts of agricultural data.

iv. **3S technology:** The terms "3S" refer to remote sensing (RS), global navigation satellite system (GNSS), and geographic information system (GIS). It is a comprehensive solution that integrates the three to achieve fast, accurate, and dependable agricultural data gathering, analysis, and updating.

v. **RS technology:** Agricultural RS technology has a one-of-a-kind impact on the monitoring and management of large-scale open-air agriculture. RS technology is being used to manage and safeguard farmland water conservation projects (Ma *et al.,* 2019), monitoring the ecological environment and making decisions in real-time to stimulate agriculture (Li, 2017).

vi. **GIS technology:** The extensive information collected by RS and GNSS can be screened using GIS to obtain unique visual information on agricultural production. Li et al. combined GIS technology and testing robot technology in the design of the nutrient analyzer to increase the analytical impact of farmland soil nutrients, and used GIS technology to generate a nutrient distribution map of the farmland (Li *et al.,* 2021).The system using these technologies has higher efficiency, more reliability and lower energy consumption.

AI approaches in agriculture:

The IoT-enabled sensors must be placed at the specified places in the field. These sensors are transducers that record information on the weather, soil moisture and fertility, root and shoot growth, ample leaf growth, photoperiod monitoring, establishing floral and seedlings, bearing grain and fruit, insect and disease symptoms as significant growth variables, and harvest state of readiness. The following list outlines the different ways that AI has aided the agriculture industry:

1. Growth estimation by IOT: These include, among other things, previous weather patterns, soil reports, recent research, rainfall, insect infestation, and images taken by drones and cameras. All of this data may be detected by cognitive IoT devices, which can provide valuable insights to optimize yield. This aids in the classification of soils depending on the soil under the surface at a specific location. Hardware solutions, such as Robot (for corns), are already combining data-gathering software with robotics to produce the appropriate fertilizers for growing corns, as well as other operations, to high quality content. It can be installed on a protected mini board that includes a Wi-Fi device, a microprocessor, a low-cost VGA image sensor, and a micro solar panel. The data can be collected at predetermined intervals by placing Wi-Fi active hot spot towers across the entire field.

2. **AI in precision farming:** Precision farming is one of the most hotly debated topics in agriculture today. Drone-based photos can aid in in-depth field analysis, crop monitoring, field scanning, and other tasks. Farmers can use a combination of computer vision technologies, IoT, and drone data to take quick actions. Drone image data feeds can create real-time alerts to speed up precision farming. Aerial tronics, for example, recently integrated IBM Watson IoT Platform and Visual Recognition APIs into commercial drones for real-time image analysis. Some applications for computer vision technology are listed below.

a. Disease detection: Image pre-processing ensures that the leaf pictures are split into areas such as background, non-diseased part, and diseased part. After that, the infected area is clipped and sent to distant labs for further analysis. It also helps in insect detection, nutrient deficient detection, and other tasks.

b. Crop readiness identification: Under white/UV-A light, images of various crops are collected to determine ripping process in crops. Farmers can build several levels of readiness based on the crop/fruit category and stack them before selling them.

c. Field management: By establishing a field map and identifying places where crops require water, fertilizer, or pesticides, authentic estimates can be created during the cultivation period using high-definition photographs from airborne systems (drones or copters). This significantly aids in resource optimization.

d. AI-based yield management: - By combining these technologies, farmers may increase average yield and have greater pricing control. In designed to facilitate business intelligence using machine learning and the Cortana intelligence suite, Microsoft is now working with farmers in Andhra Pradesh. Agricultural AI apps were used to communicate dates, soil preparation, fertilizer based on soil testing, seed treatment, and the ideal spreading depth for the pilot project. Digital agricultural robots, multimodal cameras, and laser scanning for facilities are supported by mobile robots and field sensors.

3. Irrigation automation methods and farmer empowerment: Agriculture's most labor-intensive practice is irrigation. By considering past weather patterns, the state of the soil, and the sort of crops to be grown, machines may automate irrigation and increase overall output. With irrigation accounting for about 70% of the world's fresh water, automation can assist farmers in better managing their water issues. Combined with expert system guidance and appropriate measures, such as remote control of drip irrigation, energy efficiency was improved. Hou et al. designed a remote intelligent irrigation system for orchards, taking into account both the large-scale development model of current orchards and the requirements of precision agriculture construction (Hou *et al.,* 2012). The system made use of both GPRS and ZigBee WSNs. The development of smart irrigation technology enables farmers to boost production without using a lot of labour by monitoring soil temperature, fertilizer content, water level, and weather forecasts. Turning the irrigator pump ON/OF causes the microcontroller to initiate the actuation. The soil moisture sensor and rain drop sensor use GSM technology to send the farmer an SMS letting them know how much moisture is in the soil.

4. Intelligent agricultural machinery: Agricultural equipment that is intelligent allows for efficient, standard, comfortable, and interactive operations. Cultivation, seeding, transplanting, fertilizer, drug spraying, feeding, watering, picking, harvesting, and other operations can all be completed separately. It may also gather information on the soil, the water, the crops, and aquatic goods, offering technical assistance for precision farming and ethical breeding practices (Ma and Sun, 2020). The communication and control between the operating site and remote terminals and servers is referred to as remote IoT. For construction vehicles, researchers developed an autonomous driving system and a remote monitoring and management system using microprocessors (STM32) (Xu, 2017; Liu, 2019). These systems carry out tasks such data gathering on the location of the vehicle, automatic obstacle avoidance, data transmission and reception, vehicle control, and self-checking of the state.

5. Drone technology in agriculture: Drone technology is giving agriculture a high-tech makeover. Drones can assist with seed planning, data collection for regulating irrigation and nitrogen levels, and early soil testing. Startups' drone-planting solutions have decreased planting costs by 85 percent. These systems release pods containing seeds and fertilizers into the soil, providing all of the nutrients necessary for crop development. Unmanned helicopter Yamaha RMAX was introduced for agriculture pest control and crop monitoring applications. To attain high productivity, Indian agriculture required production and protection tools. Chemicals and fertilizers for agriculture are usually required for crop development and pest control. Depending on the spatial diversity of the crops and field, drones can be used to spray chemicals like insecticides, fertilizer, and others. Depending on the crop circumstances or the severity of the insect-pest assault, the amount of chemicals to be sprayed might be changed. The combination of a UAV with a spraying system creates the possibility of creating a platform for vector and pest management. This application is precise for a vast agricultural field and is site-specific. The Quad copter (QC) system which is low cost, and lightweight, also known as Unmanned Aerial Vehicle proposed by researcher

6. Robots in agriculture: Agricultural robots are more efficient than conventional ways for sowing seeds when it comes to planting crops. Many seeds can be placed in their proper locations by the tractor around the field thanks to agricultural robot applications. The best examples of agricultural robots are intelligent tractors and vehicles, which are in charge of a variety of tasks in the fields, including pre-production, cultivation, and mostly after the development of crops like maize, vegetables, and plants. Cotton gin was invented in 1794 by U.S. - born inventor Eli Whitney. Weeding, irrigation, guarding the farms for effective reports, ensuring that adverse environmental circumstances do not affect productivity, increasing precision, and managing individual plants in many novel ways are all tasks that the robots perform independently. The development of plant was recorded by automated machines.

Recent achievement:

- **Blue river technology** was founded in 2011. This California-based business uses artificial intelligence, computer vision, and robots to create next-generation agriculture equipment that saves money and lowers chemical use. The use of sensors that identify weeds, the type of weeds and the right herbicides to apply within the right buffer around the plant. The cameras and sensors use machine learning where the images are captured and the machines can be taught in different weeds.
- **Harvest COROO robotics: COROO** is a robotic strawberry harvesting system that allows the detection and identification of ripe berries for picking strawberries using machine learning and Artificial intelligence.

- **Jivabhumi:** Jivabhumi is developing a "Smart" Agriculture Market to improve the supply and demand for agricultural products, which is frequently insufficient. It's a cutting-edge food aggregation system that combines agricultural products, marketplace services, and innovation. It collects information about items at various levels of the supply chain using block chain technologies.
- **Prospera: Prospera** was founded in 2014. This Israeli business has changed the way agriculture is done. It has created a cloud-based solution that aggregates all existing data, such as soil/water sensors, aerial photographs, and so on, that farmers have. It then combines it with an on-the-ground gadget that decodes everything. A multitude of sensors and technologies, including computer vision, power the Prospera device, which may be utilized in greenhouses or in the field. The data collected from the sensors is utilised to develop predictions and establish a link between different data types.
- **The farmer's alexa:** There is one more really intriguing AI innovation that may rank among the highlights in the digital toolset of the contemporary farmer i.e, CHATBOTS. Farmers may communicate with chatbots, artificial intelligence characters like "Alexa" from the smart home, which can assist them solve complex challenges. Chatbots may be helpful to farm consumers as well, for instance, by educating visitors about what is on a farm and how to purchase it.

Future aspect:

- LPWAN (represented by LoRa and NBIoT) will be the major direction of agricultural sensor networking in the future, complemented by 4G and 5G to enable the transmission of big files such as agricultural photos and audio recordings.
- Complete information perception standards must be defined, more embedded gateway research must be conducted, and multi-protocol conversion gateways must be designed.
- By combining augmented reality, virtual reality, and 5G communication technology, one can create an integrated network system that unites farming equipment, agronomy, crops, and farmers. This digital twin of the entire production process will then enable intelligent decision-making, process monitoring, and multi-factor intelligent traceability.

Challenges for adoption AI in agriculture sector:

- **Data collection:** A large volume of data is needed for AI systems to train their algorithms and produce accurate estimations. For extensive agricultural regions, time data are hard to get around. Even if gathering spatial data is simple. A robust machine learning model requires time to construct since data infrastructure has to be mature. This is one of the reasons artificial intelligence isn't employed in field solutions, but rather in agricultural goods like seeds, fertilizers, and pesticides.
- **Cost of change:** Another is the exorbitant expense of the several alternatives offered in the agriculture sector. For technology to be accessible even at the farm level, solutions must be more cost-effective.
- **Lack of experience about technology:** Artificial intelligence in agriculture could be useful in some regions, but it might be difficult to promote such technology in regions

with little access to agricultural technology. Farmers will undoubtedly need assistance putting it into action.

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RECENT PRACTISES IN ORGANIC FARMING FOR AGRICULTURAL DEVELOPMENT

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Introduction:

Organic farming is the use of agricultural production system reliant on green manure, compost, biological pest control, and crop rotation to produce crops, livestock and popularity (Pimental *et al.*, 1995). Organic centred agricultural production system fosters the cycling of the resources to conserve biodiversity and promote ecological balance. The use of green manure, cover crops, animal manure, and soil rotation, to interrupt the habitation of pests and diseases, improve soil fertility, and maximize the soil's biological activity are the primary aspects of organic farming. In the other words, organic farming does not allow the use of synthetic chemical fertilizer, antibiotic, herbicides, or pesticides (Regnold *et al.*, 1993). Thus, the objective of organic farming is agricultural production of fibres, grains, vegetables, flowers, fruits, foods, and animal products such as milk, eggs, and meat is the best natural way.

Organic farming system in India is not new and is being followed from ancient time. It is a method of farming system which primarily aimed at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes (crop, animal and farm wastes, aquatic wastes) and other biological materials along with beneficial microbes (bio fertilizers) to release nutrients to crops for increased sustainable production in an eco-friendly pollution free environment (Grines *et al.*, 1985). As per the definition of the United States Department of Agriculture (USDA) study team on organic farming "organic farming is a system which avoids or largely excludes the use of synthetic inputs (such as fertilizers, pesticides, hormones, feed additives etc) and to the maximum extent feasible rely upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives and biological system of nutrient mobilization and plant protection". FAO suggested that "Organic agriculture is a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs" (Harwood *et al.*, 1984).

Principles of organic farming:

The principle health: Organic agriculture must contributed to the health and well being of soil, plants, animals and human in earth.

The principle of ecological balance: We must model organic farming on living ecological system. Moreover, the methods of organic farming must fit the ecological balance and cycle.

The principle of fairness: Organic farming provides a good quality of life and helps in reducing soil infertility.

The p**rinciple of care**: We should practice organic agriculture in a careful and responsible way to help the present and future generation and the environment (Pimental *et al.,* 1995).

Techniques of organic farming:

Crop rotation: It is technique to grow various kinds of crops in the same area, according to the different season, in a sequential way.

Green manure: It refers to the dying plants that are uprooted and turned into the soil to make them act as a nutrient for the soil to increase its quality.

Biological pest control: With this method, we use living organisms to control pests with or without the use of chemicals.

Compost: Highly rich in nutrients, it is a recycled organic matter used as a fertilizer in the agriculture farms (Staiger *et al.,* 1998; Harris *et al.,* 1984).

Method of organic farming:

Soil management: After cultivation of crops, the soil loses its nutrients and its quality deplete. Organic agriculture initiates the use of bacteria that is present in animal waste. The bacteria help in making the soil nutrients more productive and fertile (Pimental *et al.,* 1995)

Weed management: Weed is unwanted plant that grows in agricultural fields. Organic agriculture focuses on lowering weed and not removing it completely. The two most widely used weed management techniques are

1. Mulching: A process where we use plastic films or plant residue on the surface of the soil to block the growth of weed.

2. Mowing or cutting: Where there is a removal of weeds of top growth.

Crop diversity: Monoculture is the practice used in the agriculture fields where we harvest and cultivate only type of crop in a particular place. Recently, polyculture has come in existence. where we harvest and cultivate kinds of crops. To meet the increasing crop demand and produce the required soil microorganism (Reganold *et al.,* 1993).

Controlling other organism: There are both useful and harmful organism in the agricultural farm which affect the field, So, we need to control the growth of such organisms to protect the soil and the crops. We can do this by the use of herbicides and pesticides that contain fewer chemicals or are natural (Handa *et al.,* 1985).

Some of the important components of organic farming are described below.

Components of organic farming

Choice of soil/ land

The success of organic farming depends on the soil type and fertility of the farm. It should always be noted that the soil in the field where you want to do organic farming should be healthy and fertile. Some insecticides are present in soil and water for years. These can adversely affect the nervous system through crop products which can also lead to serious diseases like cancer (Hallberg *et al.,* 1980). Therefore, as far as possible, one should stay away from pesticides. Before starting organic farming, the land is not considered suitable for organic food for two years. So that during this period crops can also absorb all the harmful and toxic elements present in the soil. In this way the inorganic chemical elements of the soil are completely eliminated (woose *et al.,* 1997).

Selection of species/varieties

Any species of a crop can be planted for organic farming. But it has been felt that indigenous species will be more suitable for organic farming. Because their energy demand is less. Some crops are fragile and are susceptible to pests and diseases (Niggli *et al.,* 2008). As far as possible, anti-disease species of crops should be selected. Often, a packet of seeds of such crops is inscribed. It is also notable here that transgenic crops and their species are not used in organic farming.

Organic fertilizer

Among the organic manures used in the country are dung manure, compost manure, vermicompost, poultry manure, animal laying, pigs and sheep manure and cow dung manure. Normally 5 kg of cow dung and one ton of compost manure. Nitrogen, 2-5 kg phosphorus and 5 kg potash are available. But unfortunately, we are able to use only 50 percent of them. Mostly dung is used by farmers to burn as dung cakes. Some biodynamic manures like cow urine, animal horn manure, bone manure is also being used in organic farming (Grines *et al.,* 1985). Compost made with the help of earthworms by mixing crop residues, weeds, leaves of herb vegetables and cow dung is called vermicompost or earthworm compost. By this method, organic residues are kept in a long pile and earthworms are left in the Eichenia femida. The vermi compost is prepared in about 45 days. Organic fertilizers improve soil quality as well as increase the availability of major, second and micronutrients (Handa *et al.,* 1985). Only 30 percent of the given amount of organic fertilizers in a crop is used in the first year, the remaining amount is used by the next crop. The availability of phosphorus in the soil also increases due to the humic content in organic fertilizers.

Organic manure

The use of organic fertilizers is proving beneficial in taking good production of crops. Among them, *Rhizobium* culture, *Azotobacter, Azospirillum, PSB, Azola, vesicular mycorrhiza, indigo-green algae*, bio activator etc. are prominent (Fliebbach *et al.,* 2009). Use of organic fertilizers is very important for sustainable farming and maintaining soil health. Organic fertilizers are easily available at low cost and they are also very easy to use. are considered to be the main ingredients of organic farming management. *Rhizobium* and *Azotobacter p*rovide nitrogen (78 per cent) present in the atmosphere and deposited in the ground through fixation. P*SB* By changing the insoluble phosphorus in the soil to a soluble state, the phosphorus for the plants increases the availability, which also benefits the next crops. In addition, bacterial fertilizers produce growth factor hormones around the roots of plants (rhizosphere) which have a favorable effect on plant growth and development (Hangrove *et al.,* 1986). Organic fertilizers should be selected according to the variety of crops. While using organic fertilizer, must see the production date, the last date of use and the name of the recommended crop above the packet. While using organic fertilizers should be protected from sunlight and hot air.

Use of green manures

Use of green manure can increase the quantity and availability of all secondary and micronutrients in the soil, besides the main elements like carbon, nitrogen, phosphorus and potash. Pulses are mainly used for green manure. Sanai, Dhaincha, Cowpea, Moong, Guar and Soyabean are the main among them. It takes only two months to make green manure from these crops. All these crops are short-term and fast growing (Foisnner *et al.,* 1986). These crops are pressed into the soil with the help of a soil turning plow or harrow before flowering. Green manure crop takes about 10 days to rot. After this the field is prepared and the next crop is sown and planted. Using green manures can easily secure 20-30 kg of nitrogen in the field. In addition, the reserves of phosphorus, potash and micronutrients can also be increased. Multipurpose trees and plants like acacia, neem and glyceridia leaves and twigs can also be used as green manure. Farmer brothers must grow green manure crops once in three to four years (Willer *et al.*, 2007). With this, the fertility of the land not only increases, but also improves soil health.

Use of pulses crops

Crop must be grown once a year. Pulses are not only a nutritional base for more than half of India's population, but are also the cheapest source of protein and essential amino acid supplies (Goring *et al.,* 1982). In addition, due to lack of protein in the diet, malnutrition due to lack of protein can also be prevented. The roots of lentil crops contain knots of *Rhizobium* bacteria, which act as nitrogen fixation. After harvesting wheat, coral crop should be taken (Hangrove *et al.,* 1986). After plucking two coral beans, the crop should be plowed and mixed into the soil. Its use increases the amount of bacterial substance in the soil which ultimately supplies the main nutrients as well as secondary and micronutrients in the soil after decomposition. Due to this the fertility of the land increases. Also, soil health also improves (Frieber *et al.*, 1997).

Crop residue management

Farmer brothers generally ignore the contribution of crop residues in crop production. The use of crop residues is common in the paddy-wheat crop cycle in northwest India. Due to mechanization and increasing productivity in agriculture, excessive amount of crop residue is being produced. Farmers often burn crop residues after harvesting donations after harvesting. It is quite prevalent in Punjab, Haryana and West Uttar Pradesh as well as other parts of the country. Environmental pollution is increased by the smoke emanating from the burning of crop residues. Also, heart and lung diseases also increase due to smoke (Frieber *et al.,* 1997). The amount of organic carbon in the soil can be improved by using crop residues in organic farming. Similarly, after plucking the fruits of vegetables, their stem, leaves and roots remain in the field, which by plowing and pressing in the soil improves the fertility of the field. Crop, straw, sawdust and farm residues are prominent among the crop residues. Although crop residue has an important contribution in providing nutrients. But most of the crop residues are burnt in the field or thrown out of the field. Crop residues have a favorable effect on the physical, chemical and biological functions of the soil along with providing nutrients to the plants (Willer *et al.*, 2007).

Weed control

As far as possible, weeds in organic farming should be controlled only through weeding. In addition, weeds can be controlled by deep plowing in summer, solarisation by sun rays, proper crop management and adequate number of plants per unit area (Handa *et al.,* 1985). Also, parasites and other bacteria that eat weeds can be used. In addition, weeds can also be eliminated by sowing the main crop in organic farming, giving them an opportunity to grow.

In this method, first irrigate the field, causing most weeds to grow after getting moisture. These weeds are then destroyed by running plow to the field. Outbreaks of weeds can also be reduced by adopting drip irrigation techniques in crops such as vegetables, fruits and cotton. In this method, water around the roots of the main crop is given by dripping it only when needed. Sometimes the number of weeds can be reduced by growing short-duration crops as intercrops with the main crop.

Pest and disease control

Pests and diseases under organic farming should also be controlled through biological means. Different types of insect-mites are found in crops with different vegetables, fruits and flowers (Handa *et al.,* 1985). These insect-mites suck the juice of leaves, buds, stems and fruits or munch them and eat them. This causes the quality of crops to deteriorate, as a result of which farmers are unable to get a fair price for the produce in the market. For this, one gram per liter of neemali powder can be sprayed and dissolved in water. Nowadays Neemgold, Neem oil, Nimoline etc. Organic insecticides prepared from Neem tree are easily available in the market. Trichogramma has been found to be good for preventing insects in vegetables. Trichogramma is a microscopic egg parasite that invades the eggs of insectivorous, leguminous and leaf-eating insects (Hangrove, 1986). A trichocard is a card similar to a postcard, on which about 20 thousand parasites produce trichogramma. This card is applied in the fields to control the insects that are planted in crops like cotton, sugarcane and paddy. Similarly, Trichoderma and Newmaria have proved to be good for prevention of soilborne fungal diseases such as wilt, caller rot and rotting in nurseries. For seed treatment, by adding 6 to 8 grams of powder per kg of seed and for land treatment at the rate of 2 to 3 kg of powder per hectare by mixing with cow dung and vermi compost, various groundborne fungal diseases can be prevented (Eyhorn *et al.,* 2001).

Inhana Organic Farming (IRF) Technology – A complete organic package of practices:

IRF which provides a nature pathway for crop production taking into account the interrelated and integrated relationships of all the components of the ecosystem. It blends ancient Indian wisdom with scientific knowledge and ensures healthy plant and soil system which ultimately leads to a successful crop output without disrupting the ecological harmony. This farming technology has already been widely adopted in reputed tea estates in India and has shown its effectivity towards the reduction of chemical / pesticides load and management of recurrent disease problem.In the Agriculture sector, the technology has been tired out in different crops like paddy,babay corn, green gram,cabbage, okra, tomato, potato, and had turned out be quite satisfactory. Thus is the backdrop of leading to poor quality and productivity, and prevalances of unsustainable agriculture practices. IRF technology can become one of the weapons to contest against such adversities.

Social sustainability

Sustainability is also about equity among and between generations. Organic agriculture contributes to the social well-being by reducing the losses of arable soil, water contamination, biodiversity erosion, GHG emissions, food losses, and pesticide poisoning (Handa *et al.*, 1985). Organic agriculture is based on traditional knowledge and culture. Its farming methods evolve to match local environments, responding to unique biophysical and socio economics constraints and opportunities (Helmer *et al.,* 1984). By using local resources, local knowledge, connecting farmers, consumers and their markets, the economic conditions and the development of rural can be improved. Organic agriculture stresses diversification and adaptive management to increase farm productivity, decrease vulnerability to weather vagaries, and consequently improves food security, either with the food the farmers produce or the income from the products they sell (Niggli *et al.*, 2008).

Economic sustainability

Organic farming appears to generate 30% more employment in rural areas and labor achieves higher returns per unit of labor input. By using local resources better, organic agriculture facilitates smallholders' access to markets and thus income generation; and relocalizes food production in market-marginalized areas (Helmer *et al.,* 1984). Generally, organic yields are 20% less as compared to high-input systems in developed countries but could be up to 180% higher as compared to low-input systems in arid/semi-arid areas. In humid areas, rice paddy yields are equal, while the productivity of the main crop is reduced for perennials, though agroforestry provides additional goods. Operating costs (seeds, rent, repairs and labor) in organic agriculture are significantly lower than conventional production, ranging from 50-60% for cereals and legumes, to 20-25% for dairy cows and 10-20% for horticulture products (Kustermaan *et al.,* 2008). This is due to lower input costs on synthetic inputs, lower irrigation costs, and labor cash costs that include both family labor and hired workers. Total costs are, however, only slightly lower than conventional, as fixed costs (such as land, buildings and machinery) increase due to new investments during conversion (e.g. new orchards, animal houses) and certification.

Conclusion:

Organic farming works in harmony with nature rather than against it. This involves using techniques to achieve good crop yields without harming the natural environment or the people who live and work in it. An organic farmer produces vegetables, fruit, cereal crops, or livestock without the use of chemical fertilizers, pesticides, or herbicides. In another way organic farming is kind of agricultural that provide the consumers, with fresh, tasty and reliable food while regarding natural life cycle systems. In addition to health benefits of organic products for consumers, there are vital environmental benefits for the earth. An organic farming keeps biodiversity and reduce environmental pollutions such air, water and soil. Organic agriculture has grown out of the conscious efforts by inspired people to create the best possible relationship between the earth and men.

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