ONLINE ISSN 2583-4339
www.journalworlds.com

Agri JOURNAL WORLD

Volume 4 Issue 10 October 2024 Pages 37

PUBLISHED BY LEAVES AND DEW PUBLICATION

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AGRI JOURNAL WORLD
VOLUME 4 ISSUE 10 OCTOBER, 2024

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Published By

LEAVES AND DEW PUBLICATION
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Uttam Nagar, New Delhi 110059

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FOSTERING MICROBIAL DIVERSITY THROUGH CROP DIVERSIFICATION: A PATHWAY TO RESILIENT AGRICULTURE

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ABSTRACT

The agro-ecosystem, comprising crops and their environmental interactions, is significantly influenced by soil microbial diversity, which impacts soil and crop health. Monoculture practices, prevalent in India's rice and wheat-based systems, degrade soil health and diminish microbial diversity by promoting selective microbial proliferation. Crop diversification is proposed as a sustainable alternative, enhancing soil health, microbial diversity, and resilience. By incorporating various crops, crop diversification improves nutrient cycling, soil structure, and organic matter content while reducing the need for chemical inputs. This holistic approach promotes biodiversity, pest control, and economic stability, contributing to more sustainable and resilient agricultural systems.

KEYWORDS: Crop diversification, Microbial diversity, Monoculture, Soil health

INTRODUCTION

The ecosystem comprises of various living entities and their interaction with the environment. The agro-ecosystem mainly focuses on crops and their associated environmental domains *viz.* soil, atmosphere and water. Crops and soil form an inseparable part of each other's environment where there is an interdependence of their health observed at micro and macro levels. The ecosystem functioning is affected by various factors which include climatic and edaphic factors. One of the major determinants of soil health and crop growth is the microbial diversity of soil. It plays a major role in soil and crop health as it is correlated with every single soil health character and plant developmental process. From the process of soil formation by aiding in weathering to the functioning of bio-geochemical cycles and stabilization of soil-plant ecosystem microbes play a dominant role in the entirety of edaphic functions and cycles. The microbial count, diversity and proliferation are greatly affected by the type of crop grown on the soil. Growing the same type of crop on soil promotes a particular set of microbes which eventually overgrow other species owing to the competitive advantage. India has primarily two main cropping systems *viz.*, rice-based and wheat based cropping system. Being commercial and dominant it occupies a larger part of agricultural land thus leading to the same inputs and cultivation practices over the year. Hence, it has a long-term adverse effect on the soil organic carbon and microbial faction. The contemporary period has witnessed a degradation in soil health at multiple levels due to various reasons. The bio-diversity is for sustainability which over decades has been scaled down with the advent of modern farming practices (Maitra and Ray, 2019). This has called for a more sustainable solution posing economic benefits; crop diversification being an effective holistic approach.

MICROBES IN SOIL

Soil harbours a complex and dynamic ecosystem consisting of multiple co-existing microbes which interact among themselves and with plants. The species diversity and population dynamics of microbes depend on the number of factors *viz.* moisture, aeration, pH, temperature, crop type, etc. Their density varies with their location as rhizosphere soil has higher microbial density which decreases in bulk soil. The rhizosphere has as much as twenty times more active microbes than the bulk soil due to higher plant-derived C compounds around the roots hence it is called a microbial hotspot (Kuzyakov and Blagodatskaya, 2015). They are involved in various activities that sustain the ecosystem and various dynamics of the plant-soil continuum, which mainly includes decomposition, fixation, mineralization, soil aggregate formation, plant growth promotion, bioremediation and soil health indicators. Plant microbiomes enhance and promote nutrient turnover in nutrient-poor or degraded soil and also enhance soil hydraulic properties, such as infiltration, seepage and water retention and reduce the hydrophobic nature of soil thus facilitating large-scale restoration of soil and ecosystem (Coban *et al.*, 2022). Based on population bacteria are dominant followed by actinomycetes and fungi. While fungi are dominant in terms of biomass among microbes. Soil microbes have inter and intra-specific relationships with other microbes as well as plants *viz.,* symbiotic (e.g. *Rhizobium* in roots of legumes), parasitic (e.g. soil-borne pathogens infecting roots or plants), competition for resources, amensalism, commensalism, proto-cooperation, etc. The nature and properties of the microbial interactions will discern the value of plant association which further considerably enhances plant-microbe associations and services (Duchene *et al.*, 2017).

MONOCULTURE: EROSION OF SOIL MICROBES

Monoculture refers to the practice of growing single-crop species over years on the same piece of land. Apart from having limitations in terms of unsustainable production, lack of utilization of resources, and economic risks due to loss of crop; it also has a direct effect on the soil by depletion of nutrients, an imbalance of nutrient cycling, increased activity of crop specific pest or pathogen, the input of certain chemicals in more amounts, soil compaction, etc. It creates a certain condition for a prolonged period which favors a certain set of organisms in terms of environmental conditions and substrate and eliminates other organisms not acquainting with the conditions created under the crop. A negative feedback loop is created in soils under monoculture which goes on further diminishing the microbial diversity and activity. This can be stated as the deforestation of soil microbial fauna and flora as it brings down the microbial diversity to a considerably narrow range.

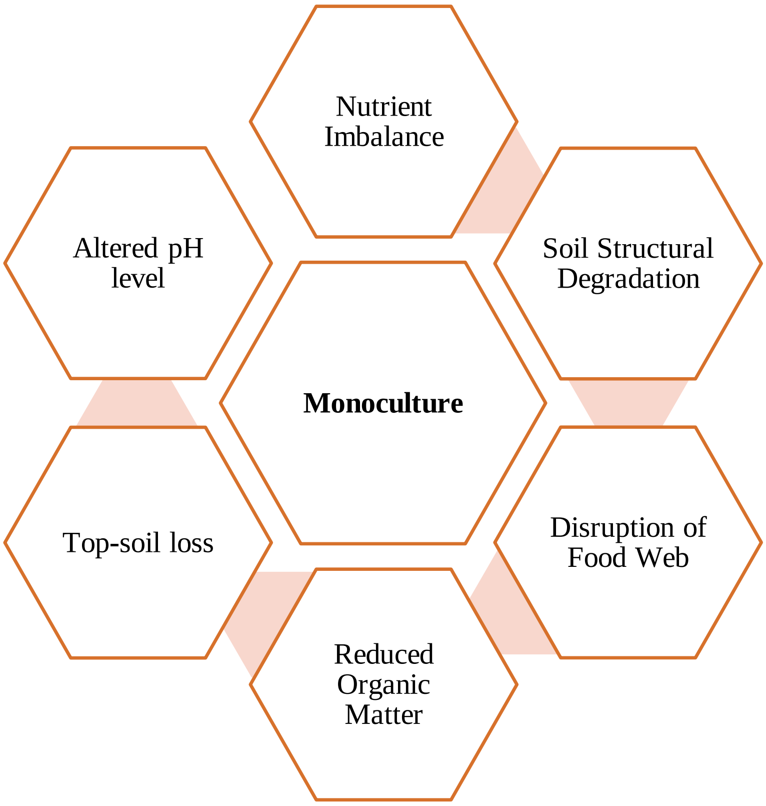

Fig. 01. Negative effects of monoculture that affect microbial diversity and population

❖ STEPS THAT CAN BE TAKEN TO MAINTAIN MICROBIAL DIVERSITY

1. PROMOTE CROP DIVERSIFICATION AND SUSTAINABLE LAND USE PRACTICES:

   Crop Diversification and Sustainable Agriculture: Adoption of practices like crop rotation, cover cropping, and reduced tillage to maintain soil health and microbial diversity.

   Agro-forestry: Integrate trees and shrubs into agricultural systems to increase carbon sequestration maintain habitat complexity and support microbial communities.

2. PROTECT AND RESTORE FORESTS:

   Protected Areas: To conserve remaining natural forests and their microbial ecosystems, protected areas should be established and enforced.

Reforestation and Afforestation: The planting of native tree species should be promoted for the restoration of degraded lands and enhancing microbial habitats. Reforestation steps should consider the original biodiversity of the area.

3. SUPPORT CONSERVATION POLICIES:

Legislation: Frame and support laws and regulations for the protection of forests and the promotion of sustainable land use.

Incentives: Policies providing economic incentives for conservation and sustainable land management practices should be encouraged.

4. PROMOTE BIODIVERSITY MONITORING AND RESEARCH:

Microbial Surveys: Regular surveys should be conducted to monitor microbial diversity and health in various ecosystems.

Research: Invest in research to understand the role of microbes in ecosystems and use this knowledge to formulate conservation strategies.

5. ENCOURAGE COMMUNITY INVOLVEMENT AND EDUCATION:

Local Engagement: Local communities should be involved in conservation efforts, as they play a crucial role in protecting microbial diversity.

Education: Raise awareness about the importance of and the impacts of monoculture and deforestation on microbial diversity and promote sustainable practices at the community level.

6. IMPROVE LAND MANAGEMENT TECHNIQUES:

Soil Conservation: Implement soil conservation practices to prevent erosion and maintain microbial habitats.

Water Management: Manage water resources carefully to avoid runoff and pollution that can impact soil and microbial health.

7. IMPLEMENT TECHNOLOGICAL SOLUTIONS:

Remote Sensing: Monitor cropping system, forest cover and its impact on ecosystems using satellite imagery and remote sensing technology.

GIS Tools: Use Geographic Information Systems (GIS) to decide, implement and monitor the conservation efforts.

CROP DIVERSIFICATION

According to IPES-Food (2016), Crop Diversification is defined as the maintenance of "Multiple sources of production, and varying what is produced across farming landscapes (intercropping) and overtime (crop rotation)."

In India, the area under crop rotation is estimated to be around 30 million ha which mainly includes cereal-based rotation systems while around 1 million ha area is under intercropping (excluding intercropping in horticultural crops), and they estimate that between 12 and 15 million farmers are practising crop rotation of which between 0.70 and 0.90 million are practising intercropping. (*https://www.ceew.in/publications/sustainable-agriculture-india/crop-rotation-intercropping*)

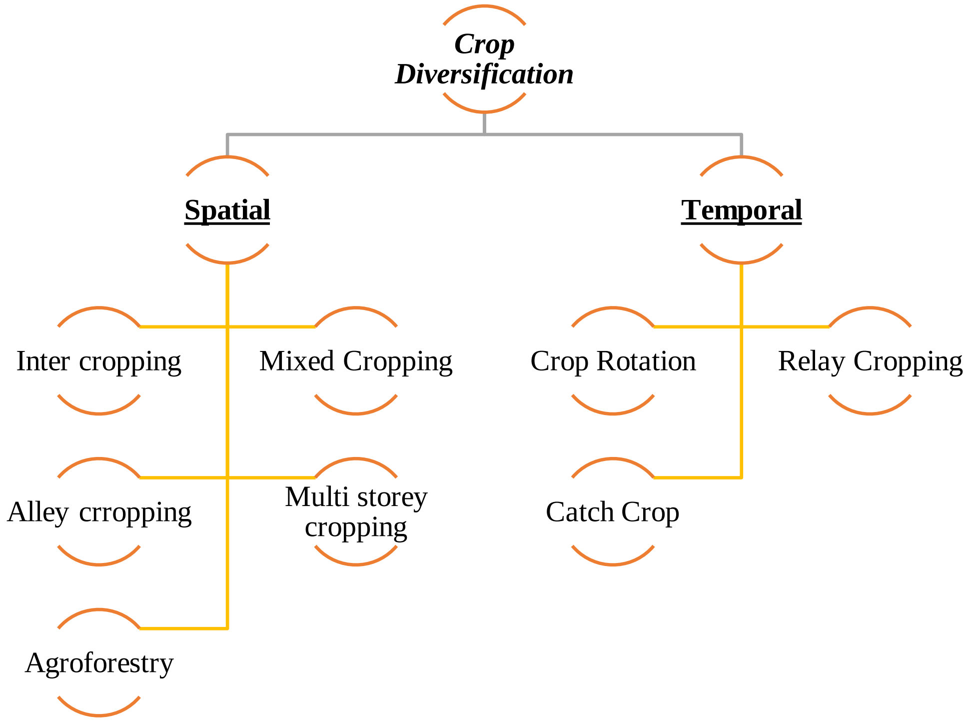

Fig. 02: Types of Crop Diversification

Spatial and Temporal Diversification are two different types of cropping patterns followed on a farm to diversify crops and enhance cropping intensity. Spatial crop diversification includes intercropping, alley cropping, multi-storeyed cropping, mixed cropping and agro-forestry where more than one plant species is incorporated on the land at the same time while temporal crop diversification is achieved through crop rotation, relay cropping and catch cropping. Multi-cropping is practised to produce more crops from a unit of land by efficient resource utilization along with providing insurance against total crop failure due to weather aberrations, particularly under rainfed conditions. Moreover, it maximizes profit without large investments and without impeding soil fertility. It also breaks the cycle of pathogens and pests.

CROP DIVERSIFICATION HAS THE FOLLOWING BENEFITS CONSIDERING AN OVERALL ASPECT OF FARM SYSTEM

1. ENHANCED SOIL HEALTH

   Growing a variety of crops helps in maintaining soil structure, fertility and overall health. Different plants have varying nutrient requirements and rooting patterns, which can reduce soil erosion and degradation in terms of nutrient depletion and physical structure along with preserving the topsoil. Moreover, it also enhances the organic matter and soil macro and micronutrients on a long-term basis.

2. RESOURCE UTILIZATION

   There is more efficient utilization of resources *viz.*, space, light, water and nutrients due to varying canopy structure, rooting pattern and nutrient requirements. This leads to more effective use of water at different depths and use of nutrients at different times. It was noted in a study that the compatibility between root systems of intercropped maize and faba bean resulted in the spreading of roots of intercropped maize underneath the roots of faba bean resulting in an increased soil space available for exploitation of water and nutrients (Xue *et al.*, 2016).

3. PEST AND DISEASE MANAGEMENT

   The cycles of insects, pathogens and weeds are disrupted by crop diversification along with increasing beneficial microbes and insect populations. A varied crop system reduces the intensity and incidences of pest and disease outbreaks, as pathogens and pests specific to one crop may not find suitable hosts in a diversified field.

4. IMPROVED RESILIENCE TO CLIMATE CHANGE

   Crop diversification increases resilience to extreme weather events and climate variability. Due to the varying tolerance of different crops to drought, heat, and floods, a mix of crops can reduce the risk of total crop failure. It also increases the resilience of the farming system against climate change in terms of sustainability, productivity and economics.

5. ECONOMIC STABILITY

   Diversifying crops can provide a safety net against market fluctuations. If one crop fails or its market price drops, other crops might still yield profits, reducing economic risk for farmers.

6. INCREASED BIODIVERSITY

   An increase in the genetic, species and ecosystem biodiversity is observed by crop diversification. It promotes biodiversity on farms, which can benefit other wildlife, including pollinators and beneficial insects. This increased biodiversity can contribute to a more balanced and sustainable ecosystem.

7. NUTRITIONAL BENEFITS

   Growing a variety of crops can promote a more diverse and balanced diet with a range of nutrients. This is particularly important in areas where dietary diversity is low. It addresses food and nutritional security.

8. SUSTAINABLE FARMING PRACTICES

   The need for synthetic fertilizers and pesticides is reduced as diversification involves rotating crops and using different farming practices. This approach supports more sustainable and environmentally friendly agricultural practices.

9. RISK MITIGATION

   Diversified cropping systems are less susceptible to risks such as market changes, price volatility, and climate impacts. This approach can provide a buffer against uncertainties and improve long-term agricultural sustainability. It also reduces the chances of loss by failure of the single crop to weather or market vagaries and provides an alternate option in periods of risk.

10. CULTURAL AND LOCAL KNOWLEDGE

    Crop diversification often involves incorporating traditional and indigenous crop varieties, which can preserve cultural heritage and local knowledge about farming practices. It also boosts the economic potential of rural communities by the development of agro-based industries.

CROP DIVERSIFICATION: RESTORATION OF SOIL MICROBES

Crop Diversification increases the genetic and species diversity of soil by flourishing a range of macro and micro flora and fauna through various interactive, stimulative and inhibitive phenomena. These number of different intermediary effects are discussed below which conclusively enhance microbial population and activities in soil.

1. VARIETY OF ROOT EXUDATES: Root Exudates are organic compounds that include sugars, amino acids and other nutrients which differ according to species, plant habit and root characteristics. The different types of exudates act as food sources for different types of soil microbes. Thus cultivating a variety of crops on a single piece of land increases the range of exudates soil which in turn thrives, diversifies and amplifies the microbial community of soil.
2. DIVERSE PLANT-MICROBE INTERACTIONS: The interaction of plants with microbes like bacteria and fungi varies according to crop type or species which promotes or hinders specific microbial growth. For instance, crops of the Leguminosae family harbour *Rhizobium* spp. in their roots while roots of higher plants have a strong Mycorrhizal network. When two cut flower species were grown together in a mixed cropping system, significantly higher (20–70%) mycorrhizal colonization was observed in

mixed-cropped plants than in the corresponding monocropped plants (Riaz and Javaid, 2017). Thus, incorporating different types of crops also creates niches for the wider range of microbes in the soil. Moreover, the production of certain organic compounds and pumping of certain ions form the basis of the functioning of many microbes eg. Methanogenic bacteria thriving in methane-rich conditions.

3. IMPROVED SOIL STRUCTURE: Different crops have varying root lengths, structures and characteristics which affect their movement in soil, moisture extraction pattern and in turn soil structure and porosity at various depths of soil profile. This consecutively affects soil water infiltration, permeability, seepage and aeration. This creates a habitable environment for soil microbes. Including a tap root plant and fibrous root plant results in the formation of various pores due to root proliferation differences and also the distribution of water in soil which in turn provides aeration and moisture in large volumes of soil thus creating a hospitable habitat for various microbes.
4. ENHANCED NUTRIENT CYCLING: Complex Nutrient Cycling processes are attributed to diverse crops. For example, atmospheric nitrogen fixation is carried out by legumes while crops harbouring Mycorrhiza can mobilize phosphorus. Thus, the enhanced nutrient cycling results in various forms of organic or inorganic forms of nutrients which directly play a role in supporting a broader spectrum of microbial life where each one is benefitted by one or the other nutrient conditions. Moreover, the inclusion of legumes as intercrops increases the total, dissolved and available form of nitrogen and phosphorus which is directly beneficial for microbes and crops. An increase in the abundance of soil bacteria and actinomycetes was observed on intercropping cucumber with garlic compared with monocultures due to increased alkaline phosphatase activity in soil (Xiao *et al.*, 2012).
5. INCREASED ORGANIC MATTER: Diversified cropping systems increase organic matter in the soil, specifically those including legumes or cover crops. It is added in the form of dried leaves or crop residues or slaughed off root residues and root exudates. Organic matter is a substrate for energy and nutrients for soil microbes as it has a high amount of carbohydrates, proteins, fats and cellulose which on breakdown release energy which is used by microbes in their physiological processes and further proliferation. Thus, organic matter being sufficient in amount it supports a rich and diverse microbial community. The enhancement in microbial properties is subjective to both the type of main crop and intercrop. Enzymatic activities are enhanced in systems involving woody crops and legumes. Moreover, many tree species grown in the agroforestry systems being leguminous increase N through fixation and produce high-quality leaf and plant litter with a narrow-C: N ratio thus increasing the organic matter of the soil. (Curtright and Tiemann, 2021)

6. REDUCTION OF CHEMICAL INPUTS: Chemical inputs like synthetic fertilizers and pesticides can be detrimental to non-target organisms. Switching to crop diversification can lower the need for chemical inputs considerably which helps in maintaining microbial diversity.
7. SUPPRESSION OF PATHOGENS

   Most of the soil-borne pathogens depend on a single host crop. Their life cycle is disrupted by crop rotation or multiple cropping. This obliteration of pathogens allows beneficial microbes to proliferate and increase soil microbial diversity. When compared with monoculture soybeans, a significant reduction was observed in root galling on soybean when grown in the intercropping system with marigolds (El-Hamawi *et al.*, 2004).

CONCLUSION

Multiple practices promoting soil health and microbial diversity can be adopted based on available resources and ecosystem characteristics. Crop diversification, due to the inclusion of multiple species of plants in spatial and temporal dimensions results in multi-faceted positive changes in soil in terms of physical, chemical and biological factors which results in an enhanced microbial community development which further results in a better plant-soil-microbe interaction at micro and macro levels due to better crop growth, soil health, nutrient cycling and resource use efficiency. Thus, it can be a one-stop solution for enriching soil in terms of microbes thus increasing soil health and resilience.

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How to cite:

Mandviwala, M. S. and Vaniya, R. (2024). Fostering microbial diversity through crop diversification: a pathway to resilient agriculture. Leaves and Dew Publication, New Delhi 110059. *Agri Journal World* 4(10): 1-10.

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ORGANIC FARMING: EMERGING TRENDS IN ORGANIC FARMING

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ABSTRACT

Organic farming is a sustainable agricultural approach that minimizes synthetic inputs and emphasizes natural practices such as crop rotation, composting, and biological pest control. This method enhances soil health, protects biodiversity, and promotes ecological balance. With growing consumer demand for eco-friendly products, organic farming offers environmental benefits and supports rural livelihoods, especially in developing countries like India. Utilizing organic inputs such as neem extracts and compost, provides a viable alternative to conventional farming, contributing to food security and long-term agricultural sustainability.

KEYWORDS: Biodiversity, Organic farming, Pest Control, Soil Health, Sustainability

INTRODUCTION

Agricultural practices have evolved significantly from ancient hunting and gathering methods to more sophisticated systems of food production. The development of modern agriculture, particularly after the Green Revolution in the mid-20th century, has led to dramatic increases in productivity due to high-yielding crop varieties, chemical fertilizers, pesticides, and farm machinery. While these advancements have helped meet the growing global food demand, they have also introduced environmental challenges, such as soil degradation, loss of biodiversity, and pesticide contamination.

Organic farming, an alternative agricultural practice, seeks to address these challenges by emphasizing the use of natural and sustainable methods. It minimizes synthetic inputs like chemical fertilizers, pesticides, and genetically modified organisms (GMOs), focusing instead on preserving soil health, protecting ecosystems, and ensuring long-term agricultural productivity.

THE ENVIRONMENTAL IMPACT OF CONVENTIONAL FARMING

Conventional farming, which relies heavily on synthetic chemicals and mechanical inputs, has led to several unintended environmental consequences. Pesticides, used to control weeds, insects, and fungal diseases, often have detrimental effects on non-target organisms, such as beneficial insects, birds, and mammals. These chemicals can persist in the environment, contaminating water sources and accumulating in the food chain, which poses risks to both wildlife and humans. Prolonged exposure to pesticide residues, even at low levels, has been linked to health issues, especially in vulnerable populations like children and pregnant women.

Chemical fertilizers, while effective in boosting crop yields, can contribute to soil degradation and water pollution. Excessive use of these inputs leads to nutrient runoff, which contaminates water bodies, causing algal blooms and eutrophication. This, in turn, depletes oxygen levels in aquatic ecosystems, harming fish and other marine life. Additionally, over-reliance on chemical inputs can reduce soil fertility over time, making it more difficult for farmers to sustain high levels of productivity.

ORGANIC FARMING AND ITS COMPONENTS

Organic farming offers an alternative to conventional practices by focusing on sustainable agricultural methods that prioritize environmental health and biodiversity. The key components of organic farming include:

1. SOIL MANAGEMENT: Organic farming prioritizes soil health through natural practices such as crop rotation, cover cropping, and composting. These techniques improve soil structure, fertility, and microbial activity, which in turn enhance crop productivity. Instead of synthetic fertilizers, organic farmers use natural sources of nutrients, such as compost, manure, and organic amendments.
2. PEST AND DISEASE MANAGEMENT: Organic farmers manage pests and diseases without synthetic pesticides. They employ biological control methods, such as introducing natural predators and beneficial insects, as well as cultural practices like crop rotation and planting pest-resistant varieties. These strategies reduce the need for chemical inputs and promote biodiversity on farms.
3. WEED MANAGEMENT: Weed control in organic farming relies on non-chemical methods, including mulching, manual weeding, and crop rotation. Organic farmers may also use mechanical techniques, such as flame weeding or tractor cultivation, to manage weed growth without relying on herbicides.
4. GENETIC MODIFICATION: Organic farming strictly prohibits the use of GMOs. Organic farmers emphasize the preservation of traditional and indigenous seed varieties, which have been adapted to local environmental conditions. This practice not only promotes genetic diversity but also reduces dependence on patented seeds from large agricultural corporations.
5. LIVESTOCK MANAGEMENT: Organic livestock farming focuses on animal welfare, promoting natural behaviors and restricting the use of growth hormones and antibiotics. Animals are raised in conditions that prioritize their health and well-being, which results in the production of organic animal products.

6. CERTIFICATION AND STANDARDS: Organic certification is a key aspect of organic farming, ensuring that farms adhere to established organic standards. Certification agencies conduct inspections to verify compliance, offering consumers assurance that the products they purchase meet organic criteria.
7. MARKET ACCESS AND CONSUMER DEMAND: The growing demand for organic products has created new market opportunities for organic farmers. Consumers are increasingly seeking sustainable and environmentally friendly food options, which often command higher prices. This has expanded market access for organic farmers, who can now cater to a broader consumer base.

ORGANIC INPUTS FOR ORGANIC FARMING

Organic farming relies on a variety of natural inputs to maintain soil fertility, control pests, and promote plant health. Some of the most commonly used organic inputs include:

- NEEM EXTRACTS: Neem is a powerful natural pesticide that targets the hormonal systems of insects rather than their nervous or digestive systems, making it less likely for pests to develop resistance. The primary active ingredient in neem, azadirachtin, has been shown to inhibit insect growth and reproduction, offering an effective and environmentally friendly pest control solution.
- BEEJAMRIT: Beejamrit is a traditional organic seed treatment used to protect seeds from diseases and promote healthy root development. This low-cost, natural method improves germination rates and offers an eco-friendly alternative to chemical seed treatments.
- COMPOST: Organic compost is created by decomposing organic matter such as kitchen scraps, yard waste, and animal manure. It is a rich source of nutrients that helps improve soil fertility and supports healthy plant growth.
- MANURE: Animal manure, particularly from cows, horses, and chickens, is a valuable organic fertilizer that provides essential nutrients to crops while enhancing soil structure.
- BONE MEAL: Bone meal, made from crushed animal bones, is a slow-release source of phosphorus and calcium, which are critical for plant development.
- ROCK PHOSPHATE: This naturally occurring mineral is a key source of phosphorus, promoting root growth and improving overall plant health.
- Chicken Litter: Chicken litter, a mixture of chicken manure and bedding material like sawdust, is an effective organic fertilizer that provides a balanced nutrient profile for crops.

AIMS OF ORGANIC FARMING

- Organic farming is rooted in a set of principles and objectives designed to promote sustainability, health, and ecological balance. The key aims of organic farming include:

- Producing high-quality food, fiber, and other agricultural products in sufficient quantities.
- Collaborating with natural ecosystems, including soil, plants, and animals, to create a harmonious agricultural environment.
- Enhancing the long-term fertility and biological activity of soils through natural methods rather than synthetic inputs.
- Encouraging biodiversity on farms and in surrounding ecosystems by using sustainable production methods.
- Promoting the conservation of water resources and ensuring the sustainability of aquatic ecosystems.
- Maintaining a balance between crop production and animal husbandry to ensure integrated and sustainable farming practices.

The four core principles of organic farming, as defined by the International Federation of Organic Agriculture Movements (IFOAM), are:

- Principle of Health: Organic farming prioritizes the health of individuals, communities, and ecosystems. Healthy soils produce healthy crops, which in turn support the well-being of animals and humans. This principle emphasizes the importance of maintaining the overall health of living systems rather than simply preventing disease.
- Principle of Ecology: Organic agriculture is based on ecological systems and processes, working in harmony with nature to create sustainable farming systems. By fostering biodiversity and ecological balance, organic farming helps maintain the health of air, water, soil, and ecosystems.
- Principle of Fairness: Organic farming promotes fairness and equity at all levels, from farmers and workers to consumers and the environment. This principle emphasizes the importance of creating fair relationships that contribute to food security, poverty reduction, and sustainable livelihoods.
- Principle of Care: Organic agriculture is guided by precaution and responsibility in the management of natural resources and the adoption of new technologies. It integrates scientific knowledge with traditional and indigenous practices to ensure that farming is both safe and ecologically sound.

PRINCIPLES OF ORGANIC FARMING

Organic farming offers numerous environmental, economic, and social benefits:

- ✓ *FOOD SECURITY:* Organic farming can contribute to food security by improving yields in low-potential and marginalized areas. It promotes sustainable farming practices that reduce the risk of crop failure and enhance the long-term productivity of agricultural systems.

- ✓ *ECONOMIC VIABILITY:* Organic farming often leads to reduced input costs, as farmers rely on natural resources rather than expensive chemical inputs. Additionally, organic products typically command higher prices in the market, providing farmers with greater income opportunities.
- ✓ *HUMAN HEALTH:* By reducing exposure to harmful chemical residues in food, organic farming supports the health of both farmers and consumers. Organic products are free from synthetic pesticides and genetically modified organisms, making them a healthier choice for individuals and communities. The organic farming offers numerous environmental, economic, and social benefits:
- ✓ *ENVIRONMENTAL BENEFITS:* Organic farming minimizes pollution, reduces soil erosion, and promotes biodiversity. By avoiding synthetic chemicals, it reduces the risk of water contamination and helps preserve ecosystems.
- ✓ *SOIL HEALTH:* Organic farming practices, such as composting and crop rotation, improve soil fertility and structure, leading to more resilient farming systems. Healthy soils are better able to retain moisture, resist erosion, and support diverse plant and microbial communities.

CONCLUSION

Organic farming represents a sustainable alternative to conventional agriculture, offering numerous environmental and social benefits. By focusing on natural inputs and sustainable practices, organic farming enhances soil health, protects biodiversity, and promotes long-term agricultural productivity. In developing countries like India, organic farming holds particular promise for improving food security, supporting rural livelihoods, and fostering climate-friendly agricultural practices. As consumer demand for organic products continues to grow, organic farming is poised to play an increasingly important role in global food systems, contributing to a more sustainable and equitable future.

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How to Cite:

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www.journalworlds.com
AGRI JOURNAL WORLD
VOLUME 4 ISSUE 10 OCTOBER, 2024

A BRIEF OVERVIEW ON RUGOSE SPIRALLING WHITEFLY (*ALEURODICUS RUGIOPERCULATUS* M.) AND IT'S BIOLOGICAL MANAGEMENT

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ABSTRACT

India's reliance on agriculture and globalization-driven trade has led to the unintentional import of various plant species, diseases, and insect pests, despite strict quarantine measures. These invasive species pose a significant threat to the nation's biodiversity and biosecurity by outcompeting native species due to the absence of natural enemies in the new environment. Pests like Leptocybe invasa, Phenacoccus solenopsis, and Aceria guerreronis have already invaded India. The Rugose spiraling whitefly (RSW), Aleurodicus rugioperculatus, first reported in Kerala in 2016, has spread across southern India, harming plants like coconuts and mangoes and encouraging sooty mold growth.

KEYWORDS: Biological management, Insect pest, Invasive species, Polyphagous, Sooty mold

INTRODUCTION

India's economy is primarily focused on the agriculture sector, which employs 50% of the labour force and accounts for 18% of the nation's GDP. The population of our nation is largely fed by agriculture. Due to low agricultural productivity and production, India experienced a severe food scarcity in the early years of its independence. However, since the start of the green revolution, everything has completely altered. The green revolution's objective was to boost food grain production by using innovative technologies to raise the output of food grain crops per hectare. The agriculture industry has benefited greatly from this adaptation (Joshi, 1999). The per-hectare yield of several agricultural and horticultural crops has improved since HYVs were introduced in the 1960s. Subsequently, the yield of cereals, pulses, vegetables, fruits, and milk per hectare in India has increased significantly. Horticultural crop production reached a peak in 2014–15, reaching 86283 metric tons from 65587 metric tons in 2007–2008 (Anonymous, 2018). The years 1990–1992 saw economic reforms pave the way for globalization, which boosted commerce in goods, particularly agricultural products, seeds, and planting materials. This increased trade raised concerns about the biosecurity of foreign pests entering India. The primary factors to be taken into account when managing biosecurity risks are globalization, the growing demand for food production, the adoption of new technologies, the legal obligations for signatories to pertinent international agreements, the flow of individuals across borders increasing the incidence of pests and diseases worldwide, the reliance of some countries on food import/export, and movement of people across borders. Several plant, insect, and pathogen species have been introduced to new areas as a result of the unrestricted commerce and movement of plant materials across national and geographic borders. The term "alien species" refers to such non-native species. Non-native or exotic creatures that exist outside of their naturally occurring, appropriate habitat and dispersal potential are known as alien species. Our agricultural and forestry systems rely heavily on a substantial amount of alien species. However, some alien species exhibit the ability to establish, invade, and outcompete native species in new places when they are accidentally introduced outside of their usual habitats. This is when they are considered invasive. When these species proliferate rapidly and harm economically significant plant species and crop plants, they become invasive because they lack the natural enemies that keep them in check within their original habitat. As an illustration, consider the invasion by the coconut eriophyid mite Aceria guerreronis, the mealy bug Phenacoccus solenopsis in cotton, the mealybug *Paracoccus marginatus* in papaya, and the Leptocybe invasa and rugose spiralling whiteflies (Ananthakrishnan, 2009) Aleurodicus rugioperculatus Martin (Hemiptera: Alleyrodidae). Spodoptera frugiperda (J.E. Smith), often known as the fall armyworm, has been detected in Karnataka's maize fields recently (Ganiger et al., 2018). These invasive species are extensively dispersed throughout the planet and encompass all classes of living things in all types of environments. However, in terrestrial ecosystems, the most prevalent alien species are plants, animals, and insects.

ORIGIN AND DISTRIBUTION

In 2009, rugose spiralling whiteflies were first reported as pests in Miami-Dade County, Florida, affecting gumbo limbo trees (Bursera simaruba). However, the species was first documented in Belize in 2004, identified as coconut plants. Its distribution is primarily in Central and North America, including Belize, Mexico, Guatemala, and the United States, likely originating from Central America. After its discovery in Florida, the pest spread to 22 countries across Central and South America. In India, the whitefly was first detected in 2016 in Kerala and Tamil Nadu, affecting coconut, mango, and guava trees, later spreading to Andhra Pradesh.

Table 1: Overview of certain pest alien insects that are invasive

SCIENTIFIC NAME	COMMON NAME	INTRODUCE FROM	YEAR OF INTRODUCTION	HOST PLANTS
Eriosoma lanigerum	Woolly apple aphid	China	1889	Primarily apple and pea.
Quadraspidiotus Perniciousus	San Jose scale	China	1911	*Populus spp.; Salix spp.; Aesculus spp.; Alnus spp.; Betula spp.; Celtis spp.; Fagus spp.*
Orthezia insignis	Lantana bug	Sri Lanka; West Indies	1915	Mainly lantana, Coffee, Jacaranda, Citrus, Sweet potato, Gumwood, Brinjal, Rose etc.
Icerya purchasi	Cottony cushion scale	–	1921	*Acacia decurrens*; A. *dealbata* in addition to numerous other forestry and agricultural Plant species
Phthorimaea operculella	Potato tuber moth	Italy	1937	Tobacco, tomato & brinjal
Plutella xylostella	Diamondback moth	Europe	1941	Crucifers viz., cabbage, cauliflower, radish, knol khol (rabi), turnip, beetroot, mustard.
Pineus pini	Pine woolly aphid	Australia, Europe, New Zealand	1970	*Pinus* spp.; *Pinus patula*
Heteropsylla cubana	Subabul psyllid	Sri Lanka	1988	Subabul.
Liriomyza trifolii	Serpentine leaf miner	USA to Kenya & rest of the world	1990	It is a polyphagous species affecting more than 78 plant species, especially on greens, cucurbits, tomato, castor and ornamental plants (Srinivasan *et al.*, 1995).
Hypothenemus hampei	Coffee berry borer	Sri lanka	1990	Both *arabica* and *robusta* types of coffee.
Aleurodicus disperses	Spiralling whitefly	Hawaii to Sri Lanka and	1994	It is a polyphagous affecting wide range of host plants – 481 plants

Russell		India		
Quadrastichus erythrinae	Erythrina gall wasp	May be Taiwan	2006	Black Pepper
Phenacoccus solenopsis	Cotton mealybug	Central America	2008	Cotton, bhendi, tomato, potato, pomegranate, hibiscus, parthenium, etc
Leptocybe invasa	Eucalyptus gall wasp	Australia	2006	*Eucalyptus camaldulensis; E. tereticornis; E. grandis; E. deanei; E. globules; E. nitens; E.botryoides; E. saligna; E.gunnii, E. robusta; E. bridgesiana; E. viminalis.*

(Source:- Sujay *et al.*, 2010)

NATURE OF DAMAGE AND SYMPTOMS

Rugose spiraling whiteflies cause stress to plants by depleting their nutrients and water. Additionally, they produce a sticky substance called honeydew, which provides an ideal environment for the growth of sooty mold. As the honeydew dries, thick black layers of mold form on the leaves and other surfaces. This mold can disrupt photosynthesis, potentially leading to physiological issues in the host plant. Honeydew also attracts ants and wasps, which protect whiteflies from natural predators. The pest not only damages plants but also creates a mess on cars, furniture, patios, and other surfaces, often requiring professional cleaning to remove the stubborn mold.

BIOLOGICAL MANAGEMENT

Rugose spiraling whitefly (RSW), being polyphagous, poses a threat of spreading to other coconut-growing countries in the Oriental region, making its presence in India alarming. As a non-native species, it may become invasive if its natural predators or parasitoids are absent or insufficient to control its population (Duan et al., 2015). Extension entomologists must collaborate with farmers and stakeholders to raise awareness and develop rapid response strategies. A coordinated effort among coconut-growing nations is essential to contain its spread and devise appropriate management plans.

Research in Tamil Nadu (Poorani and Thanigairaj, 2017) identified *Encarsia dispersa* parasitizing *A. rugioperculatus*, though the more effective parasitoid was *Encarsia guadeloupae* (Hymenoptera: Aphelinidae), which caused 40–70% parasitism in banana and 20–60% in coconut in Tamil Nadu and

Kerala. *Encarsia dispersa* was far less prevalent, with under 5% parasitism, while *E. guadeloupae* accounted for 60–70% of total parasitism..

ENCARSIA GUADELOUPAE

The Lakshadweep's Minicoy Island is where Encarsia guadeloupae was initially discovered in 1999. It was subsequently purposefully brought to the mainland and established there (Ramani, 2000). With the help of deliberate release and colonization, these parasitoids most likely moved from the Maldives to Minicoy and other Lakshadweep islands before spreading to other parts of peninsular India (Ramani, 2000; Mani et al., 2000b). Although they had been introduced with the host, it is also possible that the parasitoids were only discovered after their numbers had grown dramatically over several years due to reproducing on the growing host population.

Female E. guadeloupae key diagnostic features include body dark brown, except the side lobes of the mesoscutum and scutellum; mid lobe mostly dark brown; axillae brown; TVII yellow or brown laterally; and third valvula pale yellow. Legs: pale yellow to white, wings hyaline, coxa behind and femur dark brown. Scutellum has two pairs of setae; axillae typically have one setae each; clava is as long as the final two segments of the funiculus; mesoscutum typically has nine pairs of setae (sometimes varies to fifteen or twenty). The basal cell of the forewing with three setae preceding the parastigma. Front and rear tarsi-5 are segmented; the mid tarsi-4 are segmented. Likewise, it has been documented that E. guadeloupae and Encarsia sp. may be parasitoids of many whiteflies, including RSW (Evans, 2008: Taravati et al., 2013; Francis et al., 2016). Moreover, Encarsia sp. (GenBank Acc. No. KY223606) was generated by amplifying, sequencing, and depositing the parasitoid's COI gene (658 kb). According to (Selvaraj et al., 2016), the percentage of parasitism varied depending on the geography, with Kerala having the highest rate of parasitism among the states surveyed.

ENCARSIA DISPERSA

An exotic parasitoid with Neotropical (New World) origins is *Encarsia dispersa* Polaszek. The names *Encarsia haitiensis* Dozier, *Encarsia* sp. nr. *haitiensis*, and occasionally *Encarsia* sp. nr. *meritoria* Gahan have been incorrectly and commonly used to refer to this species by several writers from India (Ramani *et al.*, 2002) and other places. It has been accidentally and purposefully introduced all over the world to manage the spiralling whitefly, *Aleurodicus dispersus* Russell, biologically (Polaszek *et al.*, 2004). Despite their close relationship, (Polaszek *et al.*, 1992) considered *Encarsia haitiensis*, *Encarsia* sp. nr. *haitiensis*, and *Encarsia* sp. nr. *meritoria* to be different entities. According to (Polaszek *et al.*, 2004), the original populations of E. *dispersa* that were transferred to Hawaii from Trinidad are likely the source of the widely dispersed populations. *Encarsia dispersa* had been initially a species for both *Encarsia* that were unintentionally brought to South India in the 1990s, together with its host, A. *dispersus* and the other species E. *guadeloupae* (Ramani et al., 2002). Within two to three years, E. *guadeloupae* replaced E. *dispersa* in most of the South Indian locations where it was colonized, in what appears to be a case of competitive displacement (Ramani *et al.*, 2002; Mani *et al.*, 2004; Mani, 2010).

CONCLUSION

In conclusion, one alien pest that made its way to India is the rugose spiralling whitefly. Because it is polyphagous and challenging treatment, this insect has created a major dilemma for horticultural growers. A conscious effort was made to address every facet of this bug in our evaluation. Further research is necessary to have a better comprehension of this pest, including thorough examinations on some of its characteristics. In order to effectively combat the RSW in the field, mass multiplication strategies for parasitoids and predators must be standardized in a laboratory setting.

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How to Cite:

Nandi, R. (2024). A brief overview on rugose spiralling whitefly (A*leurodicus rugioperculatus* M.) And it's biological management. Leaves and Dew Publication, New Delhi 110059. *Agri Journal World*, 4(10):17-23.

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AGRI JOURNAL WORLD
VOLUME 4 ISSUE 10 OCTOBER, 2024

CULTIVATING THE FUTURE: SUSTAINABLE AGRONOMIC PRACTICES FOR GLOBAL FOOD SECURITY

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ABSTRACT

In the face of rapid population growth, climate change, and environmental challenges, the connection between agronomic practices and global food security is more critical than ever. Despite advancements, food shortages persist in regions affected by drought, disease, and political instability. With the global population projected to double by 2050, sustainable agronomic practices are essential for meeting the rising demand for food, feed, and fuel. These practices improve soil, water, and labour productivity through methods like organic matter application and efficient resource use. Integrating modern agronomic techniques can enhance crop yields, promoting sustainable food production and global food security.

KEYWORDS: Climate resilience, Crop productivity, Global food security, Resource efficiency Sustainable agronomic practices

INTRODUCTION

Food security must be attained for all living beings to sustain the earth and its environment. Food security is defined as a situation in which people do not live in hunger or fear of hunger. According to the FAO, "Food security exists when all people, at all times, have access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life." As the global population grows at an alarming rate, the demand for food is projected to double by 2050. This massive demand for food, feed, and fuel will necessitate sustainable agronomic practices to increase crop productivity (Sangakkara and Nissanka, 2017).

GLOBAL FOOD SECURITY AND CONSTRAINTS IN MEETING GLOBAL DEMANDS FOR FOOD

Even though trends in global food security have shown a transition from shortage to surplus over the last decade, food scarcity continues to affect poor populations in regions facing severe drought, disease, low nutrient availability, and political instability. A recent study estimates that global food demand will increase by 50%, and the area of cultivated land by 10% by 2030, assuming a 40% increase in yields for major crops (Godfray et al., 2010). However, the current scenario is different, as land and resources are limited, and the growing demand must be met with these finite resources. Drought and other water-related constraints present major risks to food crops, contributing to 20-30% of current yield gaps. Farmers in rural regions have limited access to new technologies. Since they are often poor, they must adapt and survive through hardships, using their meagre resources judiciously. The challenges of food production are further compounded by the unavailability of good planting materials and inputs like fertilizers and plant protection chemicals.

Agronomic Implications for Food Security: Studies by the FAO suggest that to enhance food security in developing nations, three strategies should be employed: increasing crop yields, increasing the intensity of cropping, and cultivating new land resources. Given the limited availability of land, the most viable strategy for achieving food security is to increase yields and cropping intensity. Short-term improvements in food security can best be achieved through better agronomic methods and crop management to ensure higher and more sustainable yields, even with diminishing resources.

AGRONOMIC METHODS TO ENSURE FOOD SECURITY

- SOIL QUALITY MAINTENANCE: As we continue to follow intensive agricultural practices that could lead to the degradation of soil and water resources, the maintenance of organic matter and soil conservation measures is crucial to determining soil quality. This can be achieved through the application of organic matter to the soil, either in-situ as green manuring or ex-situ as green leaf manuring. This practice improves the physical, chemical, and biological properties of the soil, thus enhancing crop yields. It also reduces the nitrogen requirement by minimizing the leaching of nitrates.
- INNOVATION IN CROPPING SYSTEMS AND FARMING SYSTEMS: Growing more crops within a single growing season maximizes the utilization of solar radiation. Multiple cropping systems have the potential to increase productivity in crop yields. Systems like intercropping, double cropping, and relay cropping optimize land use. Crop rotations, such as cereals and legume rotations, also enhance productivity. Agroforestry, an aspect of agronomy, promotes sustainability by reducing land degradation. The combination of trees and crops enhances food and nutritional security while mitigating environmental degradation. It also plays a major role in carbon sequestration, which is important in the context of global warming.

- RESOURCE USE EFFICIENCY: Alongside increasing crop productivity, optimizing the use of resources like water and nutrients is essential. In many regions, water efficiency is compromised by unnecessary losses through evaporation and seepage. Adopting proper irrigation systems and scheduling can prevent these losses and improve water use efficiency. Nitrogen, a key plant nutrient, has an efficiency rate of about 30-40% in rice fields, with losses occurring through denitrification, volatilization, and leaching. These issues should be addressed. In addition to nitrogen, the use of other nutrients must be optimized, and fertilizer use efficiency must be improved. Closing yield gaps largely depends on achieving resource use efficiency, which requires minimizing inputs while maximizing the utilization of all other resources.
- IMPROVING CROP MANAGEMENT PRACTICES: Agronomic management of crops begins with selecting a suitable site for cultivation, followed by choosing the right variety and seed, preparing the land, establishing the crop, managing fertilizers, controlling weeds, pests, and diseases, ensuring adequate moisture, and employing special techniques like mulching and timely harvesting. Carrying out these management practices at the right time helps achieve better crop productivity. Modern approaches like precision farming and information and communication technology also aid in better crop management.

CONCLUSION

To feed the rapidly growing population, improving crop productivity, managing land and water resources, and enhancing resource use efficiency will be essential. Better agronomic management of cropping systems in a sustainable manner is key. An integrated approach that considers all the above factors can guide us toward achieving global food security.

How to Cite:

Chethan, C., Melavanki, M.S., Fiskey, V. V., and Chethan Babu, R. T. (2024). Cultivating the future: sustainable agronomic practices for global food security. Leaves and Dew Publication, New Delhi 110059. *Agri Journal World*, 4(10):24-26.

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Agri JOURNAL WORLD
www.journalworlds.com
AGRI JOURNAL WORLD
VOLUME 4 ISSUE 10 OCTOBER, 2024

MODERN ASPECTS OF PANCHAGAVYA IN PLANT PROTECTION

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ABSTRACT

In India, Panchagavya is an organic blend of five or more cow-derived components used in Hindu rituals and agriculture. This biofertilizer and plant growth enhancer is made from five cow products, with "Panchagavya" meaning "five cow derivatives" in Sanskrit. Valued in sustainable agriculture, Panchagavya enhances plant health, soil fertility, and protection methods. It also boosts immunity in animals by promoting antibody production and is used to increase appetite, heal wounds, and treat conditions like psoriasis in humans. This article explores the modern uses of Panchagavya in pest and disease management.

KEYWORDS: Insect, Pests, Disease management, Panchagavya, Plant protection

INTRODUCTION

In Ayurveda and conventional Indian beneficial procedures, panchgavya—which refers to milk, urinates, dung, ghee, and curd—has a crucial medicinal role. The practice of Panchgavya is known as "Cowpathy" in Ayurveda. The cow is revered as a divinity in India, where it is known as "Gaumata," signifying its maternal qualities. By encouraging soil fertility, earthworm development, shielding crops from bacterial as well as fungal diseases, and other benefits, panchgavya may also return some of that fertility to the environment. Numerous advantageous microorganisms, including Lactobacillus, Bacillus, Saccharomyces, Candida, Streptococcus, and some others, are abundant in cow faeces. It also includes a variety of nutritional elements, including cellulose, hemicellulose, mucus, lignin, potassium, nitrogen, oxygen, and vitamins. "Gomutra," or cow urine, is a non-toxic waste water that comes out from the cow. It is well recognised that cow urine, or its distillate, has several health benefits that can extend survival rates as well as improve the quality of life in patients with serious diseases.

PREPARATION OF PANCHAGAVYA

Although panchgavya is easily available in the Indian market, we choose to manufacture our own. This is due to the fact that panchagavya is quite simple to prepare, additionally to our need to maintain quality control. The quantity of various inputs are given in Table 1.

Table 1: Quantity of various inputs used for the preparation of panchagavya

Item	Quantity required
Cow Urine (Doesn't require fresh urine)	3 Liter
Cow Ghee	500 gm
Fresh cow dung	5 kg
Cow milk	2 Liter
Fresh Cow Curd	2 Liter
New prepared coconut water	3 Liter
Fresh grapes juice	2 Liter
Blackish organic jaggery	500 gm
Good ripening bananas	13 pcs
Water	3-4 Liter

METHOD FOR USING PANCHAGAVYA

Panchagavya can be applied as a liquid fertilizer by diluting it with thirty parts water. Using a piece of cotton to filter the liquid and remove waste, you can use it to formulate a foliar spray. It will clog your spray nozzle if you don't filter it. When a plant is growing normally, we apply it as fertilizer once every two weeks; during flowering and fruiting, we use it once a week. We use it once a week as a foliar spray. We've found that after applying Panchagaya, all pests vanish and then begin to reappear after roughly a week. We therefore spray once a week. It is best to spray in the early or late hours of the day. On an average day, we may apply it in the morning between 8 and 9 AM. About a half-hour before sundown in the evening spray. Rainy days are not the time to waste your Panchagavya.

BIOCHEMICAL PROPERTIES OF PANCHAGAVYA

In addition to total reducing sugars (glucose), panchagavya also contains macronutrients (N, K, P, Ca and Mg) and micronutrients (Fe, Zn, Cu, and Mn). The ammonia intake and overall N supply were enhanced by the chemolithotrophs and autotrophic nitrifiers (nitrifiers and ammonifiers) found in panchagavya, which colonize the leaves. After 30 days of fermentation, the pH of panchagavya dropped to 4.52, possibly as a result of the Lactobacillus bacteria in the panchagavya producing more organic acids during the fermentation process. The quantity of various growth hormones in panchagavya is given in Table 2.

Table 2. Quantity of various growth hormones in panchgavya

Sl. NO	Property	Range
1	Butyrate (%)	6.40- 7.75
2	IAA(ppm)	8.5
3	GA(ppm)	3.5
4	Propionate(%)	14.39- 17.79
5	Acetate(%)	60.05- 68.28

TRADITIONAL KNOWLEDGE REGARDING THE ABILITY IMPACTS OF PANCHAGAVYA ON PLANT DEVELOPMENT

- SUPPLY OF NUTRIENT: In addition to micronutrients, panchagavya contains a variety of nutrients, such as potassium, phosphorus, and nitrogen. Plants can absorb these nutrients, which encourages the growth and development of plants.
- MICROBIAL ACTIVITY: Certain beneficial bacteria found in panchagavya can increase the diversity of microbes in the soil, aid in nutrient metabolism, and increase the availability of important nutrients for plants.
- STRESS TOLERANCE: Scientists assert that panchagavya, which is frequently sprayed on leaves, can aid plants in enduring environmental stressors such as heat, drought, and pests.
- REDUCE ENVIRONMENTAL HAZARD: The usage of panchagavya is frequently linked to organic agricultural methods, which try to reduce the dependency on artificial fertilisers and chemicals. This might improve the general sustainability and health of plants.
- EFFECT ON FERTILITY OF SOIL: Because it functions as organic manure, panchagavya plays a significant role in improving soil fertility status. It also increases plants' capacity to hold water and has been shown to increase nutrient uptake. However, it's essential to note that there is limited scientific research on the effects of panchagavya and that the results can differ based on many factors, including crop variety, soil type, and application techniques.

APPLICATION OF PANCHAGAVYA IN INSECT PEST MANAGEMENT

We can use panchagavya in various plant protection approaches. We can use it against many insect pests, fungal and bacterial diseases. It also works as a botanical insecticide. It does not leave any residue on food or in the environment; they only kill the target insects (Mandal,2024).

- ✓ In addition to providing resistance against numerous sucking pests, yearly applications of Panchagavya increased the stick output in Moringa plants.
- ✓ Panchagavya showed efficacy power against *Bemisia tabaci* (White fly) and *Amrasca biguttula biguttula* (jassid) in okra (Boomirajet al. 2004).
- ✓ It is also a powerful insect repellent. It is very successful in reducing the threat posed by fruit flies from fruit and vegetable crops.
- ✓ According to research by Mudigora et al. (2009), Panchagavya + cow faeces mixed with neem seed kernel extract(NSKE) worked well in suppressing *Atherigona soccata*. NSKE works as an insect repellent.
- ✓ Under laboratory circumstances, the combination of 3% neem oil and 3% Panchagavya showed the highest mortality rate for *Spodoptera litura*.

PANCHAGAVYA USED AS PLANT DISEASE MANAGEMENT:

Panchagavya is one of the most important organic amendments that are used as quick fertilizers and pesticides in crop cultivation. It is effectively used as an organic supplement in plant disease management mainly soil-borne pathogens to improve the agricultural and horticultural crop yields, establishment and soil health as eco-friendly. Because it depletes the nutrients as saprophytes and starvation of the pathogens. Composted cow dung enhances plant growth and is high in total nitrogen (0.74%), which includes some hormones (Dhama et al., 2005). The rice bacterial blight disease was also found to be effectively controlled by cow dung extract spray, outperforming Penicillin, Pausha Mycin, and Streptomycin. It was discovered that cow dung when utilized as organic manure, increased plant vigour and decreased the occurrence of *Phymatotrichum omnivorum*-caused root rots in cotton. A destructive fungus called damping-off affects seeds and seedlings in both field and nursery conditions. The ability of panchagavya to prevent the growth of two soil-borne diseases, namely *Sclerotium rolfsii Sacc., Phytophthora colocasiae and Fusarium solani* (Rathore and Patil, 2019). Panchagavya is known to have antifungal properties against major soil-borne pathogens, including *Fusariumsolani f. sp. pisi, F. oxysporum f. sp. pisi, Rhizoctoniasolani, SclerotiumrolfsiiSacc, Sclerotiumsclerotiorum*. The researcher reported that 90% inhibition was observed in *F. oxysporum f. sp. pisi* and *F. solani f. sp. pisi*, and 100% in *S. rolfsii*, *S. sclerotiorum*, and *R. solani* (Kumar et al., 2020). Thus, an appropriate and sustainable method of applying panchagavya can increase output productivity while reducing the risk of disease infection.

CONCLUSION

In the past agricultural growth prioritized short-term production through the use of outside inputs, which led to a disregard for and inappropriate use of local resources. The primary aspect of panchagavya is its ability to effectively recover all crop output levels when the land is transformed from an inorganic to an organic cultural system starting in the first year. The use of Panchagavya in pest and disease management should be increased. The percentage of increasing yield is the main factor for any farmer and panchagavya does it properly.

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How to Cite:

Mondal, A., and Mandal, I. (2024). Role of antibiotics in plant disease control. Leaves and Dew Publication, New Delhi 110059. *Agri Journal World*, 4(10):27-31.

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www.journalworlds.com
AGRI JOURNAL WORLD
VOLUME 4 ISSUE 10 OCTOBER, 2024

OPTIMIZING CROP YIELDS: A COMPREHENSIVE GUIDE TO SITE-SPECIFIC NUTRIENT MANAGEMENT AND PRECISION FARMING TECHNIQUES IN INDIA

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ABSTRACT

The Green Revolution in India relied on high-yielding wheat and rice varieties that thrived with increased water and fertilizer use. Although fertilizers boost soil fertility, improper and unbalanced application by farmers has raised concerns about nutrient management. Many farmers overuse nitrogen and phosphorus, neglecting other essential nutrients like potassium, leading to nutrient depletion, reduced productivity, and lower fertilizer efficiency. Site-specific nutrient management (SSNM) addresses this issue by applying nutrients based on crop needs, optimizing fertilizer use, preventing nutrient loss, and promoting balanced fertilization for improved yields and soil health.

KEYWORDS: Leaf color chart, Nutrient use efficiency, Precision farming, Site specific nutrient management

INTRODUCTION

The extensive usage of different fertilizers across the world has significantly increased food production. As per the estimates, nutrient inputs account for between thirty and fifty per cent of crop production. However, there are currently significant concerns regarding existing nutrient management methods due to low nutrient-use efficiency, associated environmental contamination, and global warming issues. For N, P, and K, respectively, the recovery efficiency of fertilizer nutrients is roughly 20–40, 15-20, and 40–50%, however, it is significantly inferior for secondary and micronutrients, between 5–12%. The constant nutrient mining from the soil as a result of imbalanced nutrient use leads to the diminution of some major, secondary, and micronutrients like N, K, S, Zn, Mn, Fe, B, etc., as well as the decreasing use of organic nutrient sources like FYM, compost, and the integration of green manures are some of the major causes of low and declining crop responses to fertilizers. Thus, the management of nutrients has always been crucial for crop growth as well as for the sustainability and health of the soil, economy, and society.

Recommendations for managing nitrogen levels in practically all farmed crops have been produced based on extensive research led over the previous 50 years. The produced guidelines specify the application time and the amount of various nutrients desired on a hectare basis. Such general recommendations led to the over use of nutrients in some areas and the underapplication of nutrients in others since they mainly ignored the heterogeneity in the innate soil fertility and other edaphic characteristics. Low nutrient-use efficiency and fertilizer waste were the outcomes of this. Research from several Asian nations has shown the drawbacks of the traditional method of recommending blanket fertilizers at a predetermined rate and time. However, the idea of site-specific nutrient management of nutrients was created in recognition of the limitations of the general nutrient recommendations.

SITE SPECIFIC NUTRIENT MANAGEMENT

The soil provides a large amount of the nutrients required by plants, but this natural supply is typically insufficient to meet the demands for high yields. To close the gap between the crop's nutrient requirements and what the soil and readily available organic inputs can supply, fertilizer application is essential. By precisely supplying nutrients like nitrogen (N), phosphorus (P), and potassium (K) to crops like rice, maize, and wheat when they are needed, site-specific nutrient management (SSNM) improves nutrient utilization efficiency. The main benefit of enhanced nutrient management for farmers using SSNM is higher profitability. By avoiding overapplication and making sure that fertilizers are not applied when crops don't require them, SSNM minimizes fertilizer waste. Additionally, it ensures that N, P, and K are applied in the exact ratios needed for that particular crop. The method of providing crops with nutrients on demand is referred to as the Principle of Site-Specific Nutrient Management (SSNM). Nutrient management and application are dynamically modified to meet crop needs specific to the region and time of year. Through higher crop yields per unit of fertilizer applied, overall higher yields, and decreased disease and insect damage, the SSNM strategy seeks to boost farmers' profits.

Soil testing remains to be a significant bottleneck. Thus, attempts have been made in India to create a type of SSNM programming that primarily uses modern technologies like LCC, SPAD, Nutrient Expert (NE), and Green Seeker which does not require a large data store. One of the main factors influencing increasing productivity, sustainability, profitability, and turbulence associated to climate change is precision nutrition. The production of food grains has increased owing to SSNM, but the efficiency of nutrient use has not increased beyond a certain point.

Leaf Color Chart

The relative greenness of a rice leaf can be tracked utilizing the leaf color chart (LCC), a simple and inexpensive diagnostic tool that displays the nitrogen (N) status of the plant. Nitrogen status of rice is a sensitive indicator of changes in crop N needs throughout the growing season as it is highly correlated with the photosynthetic rate and biomass production of the plant. Achieving optimal leaf N content and high rice yields through effective nitrogen management requires a tool that can rapidly evaluate the state of nitrogen in the leaves and direct the administration of nitrogen fertilizer. The LCC is a four-panel plastic strip with a range of colours from yellowish green to dark green that is shaped like a ruler. With two equally useful options available for use, it is utilized to monitor leaf N status from the tillering stage to panicle initiation or later. Farmers' preferences and site-specific factors, such as how often they visit their fields and how well-informed they are about the crucial growth stages for nitrogen treatment, will determine which of these options they choose. Farmers who engage in other profitable endeavours tend to favour the fixed-time/adjustable-dose option due to its time-saving nature, whereas farmers who are not well-versed in the essential phases for the ideal timing of nitrogen fertilizer N typically favour the real-time option.

HOW TO USE THE LCC?

1. Choose ten or more healthy, disease-free rice plants or hills at random from a field with a uniform population of plants.
2. Select the leaf that is completely extended at the top of each plant or hill. For comparison, position the leaf's centre section in relation to the LCC's colour panels. Make sure the leaf stays intact and attached throughout the procedure.
3. Measure the colour of the leaves beneath the body's shadow as leaf colour readings are influenced by direct sunshine. The same individual should, if at all feasible, take LCC readings at the same time of day each time.
4. Determine the average LCC reading for the selected leaves.

When N is not applied to plants, they turn yellow. Confirmation of a nitrogen deficit occurs when the LCC result falls between panels 2 and 3. The essential range for the majority of transplanted rice is between panels 3 and 4, which is where the LCC reading falls. The leaves of plants with high N rates exhibit a deep green colour. There is an excess of fertilizer N seen in the leaf colour, which is darker than the LCC panel no. 4.

SPAD (SOIL PLANT ANALYSIS DEVELOPMENT)

The SPAD meter is becoming more and more popular since it provides a non-destructive method of measuring the chlorophyll content of leaves and is portable, accurate, rapid, and easy to use. The SPAD meter is perfect for tracking plant development and nutritional condition over time because it is non-destructive and allows for several measurements on the same plant. The gadget is also reasonably priced, long-lasting, and low maintenance, which makes it a cost-effective option for growers and researchers alike. Its utility is further increased by its portability, which makes it easy to utilize in the field. To ensure that their crops stay healthy, productive, and optimized for yield and quality, farmers can use the SPAD meter to quickly assess the chlorophyll content of the plants, identify possible problems early, and take corrective action, such as adjusting fertilizer application rates or addressing pest and disease concerns.

WORKING OF SPAD

The SPAD meter is a tool used to quantify the amount of chlorophyll in plant leaves. When a photon is absorbed, it uses a reverse-biased p-n junction to produce an electrical signal. The optical absorption principle serves as the foundation for the measurement. A tiny, non-invasive sensor on the leaf's surface that emits light at particular wavelengths between 500 and 700 nm or up to 940 nm is part of the meter. These are visible light wavelengths that are similar to the absorption peak of chlorophyll a, which is the main type of chlorophyll found in green plants. The SPAD meter calculates the chlorophyll content by measuring the amount of light absorbed by the chlorophyll. The tool measures the relative amount of chlorophyll content, which is correlated with the amount of nitrogen present in plant tissue. Greater tissue nitrogen and chlorophyll content are indicated by higher SPAD values, whereas lower readings imply lower nitrogen and chlorophyll content.

NUTRIENT EXPERT

The International Plant Nutrition Institute (IPNI) developed Nutrient Expert® (NE), a nutrient decision support tool, based on the ideas of site-specific nutrient management (SSNM) and 4R nutrient management. Regardless of the availability of soil testing data, NE is a user-friendly, interactive, computer-based application that rapidly offers fertilizer recommendations to specific farmer’s fields (Pampolino et al., 2012). NE gives crop advisors a simple and effective way to use site-specific data already available to apply SSNM principles. Apart from providing nutrient recommendations suited to a particular place, the application also facilitates modification according to the farmer's available resources. Nutrient Expert calculates the achievable production and yield response to fertilizer based on site information and decision rules derived from on-farm trials. NE specifically uses the following features of the growing environment:

soil fertility indicators (soil texture, colour, and organic matter content), soil test for P or K (if available), historical use of organic materials (if any), and problem soils (if any); crop sequence in the farmer's cropping pattern; crop residue management and fertilizer inputs for the previous crop; and farmers' current yields. Notably, NE also uses these features of the growing environment. Establishing the NE decision rules need data for particular crops and regions. The datasets need to depict a range of growing environment characteristics, such as soil types, cropping techniques, crop cultivars and growth periods, and rainfall amount and distribution variations.

GREEN SEEKER

Green Seeker is a valuable tool for data necessary to calculate Red to Near-Infrared ratios and the Normalized Difference Vegetation Index (NDVI) in the field of crop research and consulting. As a variable rate application and crop vigour mapping technology, Green Seeker improves the accuracy and efficiency of regulating agricultural inputs, especially nitrogen. For real-time verification of the amount of soil nitrogen available, complex agronomic computations more especially, the NDVI are employed. Green Seeker's instantaneous fertilizer prescription, which is based on NDVI measurements, ensures that plants receive the proper amount of nutrients at the appropriate time. Green Seeker generates NDVI values based on the reflection of light from the canopy and correlates them with the concentration of chlorophyll in the leaves. Based on the needs of the crop, these NDVI measurements form the basis for decisions on nitrogen delivery. Higher values indicate better plant condition. NDVI measurements are used as markers of plant health, with a range of 0 to 1. Crop yield potential can be predicted by the Green Seeker (Harrell et al., 2011). By optimizing fertilizer use efficiency, readings from the Green Seeker help one make objective decisions about applying fertilizer. The Green Seeker provides a more accurate and effective method of managing agricultural inputs, particularly nitrogen. It based its recommendations for nitrogen on yield potential as well as the Response Index (RI). The Green Seeker calculates the right quantity of nitrogen needed at key phases of crop growth.

THE OPERATING PRINCIPLE

The Normalized Difference Vegetative Index (NDVI), provides a thorough assessment of numerous aspects of plant health, such as plant biomass, crop yield, nitrogen content in plants, chlorophyll levels in plants, evaluation of water stress, detection of plant diseases, and identification of destructive insects, is calculated by analysing the red bands and near-infrared light.

Green seeker Measures plant NDVI readings by, NDVI = NIR (reflected)– Red(reflected)/NIR (reflected)+ Red(reflected)

Based on the idea that plant chlorophyll absorbs red light while reflecting near-infrared light, the NDVI scale ranges from 0 to +1. A greater NDVI score corresponds to a healthy plant, and a value of 0 indicates a deficiency of vegetation. High near-infrared reflectance and low red-light reflectance, which translate into higher NDVI values, are indicative of robust and healthy plant growth. Green Seeker uses this technology, which has a variety of uses in identifying changes in plant health that might not be visible to the naked eye.

CONCLUSION

In India, the implementation of precision farming and site-specific nutrient management (SSNM) is a viable strategy to maximize crop yields while improving soil health and nutrient-use efficiency. To enable precise nutrient delivery, reduce waste, and increase farmer profitability, tools like the Leaf Color Chart, SPAD meter, Nutrient Expert, and Green Seeker are essential. With the management of soil fertility variations and crop nutrient requirements, these technologies support sustainable agriculture practices that are critical for tackling climate change and ensuring food security.

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How to Cite:

Melavanki, M.S. and Ram, H. (2024). Optimizing Crop Yields: A Comprehensive Guide to Site-Specific Nutrient Management and Precision Farming Techniques in India. Leaves and Dew Publication, New Delhi 110059. *Agri Journal World*, 4(10):32-37.

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