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Transfarming agriculture in Bundelkhand through rainbow revolution...

Regenerative Agriculture for Sustainable Future

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From Vice Chancellor's Desk...

Indian economy ranks fifth among the top economies of the world. In India most of the population depends on agriculture for their livelihood. The agriculture sector contributes about 15% to the total GDP of the country. It plays an important role in the country's economy and society, with more than 50% of the population directly and indirectly dependent on agriculture, of which 86% are small farmers. Presently agriculture is affected by serious challenges like climate change, soil fertility depletion and water scarcity. Agricultural systems characterized by large-scale monoculture systems and extensive land degradation have contributed significantly to environmental degradation, land degradation, biodiversity loss and climate change. As India's population continues to grow, ensuring crop and food security and livelihoods for millions of people is of paramount importance. Regenerative agriculture has emerged as a transformative sustainable and holistic approach to agriculture that aims not only to sustain food production but also to restore and revitalize the health and safety of the earth/geo-climate. It is recognized that regenerative agriculture can play an important role in mitigating climate change, conserving biodiversity, enhancing ecosystem resilience and promoting social well-being. By emphasizing the inter linkages of soil health, biodiversity conservation, water management and carbon sequestration, regenerative agriculture provides a holistic and integrated solution to the complex challenges facing our agricultural systems. Regenerative Agriculture provided a meaningful platform for participants from farming communities, private sector, society and government to collaborate, share ideas and chart the course for the future of a sustainable and regenerative agriculture that will protect the environment and support millions of small farming communities. Carbon-rich soil is not only healthy but also capable of retaining large amounts of moisture. This carbon-rich soil also helps provide greater amounts of nutrients to plants. Scaling up regenerative agriculture requires all-out efforts from farmers, policy makers, researchers and all stakeholders in the agricultural value chain. By adopting various practices, we can nurture the earth for a sustainable future by promoting a capable ecosystem, thereby; agriculture will play a vital role in our environmental safety and health.

The current issue of Agri-Life, entitled "Regenerative Agriculture for Sustainable Future" is an attempt to present the views of various authors relevant to agricultural production techniques and various policy aspects. I hope that this issue of Agri-Life will create awareness for promoting the regenerative agriculture in Bundelkhand in particular and the country in general it's time for all of us to work together on new dimensions for research and development.

(A. K. Singh)
Vice Chancellor

Editorial

"Regenerative agriculture for sustainable future"

Revolutionizing agriculture with sustainable solutions for the health of Panch-Maha-Bhuta and crop health as well as nutrition is an ideal way to our future survival. Thus, adoption Regenerative Agriculture (RA), which is a comprehensive system of farming, combines a number of cultivation practices specifically focusing on regenerating top-soil to restore degraded soil biodiversity, rebuild soil organic matter, and improve water retention and nutrient uptake. Relentless depletion of biodiversity, degradation of soil health, and change in climate have necessitated reversing the direction of agriculture from "degeneration to regeneration". RA also helps in mitigating climate change by arresting soil organic carbon (SOC), while allowing farmers to maintain productivity growth, and farm income. Fundamentally, RA 'does no harm' to the land, rather improves it, using innovations that regenerate and revitalize the soil and environment through adopting practices of conservation agriculture (no-till, soil cover, crop diversification), increase use of compost/ animal manures, recycling waste to ameliorate soil biology and cantering on regulated grazing, mixed cropping/intercropping, etc. leading to healthy soils to produce nutrient rich and high-quality food.

Agriculture is both the victim and cause of ongoing depletion of vital natural resources-soil, water, air, biodiversity, etc. When in good health, these natural assets nurture productivity growth necessary for food security, minimize the effect of climate change and improve biodiversity inspiring sustainable development of agriculture. On the contrary, degradation in health of natural resources destabilizes agricultural growth, compromising food, and environmental security. Whether it is degeneration in soil fertility, biodiversity depletion or climate change, the epicenter is loss of soil health and land quality. Currently, world-wide one billion ha of land area is affected by soil degradation (India's share ~10 %). In India, the Green Revolution based agricultural practices have paid good dividends in a short span of time and as a result the country became not only self-sufficient in food but also a net food exporting nation. However, as the time rolled by, these practices high yielding varieties having narrow genetic base, monoculture, cereal-cereal rotations, repeated tillage, exclusive use of agro-chemicals, excessive irrigation, etc. started weakening agricultural sustainability with declining partial factor productivity and plateauing output growth rates. Continuing such impassivity has led to degradation of soil health because of mining more and replenishing less nutrients. Deterioration in soil health in turn became a source of biodiversity loss, build-up of contaminants and pollutants, and rising specter of climate change whose consequences remain uncertain and unpredictable. By now, it is well known that around deteriorating soil health nucleates food and nutritional security, farm income, ecological integrity, and global warming.

India or for that matter any other country can hardly afford to live with this kind of adverse developments that are at odds with the sustainable growth of agriculture. Therefore, several alternative systems of farming (ASF) to revive soil heath have been proposed from time to time. Low input sustainable agriculture (LISA), conservation agriculture (CA), organic farming (OF), natural farming (NF), and zero budget natural farming (ZBNF) are some prominent ASFs recommended to replace or strengthen modern agriculture. While majority of the ASFs protect soil health (SH) but fail to raise the bar of needed productivity growth. However, among the proposed ASFs, CA has received the maximum attention, being practiced in 102 countries over 205 million ha area covering more than 15 per cent of annual croplands globally and expanding at 10.5 per cent annually. Recently, RA is being projected as a holistic approach for improving soil and environmental health and increased biodiversity leading to productive farms, healthy communities and better economics of farming community. This will take a lead in promoting the importance of regenerative agriculture to greater extent in the country.

I hope this Farmer's Fair special issue of Agri-Life with the theme "Regenerative agriculture for sustainable future" having 14 articles covering various aspects of the theme will be useful to all stakeholders and used widely across our country.

(Anil Kumar)
Editor in Chief

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Environment for Life and Life for Environment

Garima Gupta, Pankaj Lavania, Prabhat Tiwari, R.P. Yadav and M.J. Dobriyal

"Environment for Life and Life for Environment" is a particularly relevant and important concept. It signifies a relationship between humans and the environment based on mutual respect, dedication, and support. In reality, the environment encompasses air, water, land, vegetation, fauna, humans, and their various activities. The environment ensures our economy, society, and existence. Forests, rivers, oceans, and soil provide us with food, clean air, and other essential services crucial for our health and well-being. If we start understanding the value of nature for our society and economy, we will recognize the importance of living in harmony with nature for long-term benefits rather than destroying it for short-term gains. Through small daily efforts such as water conservation, tree planting, waste management, etc., we can contribute to environmental conservation. We should strive to live a sustainable and responsibly managed life by changing our consumerist perspective.

The word is derived from the french word environer, which means to surround, enclose or encircle. In essence, the environment represents the collective amalgamation of physical, chemical, and biological elements that shape the existence of any living or interconnected population, delineating their structure, vitality, and sustenance. A cursory observation of nature reveals earth, water, sky, fire (heat), and air embracing us from all directions. These elemental constituents form the bedrock of our natural world, defining what we perceive as our environment. Upon introspection, it becomes evident that our bodies are intricately woven from these same elements. In this context, a verse from the Shri Ramcharitmanas penned by Tulsidas resonates:

"छिति जल पवावक गगन समीरा। पंच रचित अति अधम सरीरा"

Similary, the Upanishads echo:

This underscores the interconnectedness between the microcosm (the human body) and the macrocosm (the environment), emphasizing that what exists within one permeates the other. The foundational principles of Ayurveda further underscore the importance of maintaining balance among these five elements within the human body. Ayurveda posits that diseases and disorders stem from imbalances in the three doshas - Vata, Pitta, and Kapha - representing kinetic energy, nutritional/metabolic energy, and static energy, respectively. Hence, the intricate relationship between the external environment and our health becomes apparent, as alterations in the external milieu significantly impact our well-being.

The environment exerts both direct and indirect influences on our health, economy, society, and overall existence. Additionally, it bestows upon us a plethora of resources and services collectively known as ecosystem services. According to the Millennium Ecosystem Assessment conducted by the United Nations in 2005, these services encompass provisioning, regulating, supporting, and cultural aspects. They encompass vital resources such as food, renewable energy sources (solar, wind, geothermal), and non-renewable resources (fossil fuels, minerals), essential for our survival. These natural assets, often referred to as the 'natural capital' of the world, make invaluable contributions to the global economy, estimated at a minimum value of $125 trillion annually.

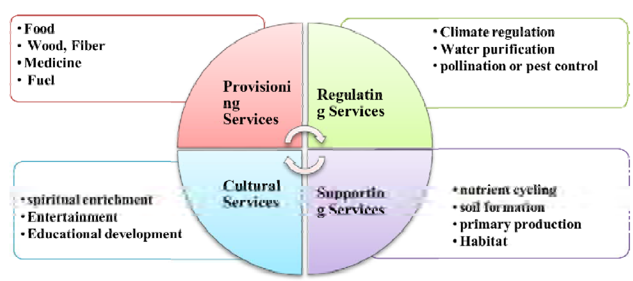

Fig 1: According to the Millennium 2005, ecosystem services

However, despite the invaluable contributions of these ecosystem services, our modern economies persist in relying on outdated metrics such as GDP, prioritizing production and consumption without adequate consideration for the depletion of natural resources and its adverse effects on human well-being and the sustainability of civilization. Over the past 50-60 years, the continuous increase in human population and per capita consumption has posed a significant challenge to natural resources. Additionally, urbanization, industrialization, and modern agricultural practices have polluted water, air, and soil resources worldwide. The

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escalating emission of greenhouse gases is leading to visible global warming effects, with glaciers and polar ice melting at rates 2-3 times higher than in the previous century. It is estimated that Earth is currently experiencing the greatest loss of biodiversity in history, with human-induced extinction rates hundreds of times higher than natural rates. According to a report by the United Nations, the current human-induced extinction rate for both plant and animal species is hundreds of times greater than the natural background rate, and it could increase thousands of times in the near future. For example, it is estimated that at the current rate of coral reef depletion, they could be completely lost in the near future, along with many other species dependent on them. Thus, not only are natural resources being excessively depleted, but they are also becoming contaminated with toxic chemicals, making survival difficult for future generations. Every year, more than 12 million people worldwide die due to unhealthy environments. The World Health Organization's World Health Report 2002 revealed that 85 of the 102 major diseases and injuries studied were linked to an unhealthy environment. Therefore, reducing environmental risks could prevent nearly a quarter of global diseases.

Today, knowingly or unknowingly, in our quest for curiosity and continuous exploration, we are disturbing the environment, leading to its pollution. The environment and living beings are interdependent. That is why the concept of environmental conservation has been as ancient as human history in Indian thought. Environmental conservation has been integral to Indian culture from the beginning. Environmental conservation has shaped our way of life. If we start understanding the value of nature for our society and economy, we will recognize the importance of living in harmony with nature rather than destroying it for short-term gains. From 2021, the Indian government has also promoted 'Lifestyle for Environment (LiFE)' as a global grassroots program involving people and groups from around the world. Responsible people that prioritize environmental protection and conservation will be recognized by LiFE as Pro Planet People.

Environmental conservation is now a global concern. Most nations have enacted laws for environmental protection, and international treaties have also been made so that collectively we can work towards conserving the natural heritage for human welfare. Various Earth summits organized globally have also deliberated on this issue. It is essential to regularly assess the impact of human activities on local ecosystems and the world as a whole. Although modern technologies assist in assessing the problem, finding environmentally friendly solutions is also necessary. Biotechnology and green technologies are presenting solutions to these problems. Scientists are currently working on developing environmentally friendly energy sources and modern energy production technologies that can be alternatives to petroleum products and can produce sustainable energy to reduce greenhouse gas emissions. Bioremediation is being used effectively to control pollution from pollutants, organic waste, and contaminated sites. Bioremediation efforts focus on restoring damaged ecosystems by reintroducing microorganisms and using phytoremediation techniques. Even though significant scientific efforts are underway, we can contribute to environmental conservation through small daily efforts. According to the UNEP, global carbon emissions could reduce by 20% if one billion of the eight billion people on Earth adopted eco-friendly practices.

We should change our consumerist mindset and strive for a sustainable and responsible lifestyle. Responsible use of natural resources, such as harnessing solar energy, adopting clean energy sources for vehicles, and managing natural resources properly, can be positive steps for our environment. In this context, the three Rs (Reduce, Reuse, Recycle) are essential in English. The first R stands for Reduce, which means reducing consumption, i.e., using natural resources appropriately. The second R stands for Reuse, meaning using resources again, and the third R stands for Recycle, meaning recycling resources. Along with this, efforts should be made to minimize the use of things that cause harm to the environment.

Conclusion

Thus, environmental stability stands as one of the greatest challenges and most significant goals of the present time. It is a primary focus area for researchers, educators, scholars, governments, and non-governmental organizations worldwide, encompassing individuals, communities, nations, continents, and the entire globe. The exponential growth of the human population and the extensive exploitation of the environment by humans form the backdrop against which environmental stability emerges as a key strategy. The pressing concern of modern society is that while people today enjoy the benefits of economic development, future generations are poised on the brink of facing scarce natural resources and polluted environments. Leaving the planet as a self-sustaining system is our most crucial responsibility. It is not only about providing equal opportunities for our future generations but also about ensuring the survival of all other species that coexist with us.

Soil erosion and its control measures

Vishwanath, Susheel Kumar Singh, Yogeshwar Singh, Sridhar Patil, Harsha Hegde, Rakesh Choudhary and Anil Kumar Rai

For the survival of the human world and animals, not only is it necessary to make maximum use of land in a scientific manner, but it is also equally important to protect it properly. As a result of land degradation or soil erosion, even fertile land becomes unfit for agriculture. Indian geologists It is believed that if this situation continues for the next twenty years, one third of the agricultural land will be completely destroyed. To stop land degradation in the country, on one hand, traditional measures like tree plantation, dam construction etc. It is necessary to expand construction, flood control, embankment, controlled animal grazing etc. On the other hand modern and research based measures like mulching method, strip cropping, mixed farming, surface ploughing and it is also very important to adopt contour farming etc. Concept of cultural heritage conservation and the approach of social participation also play a decisive role in the conservation of land, forests, mountains and trees etc.

Introduction

Soil erosion is the process by which the upper layer of soil is removed, and it can be caused by various natural and human activities. The 10 to 20 cm layer of cultivable soil on the upper surface of the land is called soil. It is a storehouse of nutrients necessary for the growth and development of plants. Every year, some natural forces, mainly water and wind, keep transferring the upper layer of soil to other places by flowing or blowing it. Along with this, trees and plants absorb as much nutrients as their food from the soil. Many times more of its nutrients get destroyed by flowing or flying away from the soil. The movement of soil particles from their place, whether naturally or artificially, is called soil erosion. In most cases water is a factor of transportation. But this work is also done by air. About 150 million hectares of land in India is suffering from terrible problems of erosion. Out of this, 111.30 million hectares are affected by water erosion and 39 million hectares are affected by wind erosion.

Causes of soil erosion

a. **Tillage:** Plowing and tilling the soil can break down soil structure and make it more susceptible to erosion.

b. **Overgrazing:** Livestock overgrazing can remove vegetation cover, exposing soil to erosion.

c. **Monoculture Farming:** Growing the same crop repeatedly can deplete soil nutrients and reduce soil structure.

d. **Tree Removal:** Cutting down trees for timber or to clear land for agriculture reduces the root systems that hold soil in place.

e. **Land Development:** Construction activities can disturb the soil and vegetation cover, increasing erosion.

f. **Surface Mining:** Removing vegetation and soil to access minerals can leave large areas of soil exposed.

g. **Unsustainable Practices:** Lack of soil conservation techniques can exacerbate erosion.

Impact of soil erosion

a) **Loss of Soil Fertility:** Erosion removes nutrient-rich topsoil essential for plant growth.

b) **Sedimentation of Water Bodies:** Soil particles washed into rivers and lakes, leading to reduced water quality and aquatic habitat degradation.

c) **Habitat Destruction:** Erosion disrupts natural ecosystems, impacting flora and fauna.

d) **Increased Flooding:** Sediment-laden runoff can block drainage systems and increase flood risk.

e) **Reduced Agricultural Productivity:** Erosion diminishes soil quality, leading to decreased crop yields and economic losses.

Control measures of soil erosion

Soil erosion control is essential for maintaining soil health, preserving agricultural productivity, and

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preventing environmental degradation. Effective control measures can be categorized into vegetative, structural, and management practices. Here's a comprehensive look at these control measures:

1. **Vegetative Measures**

   a. **Cover Crops:** Cover crops such as clover, rye, and vetch are planted during off-seasons to cover the soil. These crops protect the soil from rain impact, reduce runoff, improve soil structure, and add organic matter.

   b. **Grass Strips:** Narrow strips of grass or other perennial vegetation are planted along the contour lines of a field. They act as barriers to slow down water flow, trap sediment, and increase water infiltration.

   c. **Afforestation and Reforestation:** Planting trees and restoring forests on degraded lands. Tree roots bind the soil, reduce wind speed at the soil surface, and increase water absorption.

2. **Structural Measures**

   a. **Terracing:** Creating step-like flat surfaces on steep slopes. Reduces the speed of water flow, prevents runoff, and allows water to infiltrate into the soil.

   b. **Contour Plowing:** Plowing along the natural contours of the land rather than in straight lines. Creates natural barriers for water flow, reducing soil erosion and promoting water absorption.

   c. **Check Dams:** Small barriers constructed across the direction of water flow in gullies. Slows down water flow, traps sediment, and helps in groundwater recharge.

3. **Management Practices**

   a. **Conservation Tillage:** Reducing the frequency and intensity of tillage. Maintains soil structure, reduces disturbance, and retains crop residues on the soil surface to protect against erosion.

   b. **Crop Rotation:** Alternating different crops in the same field across seasons. Improves soil structure, reduces pest and disease cycles, and increases biodiversity which can enhance soil health.

   c. **Contour Farming:** Implementing farming practices along the contours of the land. Reduces soil erosion by creating natural water breaks, thus slowing down water flow.

   d. **Mulching:** Applying a layer of organic or inorganic material on the soil surface. Protects soil from raindrop impact, conserves moisture, and adds organic matter to the soil.

4. **Innovative Techniques**

   a. **Agroforestry:** Integrating trees and shrubs into agricultural landscapes. Enhances biodiversity, improves soil structure, and provides additional income sources through timber and fruit production.

   b. **No-Till Farming:** Growing crops without disturbing the soil through tillage. Reduces soil erosion, maintains soil structure, and enhances soil moisture retention.

Conclusion

Implementing these control measures requires a comprehensive understanding of local soil types, climate, and land use practices. By combining vegetative, structural, and management strategies, it is possible to significantly reduce soil erosion, thereby ensuring long-term soil health and sustainability. Farmers, land managers, and policymakers must work together to promote and adopt these measures, integrating traditional knowledge with modern techniques to combat soil erosion effectively.

Integrated Nutrient Management: Traditional and Modern Methods in Soil Nutrition

Yumnam Bijilaxmi Devi

Integrated nutrient management refers to using organic, inorganic and biological components in an integrated manner. The main objective of this technology is to maintain the desired productivity by taking advantage of all these sources to maintain soil fertility and supply of plant nutrients at optimum levels. In other words, integrated nutrient management can be called providing balanced quantity of manure and fertilizer to the soil and maintaining agricultural production, soil productivity and environmental protection. Traditional integrated nutrient management relies heavily on synthetic chemical fertilizers. The idea of integrated nutrient management approach has evolved in line with ongoing research and development efforts aimed at addressing soil fertility issues. The transition from traditional integrated nutrient management to modern integrated nutrient management in agricultural systems has seen a significant shift towards a more sustainable and environmentally conscious approach. Incorporating practices such as crop rotation, cover crops and balanced nutrient management are important for the long-term health of the soil. Modern integrated nutrient management represents a progressive and responsible path forward that will lead to a better and more sustainable future for agriculture.

Concepts in Integrated Nutrient Management

- Regulated nutrient supply for optimum crop growth and higher productivity
- Improvement and maintenance of soil fertility
- Zero adverse impact on the quality of agro-ecosystem by balanced fertilization of organic manure, inorganic fertilizers and bio-inoculants.

Sources of nutrients

- **Soil –** Lots of nutrients are present in soil, which plants can use for their growth.
- **Inorganic fertilizers –** Fertilizers are man-made formulas that can be formulated to have different rates of nutrient release. The most common of these fertilizers are urea, single super phosphate and muriate of potash. All these fertilizers are necessary for the growth of plants.

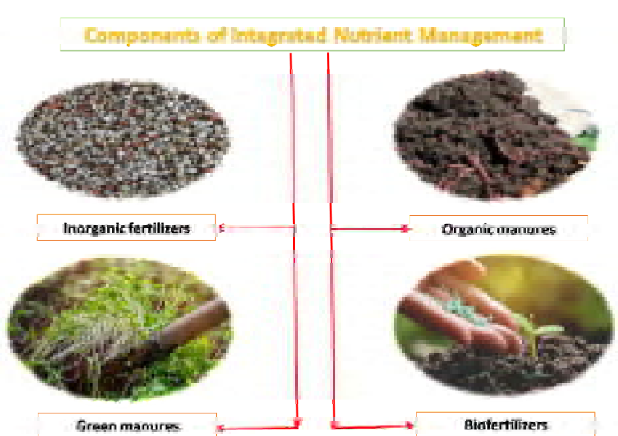

Fig. 1: Components of integrated nutrient management

- **Organic fertilizer –** The use of living organisms or their remains for better growth and nutrition of crops is called organic nutrients or organic fertilizer. The purpose of organic fertilizer that organic substances produce organic matter when they decompose or decompose and they make the environment sustainable. Overall, this component is useful in providing nutrients to plants as well as in environmental protection.
- **Green manure** – Green material used as fertilizer is called green manure. This is obtained in two ways: by growing green manure crops or by collecting green leaves (along with twigs) from plants growing in barren lands, field paddies and forests. Green manure consists of plants growing in fields, usually belonging to the legume family, that are added to the soil after sufficient growth. Plants grown for green manure are called green manure crops. The most important green manure crops are *Sunhemp, Dhaincha, Sesbania* etc.
- **Biofertilizers –** Biofertilizer can be defined as organic products containing live microorganisms which, when applied to seeds, plant surface or soil, enhance growth by several mechanisms such as increase in supply of nutrients, increase in root biomass or increase in root area and increases the plant's nutrient uptake capacity. Some examples are *Rhizobium, Azotobacter, Pseudomonas* etc.

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Understanding these sources highlights their importance and that unless these components are optimally applied to the soil, integrated nutrient management cannot be successful.

Benefits of Integrated Nutrient Management

- Increases the availability of applied and native soil nutrients.
- It matches the crop's nutrient demand with nutrient availability from applied and native sources.
- Provides balanced nutrition to crops and minimizes hidden deficiencies and adverse effects resulting from nutrient imbalances.
- Improves and maintains the physical, chemical and biological functioning of soil.
- Reduces soil, water and ecosystem degradation by promoting carbon sequestration, reducing nutrient losses to ground and surface water bodies and the atmosphere.

Traditional methods in integrated nutrient management

Traditional integrated nutrient management relies heavily on synthetic chemical fertilizers as the primary means of meeting plant nutrient requirements. This approach usually involves the application of specific proportions of nitrogen (N), phosphorus (P), and potassium (K) to the soil. A major drawback of traditional practices is the limited emphasis on organic inputs such as manure, compost and crop residues. This oversight can result in reduced organic matter content in the soil, which can result in potential soil health problems. Furthermore, excessive use of chemical fertilizers poses a great risk of soil degradation, affecting the physical, chemical and biological properties of the soil. Runoff from fields containing these fertilizers can contribute to pollution, raising environmental concerns.

Additionally, conventional agriculture often promotes monoculture, leading to imbalances in nutrient absorption by crops and depletion of soil nutrients. In this view, the high use of chemical fertilizers also plays a role in contributing to greenhouse gas emissions, thereby exacerbating its negative environmental impacts.

Evolution of integrated nutrient management

Integrated nutrient management has evolved over time, integrating scientific knowledge, environmental considerations and technological advances to create a more sustainable and efficient approach to nutrient management in agriculture.

Over the past 50 years, the idea of integrated nutrient management approach has evolved in line with ongoing research and development efforts aimed at addressing soil fertility issues. In the 1960s and 1970s, the primary focus was on the use of external productive inputs, primarily mineral fertilizers, to increase crop production. This approach was influenced by the success of the Green Revolution in Asia and Latin America, which emphasized the use of productive inputs such as fertilizers, lime, and irrigation water. However, this strategy faced limited success due to challenges in infrastructure, policy and agricultural systems. In the 1980s, there was a shift towards organic inputs, but this approach had limited adoption as it required significant resources such as livestock, substantial land and labour. By 1990s, a balanced approach emerged, emphasizing the use of both organic matter and mineral fertilizers, with the organic matter serving as the entry point. This period saw the broader definition of integrated nutrient management as a holistic approach to soil fertility management that considered a variety of issues and consequences, including biological, physical, chemical, social, economic and political aspects of soil degradation.

This led to an emphasis on localized adoption and integrated nutrient management around specific crops. In recent years, research has focused on combining mineral fertilizers and organic resources adapted to local conditions to achieve satisfactory crop yields and efficient fertilizer use efficiency. This ongoing development reflects an understanding of the complexity of soil fertility management, incorporating diverse elements to achieve sustainable and sustainable agricultural practices.

Modern methods in integrated nutrient management

Modern integrated nutrient management takes a holistic approach by emphasizing diverse nutrient sources including chemical fertilizers, organic manures, green manures and biofertilizers. This strategy aims to optimize nutrient availability and increase soil fertility.

Integration of organic inputs is a major focus in modern integrated nutrient management, with priority given to the inclusion of materials such as manure and compost to improve soil structure, water retention and microbial activity.

Additionally, it often integrates organic farming practices, which contribute to sustainable and resilient agricultural systems. Precision farming techniques are integral to modern integrated nutrient management, tailoring nutrient applications to the specific needs of different crops and soil types and using technologies such as soil testing and nutrient mapping, thereby optimizing nutrient use efficiency.

Promoting crop rotation and cover crops is another aspect, which encourages diversification of plant species and breaks pest and disease cycles. These practices contribute to better nutrient cycling and reduce the need for over-fertilization.

In terms of environmental sustainability, modern integrated nutrient management aims to reduce the environmental impact of agriculture by reducing nutrient runoff and emissions associated with synthetic fertilizers. It is consistent with ecological principles, promoting long-term environmental health. Finally, the balanced nutrient management approach is at the heart of modern integrated nutrient management, which focuses on providing a balanced nutrient supply to crops, considering both macro and micronutrients. This helps in preventing deficiency or excess of nutrients which might otherwise adversely affect the yield and quality of the crop. Overall, modern integrated nutrient management represents a more environmentally conscious and sustainable approach to nutrient management in agriculture.

Conclusion

The transition from traditional integrated nutrient management to modern integrated nutrient management in agricultural systems has seen a significant shift towards a more sustainable and environmentally conscious approach. Recognizing the limitations of heavy reliance on synthetic fertilizers, modern integrated nutrient management adopts a holistic strategy that integrates a variety of sources of nutrients and emphasizes organic inputs such as manure and compost. This not only improves soil structure and microbial activity but also increases the resilience and sustainability of agricultural systems.

In environmental impact, modern integrated nutrient management reduces the risks associated with fertilizer overuse by increasing nutrient use efficiency. Incorporating practices such as crop rotation, cover crops and balanced nutrient management are important for the long-term health of the soil. Integrated nutrient management represents a progressive and responsible path forward that will lead to a better and more sustainable future for agriculture.

Integrated Pest Management for sustainable crop disease management

Prashant P. Jambhulkar, Shubha Trivedi and Anita Puyam

IPM is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Govt. of India has adopted Integrated Pest Management (IPM) as cardinal principle and main plank of plant protection in the overall Crop Production Programme since 1985. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment. The most effective, long-term way to manage pests is by using a combination of methods that work better together than separately. Approaches for managing pests are biological control, cultural control, mechanical and physical control and chemical control. IPM provides economic, health, and environmental benefits. IPM practitioners use knowledge of pest and host biology in combination with biological and environmental monitoring to respond to pest problems with management tactics.

Introduction

Integrated pest management (IPM) is an integrated approach of crop management to solve ecological problems when applied in agriculture. These methods are performed in three stages: *prevention*, *observation*, and *intervention*. It is an ecological approach with a main goal of significantly reducing or eliminating the use of pesticides while at the same time managing pest populations at an acceptable level. For their leadership in developing and spreading IPM worldwide, Dr. Perry Adkisson and Dr. Ray F. Smith received the 1997 World Food Prize.

Integrated Pest Management (IPM) is a holistic approach to managing pests that aims to minimize their impact on crops, human health, and the environment. It involves combining various pest control methods such as biological control, cultural practices, habitat manipulation, and the judicious use of pesticides when necessary.

IPM promotes sustainable pest management by reducing reliance on chemical pesticides, minimizing negative impacts on non-target organisms, conserving natural resources, and promoting long-term pest suppression. It's widely adopted in agricultural systems, but its principles can also be applied in urban settings, forests, and natural ecosystems

Definition:

By FAO *"Integrated pest control is a pest management system that in the context of associated enviromment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury".*

One commonly used definition that is easy to understand is the following:

"IPM is a decision-making process that utilizes all available pest management strategies, including cultural, physical, biological and chemical control to prevent economically damaging pest outbreaks and to reduce risks to human health and the environment."

Tools of IPM

- ***Monitoring*** : Keep tracks of the pests and their potential damage. This provides knowledge about the current pests and crop situation and is helpful in selecting the best possible combinations of the pest management methods.
- ***Pest resistant varieties*** : Breeding for pest resistance is a continuous process. These are bred and selected when available in order to protect against key pests.
- ***Cultural pest control*** : It includes crop production practices that make crop environment less susceptible to pests. Crop rotation, cover crop, row and plant spacing, planting and harvesting dates, destruction of old crop debris are a few examples. Cultural controls are based on pest biology and development.

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- ***Mechanical control***: These are based on the knowledge of pest behaviour. Hand picking, installation of bird perches, mulching and installation of traps are a few examples.
- ***Biological control***: This includes augmentation and conservation of natural enemies of pests such as insect predators, parasitoids, pathogen and weed feeders. In IPM programes, native natural enemy population are conserved and non-native agents are released with utmost caution.
- ***Chemical control*** : Pesticides are used to keep the pest population below economically damaging levels when the pests cannot be controlled by other means. It is applied ONLY when the pest's damaging capacity is nearing to the threshold.

Disease and Insect pests monitoring methods:

A. Ground truth Analysis (GTA)

AESA is an approach, which can be gainfully employed by extension functionaries and farmers to analyze field situations with regard to pests, defenders, soil conditions, plant health, the influence of climatic factors and their interrelationship for growing healthy crop. Such a critical analysis of the field situations will help in taking appropriate decision on management practices. The basic components of GTA are:-

1. Plant health at different stages.
2. Built – in – defense abilities of the plants.
3. Pest and predator population dynamics.
4. Soil conditions.
5. Climatic factors.

B. Survey / Field Scouting

The objective of surveys through roving surveys is to monitor the initial development of pests and diseases in endemic areas. Therefore, in the beginning of crop season survey routes based upon the endemic areas are required to be identified to undertake roving surveys. Based upon the results of the roving surveys, the State extension functionaries have to concentrate for greater effort at Block and village levels as well as through farmers to initiate field scouting. Therefore, for field scouting farmers should be mobilized to observe the pest and disease occurrence at the intervals as stipulated hereunder. The plant protection measures are required to be taken only when pests and disease cross ETL as per result of field scouting.

Roving survey :- Undertake roving survey at every 10 km distance initially at weekly intervals and thereafter at 10 days intervals (depending upon pest population). Record incidence of bollworms on all host crops of the locality. Observe at each spot diagonally criss cross 20 plants/acre at random. Record the population potential of different biocontrol fauna. Record the major disease and their intensity.

Field scouting :- Field scouting for pests and biocontrol fauna by extension agencies and farmers once in 3–5 days should be undertaken to workout ETL. For sucking pests, population should be counted on three leaves (top & middle portion) per plant. For whitefly, third and seventh leaves from the top of the plant should be observed for nymphs and adults. For bollworm eggs terminal leaves should be observed. Observe larvae on fruiting bodies and leaves per plant. For percent bollworm incidence count total and affected fruiting bodies on the plant and also in the shed material and work out the percent infestation.

The State Departments of Agriculture should make all possible efforts by using different media, mode and publicity to inform the farmers for field scouting in the specific crop areas having indication of pest or disease build up.

C. Pest Monitoring through Pheromones / Yellow Pan / Sticky Traps etc.

Certain pests require positioning of various kinds of traps like pheromones, yellow pan and sticky traps to monitor the initial pest build up. Therefore, the State Department of Agriculture is to initiate action for positioning of different kinds of traps based upon the results of roving surveys at the strategic location at village level. While the concept needs to be popularized amongst farming community, the State Department of Agriculture is to take greater initiatives for pest monitoring through specific pheromone trapping methods as per following details.

Pheromone trap – monitoring :- Use pheromone traps for monitoring of American bollworm, spotted bollworms, pink bollworm and Spodoptera. Install pheromone traps at a distance of 50 m @ five traps per ha. for each insect pest. Use specific lures for each insect pest species and change it after every 15 – 20 days. Trapped moths should be removed daily. ETL for pink bollworm is 8 months per days per trap consecutively for 3 days. ETL for American bollworm is 4 – 5 moth per day per trap.

Yellow pan / sticky traps: Set up yellow pan / sticky traps for monitoring whitefly @ 25 yellow pans / sticky traps per ha. Locally available empty yellow palmoline tins coated with grease / vasline / castor oil on outer surface may also be used.

Techniques of Integrated Pest management

Integrated Pest Management (IPM) incorporates various disease management techniques alongside strategies for managing pests. These techniques aim to minimize the impact of plant diseases on crops while also considering environmental and human health concerns. Here are some disease management techniques commonly integrated into IPM programs:

1. **Cultural Practices:** Implementing cultural practices that promote plant health and reduce disease pressure. This includes practices such as crop rotation, proper irrigation and drainage, planting disease-resistant varieties, maintaining proper spacing between plants to improve air circulation, and removing and destroying infected plant material.
2. **Sanitation:** Proper sanitation measures to reduce the spread and survival of pathogens. This involves removing and destroying infected plant debris, cleaning tools and equipment to prevent transmission of diseases, and practicing good hygiene in greenhouse and field operations.
3. **Biological Control:** Using beneficial microorganisms, such as certain bacteria, fungi, and viruses, to suppress plant diseases. Biocontrol agents can compete with pathogens for resources, produce antimicrobial compounds, or induce systemic resistance in plants.
4. **Genetic Resistance:** Breeding and selecting crop varieties with genetic resistance to specific diseases. This approach involves identifying and incorporating resistance genes from wild or cultivated relatives into commercial cultivars to improve their ability to withstand disease pressure.
5. **Chemical Control:** While chemical control is often considered a last resort in IPM, fungicides may be used strategically to manage severe disease outbreaks. Integrated with other disease management tactics, fungicides are applied judiciously and according to monitoring data to minimize environmental impacts and reduce the risk of pesticide resistance.
6. **Crop Monitoring and Forecasting:** Regular monitoring of crops for disease symptoms and using predictive models to anticipate disease outbreaks. This allows growers to implement timely interventions and optimize the use of disease management tactics.
7. **Crop Rotation and Diversification:** Rotating crops with different susceptibility to diseases and diversifying cropping systems to disrupt disease cycles and reduce pathogen buildup in the soil.
8. **Soil Health Management:** Practices that improve soil health, such as organic matter addition, balanced nutrient management, and maintaining soil pH, can enhance plant vigor and resilience to diseases.

By integrating these disease management techniques into a comprehensive IPM program, growers can effectively manage plant diseases while minimizing reliance on chemical pesticides and promoting sustainable agricultural practices

Recent updates in IPM

(IPM) continues to evolve with ongoing research efforts aimed at improving its effectiveness, sustainability, and applicability across various agricultural systems. Here are some recent research updates and trends in IPM:

1. **Biological Control:** Advances in understanding the ecology and behavior of natural enemies, including predators, parasitoids, and pathogens, are leading to the development of more targeted and effective biological control strategies. Researchers are exploring innovative approaches such as the use of microbial biopesticides, augmentation of natural enemy populations, and habitat manipulation to enhance biological control in agricultural landscapes.
2. **Precision Agriculture and Digital Technologies:** Integration of precision agriculture technologies, such as remote sensing, GPS-guided machinery, and sensor networks, into IPM systems allows for more accurate and site-specific pest monitoring, decision-making, and intervention. Digital tools and models are being developed to predict pest outbreaks, optimize pesticide applications, and assess the impact of management practices on pest populations and ecosystem services.

3. **Genomics and Molecular Tools:** Advances in genomics, transcriptomics, and molecular biology are providing insights into the genetic basis of pest resistance, host-plant interactions, and microbial biocontrol agents. This knowledge is being leveraged to develop new diagnostic tools for rapid pest detection, identify molecular markers for breeding resistant crop varieties, and engineer microorganisms for enhanced biocontrol efficacy.

4. **Microbiome-Based Approaches:** Research on the plant microbiome and its role in shaping plant health and pest resistance is informing the development of microbiome-based IPM strategies. Harnessing beneficial microbes present in the rhizosphere, phyllosphere, and endosphere can help modulate plant immunity, suppress pathogen proliferation, and promote crop productivity in a sustainable manner.

5. **Climate Change Adaptation:** Climate change is altering the distribution and abundance of pests and beneficial organisms, challenging traditional IPM practices. Research is focusing on understanding the impacts of climate change on pest dynamics, exploring resilient cropping systems and management practices, and developing climate-smart IPM strategies that enhance agricultural productivity while mitigating climate-related risks.

6. **Social and Economic Dimensions:** IPM research is increasingly recognizing the importance of socio-economic factors in the adoption and success of pest management practices. Studies are investigating the socio-economic drivers of farmer decision-making, assessing the economic feasibility and profitability of IPM adoption, and exploring innovative extension and education strategies to promote IPM knowledge and adoption among farmers.

Overall, ongoing research in integrated pest management is interdisciplinary and collaborative, drawing on insights from ecology, agronomy, entomology, plant pathology, genetics, and socio-economic sciences to develop innovative solutions for sustainable pest management in diverse agricultural systems.

Integrated Pest Management (IPM) encompasses the management of various pests, including diseases caused by pathogens such as fungi, bacteria, viruses, and nematodes. Here are some examples of diseases commonly managed using IPM strategies:

1. **Late Blight in Tomato and Potato:** Late blight, caused by the oomycete pathogen *Phytophthora infestans*, is a devastating disease affecting tomato and potato crops worldwide. IPM approaches for late blight management include planting disease-resistant cultivars, cultural practices such as proper irrigation and crop rotation, early detection and monitoring, use of biofungicides, and judicious application of chemical fungicides when necessary.

2. **Citrus Canker:** Citrus canker, caused by the bacterium *Xanthomonas citri* subsp. *citri,* affects citrus trees and causes characteristic lesions on leaves, fruit, and stems. IPM strategies for citrus canker management include sanitation measures to remove infected plant material, use of copper-based bactericides, cultural practices to reduce disease spread, and breeding of resistant citrus varieties.

3. **Apple Scab:** Apple scab, caused by the fungus *Venturia inaequalis*, is a common disease affecting apple trees. IPM tactics for apple scab management include planting resistant apple cultivars, maintaining good orchard hygiene by removing fallen leaves and pruning infected branches, applying fungicides at appropriate timings based on disease forecasting models, and promoting natural enemies of the scab fungus.

4. **Powdery Mildew in Grapes:** Powdery mildew, caused by various fungal species such as *Erysiphe necator*, affects grapevines and can reduce yield and quality of grapes. IPM strategies for powdery mildew management in grapes include canopy management to improve air circulation, use of sulfur and other fungicides, application of biological control agents such as mycoparasitic fungi, and timing of fungicide applications based on disease monitoring.

5. **Soybean Cyst Nematode:** Soybean cyst nematode (*Heterodera glycines*) is a major pest of soybean crops, causing significant yield losses. IPM approaches for soybean cyst nematode management include planting resistant soybean varieties, crop rotation with non-host crops, use of nematicides, soil amendments to suppress nematode populations, and biological control with nematophagous fungi and bacteria.

6. **Black Sigatoka in Banana:** Black Sigatoka, caused by the fungus *Pseudocercospora fijiensis*, is a serious disease affecting banana plants. IPM

strategies for black Sigatoka management include cultural practices such as removing infected leaves, planting disease-resistant banana varieties, applying fungicides judiciously, and integrating biological control agents such as antagonistic fungi.

These examples illustrate how integrated pest management combines multiple tactics, including cultural, biological, chemical, and genetic approaches, to effectively manage plant diseases and reduce reliance on pesticides while promoting sustainable agriculture.

Constraints of Integrated past management

While Integrated Pest Management (IPM) offers a sustainable and environmentally friendly approach to pest management, it is not without its constraints. Some of the main constraints of IPM include:

1. **Knowledge and Expertise:** Implementing IPM effectively requires a good understanding of pest biology, ecology, and management strategies. Farmers and practitioners may lack the necessary knowledge and expertise to correctly identify pests, monitor populations, and implement appropriate control measures.

2. **Cost and Labor:** Some IPM practices, such as biological control and cultural management, may require additional labor and resources compared to conventional pest control methods. Initial investments in infrastructure, equipment, and training can also be barriers to adopting IPM, particularly for small-scale farmers with limited financial resources.

3. **Risk of Crop Losses:** IPM relies on a combination of pest management tactics, which may not always provide immediate or complete control of pests. There is a risk of crop losses if control measures are not implemented effectively or if environmental conditions favor pest outbreaks.

4. **Market and Certification Requirements:** Certain markets and certification schemes may impose restrictions or requirements on pesticide use, residue levels, and pest management practices. Compliance with these standards can be challenging for farmers practicing IPM, especially if they face limited market access or higher production costs.

5. **Resistance Management:** Prolonged reliance on a single pest management tactic, such as chemical pesticides, can lead to the development of resistance in pest populations. IPM aims to mitigate this risk by integrating multiple control methods, but resistance management remains a challenge, particularly with rapidly evolving pests and pathogens.

6. **Scale and Infrastructure:** IPM implementation may be more challenging on large-scale farms or in regions with limited infrastructure and extension services. Coordinating pest monitoring, implementing control measures, and accessing inputs such as biocontrol agents or disease-resistant cultivars may be more difficult in these contexts.

7. **Behavioral and Social Factors:** Farmer attitudes, beliefs, and perceptions about pests, pesticides, and alternative management practices can influence the adoption and success of IPM. Overcoming cultural barriers, building trust in new approaches, and fostering collaboration among stakeholders are important considerations for promoting IPM adoption.

Despite these constraints, ongoing research, education, and extension efforts are aimed at addressing challenges and promoting the adoption of IPM as a sustainable and effective approach to pest management in agriculture. Collaboration among farmers, researchers, policymakers, and extension services is essential for overcoming barriers and promoting the widespread adoption of IPM practices.

Important Role of Soil Amendments in Ensuring Sustainable Soil Health

Thounaojam Thomas Meetei[1] and Yumnam Bijilaxmi Devi[2]

Soil degradation, associated with the deterioration of soil health, poses a threat to agriculture and environmental sustainability. Urgent, sustainable methods using organic and inorganic materials are imperative to restore the already degraded soil, improving biodiversity, and ensuring food security. Soil amendments optimize soil's physical, chemical, and biological characteristics, fostering plant growth. They encompass natural and synthetic substances that enhance soil structure, pH balance, water retention, and microbial activity, which are essential for regenerating degraded soils. Organic amendments like manure, compost, and biochar increase microbial activity and nutrient availability, while inorganic counterparts such as gypsum and lime regulate pH and enhance soil health. Both types play pivotal roles in sustainable agriculture by combating compaction, improving water retention, and fortifying nutrient availability. Urgent adoption of innovative, site-specific strategies utilizing organic and inorganic amendments is imperative for sustainable soil enhancement amidst escalating soil degradation. These nutrient-enriched amendments mitigate chemical dependence, sustain soil health, and enhance agricultural productivity.

Introduction

Soil degradation poses a significant threat to the sustainability of crop production and human survival, exacerbated by the impacts of climate change and the increasing pressure of a growing global population. Erratic rainfall patterns, temperature fluctuations, and changing climate conditions challenge farmers and policymakers, leading to food insecurity. Traditional agricultural practices, including genetic manipulation, excessive fertilizer use, and chemical inputs, have contributed to soil health deterioration, biodiversity loss, and declining productivity. To address this, there is an urgent need for site-specific management strategies that reverse soil degradation and enhance soil properties sustainably. Emphasizing the importance of soil health improvement, alternative solutions to reduce reliance on chemical inputs are essential for maintaining and restoring soil fertility. The addition of organic and inorganic materials as soil amendments becomes crucial in amending degraded soils, promoting a healthy balance of organic and inorganic components for increased biodiversity and improved nutrient concentration. Rejuvenating soils through environmentally safe amendments is vital for enhancing crop productivity and ensuring the livelihood security of farmers, offering a sustainable approach to conserve natural resources for future generations.

Soil amendments are specialized materials containing essential nutrients that contribute to enhancing the physical, chemical, and biological properties of soil. They act as beneficial agents in transforming the soil into an ideal environment for plant growth. These materials can either be naturally occurring, such as plants and microbes, or artificially produced, including polymers and industrial waste products. The significance of soil amendments lies in their multifaceted roles: they regulate soil pH, particularly in challenging environments like acidic or alkaline soils, and enhance soil attributes in terms of structure, aeration, water retention, and permeability. Soil amendments foster a conducive soil environment that attracts beneficial microorganisms and earthworms, contributing to overall soil health. Moreover, they play a crucial role in revitalizing impoverished soils and restoring those damaged due to improper management practices. By introducing essential nutrients, they enrich the soil, promoting healthier and more productive plant growth. Additionally, soil amendments mitigate issues such as soil compaction and the formation of hard layers, sustaining soils in a state of optimal health and functionality. Overall, these materials serve as indispensable tools for sustainable agriculture, acting as allies to the soil and supporting the vitality of plant life.

Types of soil amendments

Soil amendments play a vital role in soil reclamation, enhancing physical, chemical, and biological properties. They can be categorized into inorganic and organic resources, with preferred amendments including minerals like gypsum, pyrite, lime, and organic materials such as animal manures, compost, and vermicompost. Organic amendments often derived from agriculture, forestry, and urban sources, stimulate microbial activity, releasing organic acids that improve nutrient availability. Animal

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manure is a common source in agriculture, promoting microbial activity and nutrient availability. Crop residues, forest-origin materials, and industrial wastes also contribute to organic amendments, with biochar gaining popularity. Inorganic amendments, either mined or man-made, include lime and gypsum as common soil conditioners. These minerals, like sulfur, perlite, bentonite clays, Epsom salt, and sodium chloride, adjust soil pH and enhance its physical, chemical, and biological properties. Gypsum, a key amendment, rehabilitates saline-sodic soil and supplies essential nutrients. Flue gas desulfurization gypsum is also utilized as a by-product from coal-fired power plants for soil reclamation. Both organic and inorganic amendments contribute significantly to improving soil health and supporting sustainable agriculture.

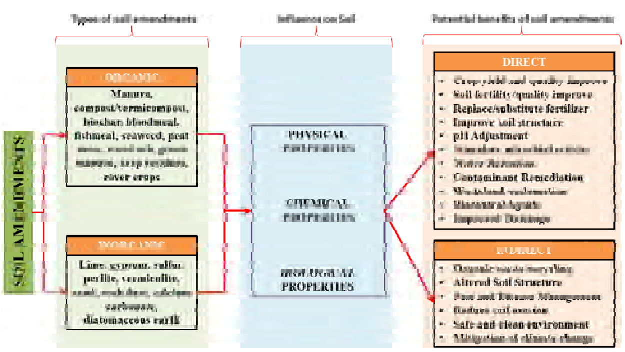

Fig. 1 Types of soil amendments and their influences on soil health

Soil properties influenced by soil amendments

Soil amendments serve a crucial role in creating optimal conditions for plant growth and sustaining soil health. They counteract soil compaction, ensuring loose and conducive soil for root development and nutrient absorption. Additionally, soil amendments enhance water retention, crucial during dry periods, and balance soil pH for optimal nutrient availability. Facilitating the release of essential nutrients and preventing leaching, they contribute to efficient fertilizer use. Moreover, soil amendments promote biological activity by encouraging beneficial microorganisms, aiding nutrient cycling, and improving overall soil health. Erosion mitigation is achieved through enhanced soil structure, preserving landscapes and fertility. Contributing to sustainable agriculture, soil amendments reduce reliance on chemical treatments, fostering long-lasting soil well-being. In the context of intensified agriculture, the effects of soil amendments are significant, utilizing agricultural waste as valuable sources for sustainable soil conditioning. They influence physicochemical and biological characteristics of the soil, enhancing soil quality, nutrient cycling, and overall agricultural productivity. Notably, the profound impact of soil amendments on soil properties, pH regulation, and nutrient availability underscores their indispensable role in creating and maintaining a healthy and sustainable environment for plant growth.

Soil amendments and carbon farming

Carbon farming refers to the intentional adoption of specific on-farm practices aimed at extracting carbon dioxide from the atmosphere and storing it within soils and plant materials. This approach plays a crucial role in addressing climate change by mitigating the effects of greenhouse gas emissions. Carbon farming practices encompass a variety of techniques, including the application of soil amendments such as compost or biochar, conservation tillage, agroforestry, whole orchard recycling, and the use of cover crops with an emphasis on maximizing living roots. The primary objective is to enhance soil organic matter on croplands and rangelands, leading to the sequestration of carbon in the soil. This process not only helps combat climate change by reducing atmospheric carbon dioxide levels but also offers potential co-benefits for soil health and increased adaptive capacity. Soil amendments, such as compost or biochar, play a crucial role in this carbon sequestration process by increasing the amount of carbon stored in soil organic matter. By adopting carbon farming practices, farmers contribute to sustainable agriculture, support climate resilience, and foster healthier soils, all while actively participating in global efforts to combat climate change.

Conclusion

Urgent action is needed to address soil degradation exacerbated by climate change and population growth. Traditional agricultural practices necessitate innovative, site-specific strategies for sustainable soil improvement. Incorporating both organic and inorganic amendments is crucial for reversing degradation and regulating soil properties. These amendments, rich in essential nutrients, contribute to sustainable agriculture by reducing reliance on chemicals, fostering long-term soil well-being, and supporting agricultural productivity. As agriculture evolves, the incorporation of diverse amendments becomes indispensable for creating a healthy, sustainable environment. The concept of carbon farming underscores the pivotal role of soil amendments, such as compost or biochar, in combating climate change and promoting soil health, with farmers actively contributing to global efforts for resilience and sustainability.

The Role of Crop Residues in Regenerative Agriculture

Rakesh Kumar, Manmohan Dobriyal, and Aman Dabral

India, a country that relies heavily on agriculture, produces over 500 million tonnes of crop residue annually. Cereal crops contain more than 70% of this waste, most of which is incinerated by the farmers. This practice leads to a considerable loss of organic carbon and depletes the soil nutrients while emitting substantial quantities of environmentally and health-damaging gases, such as carbon dioxide (CO_2), sulfur dioxide (SO_2), and carbon monoxide (CO). To counter the negative impacts of these non-scientific farming practices, regenerative agriculture is advocated as an effective management strategy. It focuses on enhancing the health of the soil, rehabilitating degraded lands, improving water quality, promoting plant development, and increasing the productivity and rotation of crops using suitable organic modifications. By adopting this approach, the agricultural system not only bolsters ecological stability but also augments the economic gains for farmers and contributes to better human health.

Introduction

Annually, over five billion metric tons of agricultural residue are produced worldwide, of these, India alone accounts for more than 500 million tons. Importantly, among various crops, cereals generate the most residues (352 metric tons), followed by fibrous crops (66 metric tons), oilseeds (29 metric tons), pulses (13 metric tons), and sugarcane (12 metric tons). Cereal crops (rice, wheat, maize, and millet) contribute 34% to the crop residues. In India, rice crops produce about 33%, wheat 22%, fibrous crops 13%, and cotton 11% of the crop residues. Specifically, cereal crops, such as rice, wheat, maize, and millet account for 34% of these residues. In India, rice accounts for the largest share of each crop's contribution (33%), followed by wheat (22%), cotton (11%), and fibrous crops (13%). However, the residue can be used as fuel for both home and commercial appliances, as well as for roofing and animal feed. Still, a significant amount of unused residue is often burned by farmers to quickly clear fields for the next planting season, seeking to derive economic advantages from such practices. This necessitates effective residue management to avoid soil nutrient depletion and mitigate environmental pollution. In response, the Indian government promotes regenerative farming techniques. This holistic approach to agriculture aims to enhance soil health, food quality, biodiversity, and water and air quality by reducing reliance on chemical inputs, decreasing tillage, incorporating livestock, and employing cover crops.

The need for regenerative agriculture

The extent of soil fertility degradation, biodiversity loss, and lack of knowledge about native seeds can pose serious threats to human existence in the future. According to some research, if decarbonization, erosion, desertification, and chemical pollution continue at their current rate, in 50 years mankind will not only have a severely inadequate food supply for their consumption that poses a serious health risk to the public but will also run out of arable topsoil to feed themselves. Regenerative agriculture requires urgent action to safeguard the world's agricultural systems. The regenerative agricultural practice helps minimise water use, improve nutrient content, and combat climate change. It helps to preserve the fertility balance and health of the soil, which increases agricultural yields. Regenerative agriculture offers farmers a new perspective on producing safe and profitable crops, utilizing genetic elements while properly conserving the environment. This leads to increased biodiversity and supports sustainable agricultural systems, ensuring a healthy and prosperous future for our coming generations. Moreover, regenerative agriculture is a holistic farming system that improves soil health, food quality, and biodiversity through methods such as reducing the use of chemical fertilizers and pesticides, reducing tillage, integrating livestock, and using cover crops that aim to improve water and air quality.

Principles of Regenerative Agriculture

Regenerative agriculture includes five main principles, such as Reducing Soil Disturbance. Industrial agricultural practices accelerate soil erosion, covering the soil, ensuring live roots in the soil all year round, practicing crop diversity, and integrating livestock, which

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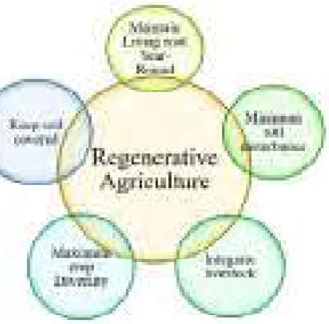
not only prevents soil erosion but also actively contributes to soil formation. This agricultural method can yield high crop production with minimal external inputs and improve financial returns for farmers while enhancing human health.



Benefits from crop residues

a) Crop residues prevent soil erosion by protecting the soil from direct contact with air, water, and sunlight. They also aid in soil structure, water infiltration, and reducing erosion caused by temperature fluctuations and runoff.

b) Crop residues enhance soil fertility by increasing organic matter, nutrient content, water retention, and microbial activity, leading to improved soil fertility and increased crop productivity.

c) Crop residues assist in regulating the water requirement for irrigation in the fields.

d) They reduce the incidence of weeds in the field.

e) They help in reducing the cost involved in preparing agricultural land.

Challenges of crop residue management

a) Huge amount of crop residue

b) Collection and storage

c) The period between harvesting and sowing of two crops

d) Use of crop residues

e) Cost-effective mechanization

f) Lack of awareness and availability of appropriate machinery.

Crop residue management

Crop residue management can be classified into two parts based on production site:

i. Crop residue management options in the field

a) Residue Retention: Crop residues left in the agricultural land after harvesting, called residue retention. Crop leftovers improve the biological, chemical, and physical characteristics of the soil while they remain on the soil's surface. Using technology like the Happy Seeder and Turbo Happy Seeder, the leftovers left on the field's surface are mixed into the soil when the following crop is sown.

b) Utilization of Crop Residues as Mulch: This is a traditional management practice where crop residues (rice/wheat straw) are cut into small pieces and evenly spread on the ground. By using the Happy Seeder, the field is sown while following the zero-tillage traditional method covered with mulch. Mulching not only controls weeds but also protects the soil.

c) Using Crop Residues as Fertilizer: Converting crop residues into valuable manure or compost through the aerobic and anaerobic activities of microorganisms under controlled conditions is a natural decomposition process. Crop residues are transformed into valuable fertilizers or compost.

ii. Off-farm crop residue management options

a) Crop Residues for Animal Feed: Crop residues contain high nutritional value, making them suitable for use as animal feed.

b) Production of Biofuel and Bio-Oil: Crop residues are a rich source of lignin, and alcohol is produced from lignocellulosic biomass. Bioethanol can be mixed with petrol and diesel, reducing harmful gas emissions in the transportation sector. Apart from sugarcane molasses, rice straw is also found to be ideal for biofuel production due to its easy availability at low costs. Various types of crop residues can be used in the production of bio-oil through the process of pyrolysis, where biomass is kept at a temperature of 400-500°C for a few seconds. This results in the thermal breakdown process, which quickly cools down the condensate, producing a deep brown viscous liquid called bio-oil that has a calorific value of 16-20 MJ/kg.

c) Crop Residues for Mushroom Cultivation: Wheat and rice straw are excellent substrates for the cultivation of button mushrooms and straw mushrooms. Utilizing crop residues for mushroom production is a profitable venture in diverse agriculture, where crop residues can be used for high-value and nutritious food.

d) Construction Material: In many villages in India, crop residues are still used for roofing houses. Making bricks and walls from a mixture of crop residues and soil is a traditional technique where straw is used to give strength to the material. Crop residues are also used in modern applications such as making boards with gypsum, bio-composite materials, etc., and packaging, roofing, etc.

e) Biochar Production: Biochar production is done through pyrolysis, where residual biomass is burned at high temperatures (300-600ºC) with limited or no oxygen. Carbon from crop residues, which would otherwise be released as CO_2 into the atmosphere, is sequestered for a considerably long period as biochar, making this technique capable of reducing agriculture's carbon footprint. Application of biochar in soil as an amendment can help increase soil fertility, increase soil organic carbon, reduce greenhouse gas emissions, and enhance nutrient use efficiency by reducing leaching, thereby aiding in crop performance.

Summary

India is the world's most populous country and its economy is largely dependent on agriculture. There is a need to adopt sustainable farming systems to ensure food security in the country. A sustainable production system can be determined through regenerative agriculture principles. Crop residues should be used in the field to ensure the country's food security and maintain agricultural production and healthy soil resources. At present, there is a need for research, policy, and development programs working at local and regional levels in the management of crop residues so that in the future we can ensure food security by conserving air, water, and soil and maintaining harmony with nature.

Zero budget farming and other regenerative farming methods

Anil Kumar Rai, Yogeshwar Singh, Amit Kumar Singh, Shiv Vendra Singh, Susheel Kumar Singh and Vishwanath

Natural farming is a method of chemical-free agriculture borrowed from traditional Indian practices, although internationally natural farming is considered a form of regenerative agriculture, natural farming is a unique model of farming practice that relies on agro-ecology, Natural farming aims to reduce the cost of production and promote returns to a sustainable level, in natural farming there is no need for expensive inputs like fertilizers, pesticides and intensive irrigation, natural farming is done by microorganisms and earthworms on the soil surface. Encourages the decomposition of organic matter, and slowly adds nutrients to the soil over time.

Zero budget natural farming:

This method is based on native traditional Indian practices, and cow dung and urine. In this method, agricultural inputs like fertilizers, pesticides, herbicides and fungicides and irrigation are not required. Due to which the cost of agriculture reduces significantly. That is why it has been named zero budget natural farming.

Benefits of zero budget natural farming-

- No need for expensive agricultural inputs.
- Reduction in production costs.
- Multiple cropping possible.
- Higher yields at lower costs.
- Increase in soil fertility.
- Better quality of produce.
- Higher prices of produce in the market.
- Increase in water holding capacity of soil.

Some special aspects of natural agriculture-

1. This method is based on nature, and science,
2. This farming can be done only with the help of a native cow. In this method, chemical fertilizers, pesticides, fungicides, weedicides, are not to be used. dung manure, organic fertilizers, earthworm manure.
3. Crop production will be poison-free, high quality, nutritious and tasty.

Principles of natural agriculture-

1. **Desi Cow-** This agriculture is mainly based on desi cow. The smell of cow dung and urine brings local earthworms to the surface of the soil and makes the land fertile. cow dung contains main nutrients. These 16 elements are useful for the growth and development of our plants. Therefore the indigenous cow is the foundation of natural agriculture.
2. **Ploughing-** Deep plowing is not done in natural agriculture because it reduces the fertility of the land. And the process of formation of humus stops due to which the fertility of the land reduces.
3. **Water management-** In natural agriculture, irrigation is done at some distance from the plants. Only 10 percent water is used in this, due to which 90 percent water is saved. Watering plants from some distance increases the length of plant roots. As the length of roots increases, the thickness of plant stems increases. The height of the plants also increases due to this action. As a result production increases.
4. **Companion crops-** In natural agriculture, companion crops are cultivated simultaneously with the main crop so that the main crop continues to get nitrogen, phosphorus, potash etc. Plants grow with the help of nitrogen fixing bacteria like Rhizobium, Azospirillum, Azotobacter etc. near the roots of allied crops. In natural farming, planting of allied crops along with the main crops simultaneously provides pest control on the main crop.

Pillars of Zero Budget Natural Farming-

Zero budget natural farming is based on sustainable agro-ecosystem approach and helps in balancing the ecosystem. These are the main pillars of this method.

Jeevamrit, 2. Vhapsa, 3. Beejamrit, 4.Soil cover, 1. Jeevamrit- It is a fermented mixture of micro

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organisms prepared from cow dung and urine, jaggery, pulses, water and soil. It enhances the beneficial micro activities in the soil and increases the amount of nutrients.

Cow dung - 10 kg, Cow urine - 8-10 litres, Jaggery - 1-2 kg, Gram flour - 1-2 kg, Soil under banyan or peepal tree - 1 kg, Water - 180 litres.

Usage method- Use 200 liters of Jeevamrit per acre on standing crops or with water irrigation

2. Beejamrit - Beejamrit prepared from cow dung, urine, and lime is done. Which is used as seed treatment to protect the seeds from pests and soil borne diseases. According to scientific research, sowing of pulse crops gram, lentil, soybean, tur, urad, moong etc. by treating seeds with beejamrit increases the germination percentage, seedling growth and seed vigor index.

   Cow dung - 5 kg, Cow urine - 5 litres. Lime 250 grams, water-20 litres. Field soil – a handful

   Usage method - Keep all these substances in water for 24 hours. Stir with a stick twice a day, after this treat the seeds by pouring beejamrit and dry them in the shade and sow.

3. Vhapsa - Plants need water for growth and development. In fact, plant roots do not need water, but plant roots need moisture. Plants do not need much water to grow and plants can also grow with the help of steam.

4. Mulching - Mulching means covering the upper surface of the land. It works to protect and preserve the liveliness and fertility of the land.

Straw Mulch - Straw mulch is one of the best mulch materials. Straw mulch is mostly used in vegetable cultivation. Paddy and wheat straw can be used in vegetable cultivation.

Regenerative agriculture:

The main goal of regenerative agriculture systems is to enhance soil quality and biodiversity while producing profitable agricultural products.

There is no universal definition of regenerative agriculture. The term often refers to promoting soil health by restoring organic matter present in the soil. Regenerative agriculture practices aim to use organic matter.

Main five principles of regenerative agriculture:

1. There are some basic principles of natural farming. The amount of bacteria in soil is the most important part of soil productivity. These bacteria make naturally available nutrients in soil, air and agricultural residues/biomass available for plants to use. Pesticides kill insects harmful to crops as well as friendly organisms. Chemical fertilizers also hinder the growth of bacteria in the soil, hence the first task is to increase the number of bacteria in the soil. For this it is important that pesticides and other chemicals are not used.

2. The next principle is that there should be bio-diversity in the field, that is, instead of sowing only one type of crop, many types of crops should be sown in the field at the same time. Bio-diversity or mixed farming proves helpful in both increasing soil productivity and controlling pests. As far as possible, sow a mixture of legume or pulse crops and monograin crops like cotton, wheat or rice in every field. Even in pulses or legume crops i.e. cotton etc., one should not sow only one variety and use different varieties. The crop rotation should also be changed from time to time.

1. Reduce soil tillage

2. Covering the soil

Ensuring soil cover is important for building or reviving soil. A layer of green crops protects the soil surface from harmful sun rays and cold. It increases the water holding capacity of the soil and accelerates the better nutrient cycle.

Regenerative agriculture practices include the following farming practices:

Low tillage farming

Low-till farming is an integral part of reducing soil disturbance. In this technique pasture crops are sown through disc planters or special drillers. Sowing of dormant annual plants in perennial pastures is required to promote crop diversification and improve productivity.

2. Organic crops

Organic farming involves the use of organic pesticides and fertilizers, such as manure, animal manure and plant waste, in an environmentally friendly manner. The ecological benefits of organic farming practices include reduced soil erosion, minimal leaching of nutrients into groundwater and utilization of waste materials.

3. Perennial crops

Planting perennial crops is a soil shield (protect) method. This is useful for reducing erosion by transport agents such as wind and water, reducing the need for chemicals and tillage operations.

4. Agroforestry/forest fodder

Agroforestry involves planting trees, shrubs, palms and bamboo with extensive root systems to protect crops from strong winds and rain. Forest pastures, on the other hand, involve the deliberate management of livestock, trees and fodder, similar to productive agriculture. Both of these practices diversify and sustain production to increase social, economic and environmental benefits.

How to start

Obviously, a small farmer who is completely dependent on farming cannot immediately adopt natural farming, he cannot risk his livelihood, but there is a belief that even if the production decreases, it will increase again in 2-3 years. And it is dangerous to follow the current path, so we can consider this initial risk as an investment for the future. Therefore, we can start with half an acre or one or two acres of our land. Because of this, you can take the risk of loss of income for a short period of time. Stop using chemical fertilizers and pesticides completely in this part of your farm. But keep in mind that merely stopping the use of urea etc. So that will definitely reduce the yield. Along with this, we will also have to implement all the other measures of natural farming. Along with this, we should also adopt as many of these measures as possible in the rest of the farm.

Many people do not start thinking that if we stop using pesticides but our neighbors keep using pesticides, then the use of in our fields will pests increase. This fear is wrong. Neighbors should leave. Even if a farmer stops using pesticides in one part of his field and continues using chemicals in the remaining part, he will not suffer any loss. After harvesting, grazing of animals helps in converting the crop into organic manure.And if a 2-4 inch layer of biomass is formed in the field then it is very good. This layer does many things. Saves water by reducing evaporation, protects soil during rain and strong wind and storm. Prevents weeds. By controlling the temperature, it creates a suitable environment for the soil bacteria even in extreme summer and winter and prepares their food and ultimately increases the fertility of the soil by decomposition. It is better to add small pieces of biomass to cover the ground. Broad leaves and thick branches should not be used as biomass.

Role of Soil Health Card in improving soil health

Susheel Kumar Singh, Vishwanath and Anil Kumar Rai

Soil health and fertility are the foundation of sustainable profitability and the first step towards sustainable farming for farmers. The optimum dosage of fertilizers and cropping pattern as per scientific recommendations is the basic component of soil health and its sustainability. Soil test based nutrient application is a good approach to judicious use of fertilizers, which works on the principle of profitability, *i.e.* if all the factors of production are at optimum level and none of them are limited, then the ad-hoc applied is a more beneficial reaction than. It is a science-based and time-tested tool for assessing soil fertility status and is a pre-requisite for obtaining a Soil Health Card.

Introduction

Soil Health Card is useful in maintaining soil fertility and supply of plant nutrients at optimum levels to maintain desired productivity through optimization of benefits from all possible sources of organic, inorganic and biological components in an integrated manner. At present, Indian soils are deficient in various nutrients, such as 95%, 94% and 48% for nitrogen, phosphorus and potassium (primary nutrients) respectively; 25% for sulfur (secondary nutrients) and 41%, 20%, 14%, 8% and 6% for zinc, boron, iron, manganese and copper (micronutrients) respectively (Press Information Bureau, 2020, Release 1603569). These limited nutrients also hinder the expression of other nutrients, resulting in reduced efficacy of chemical fertilizers and crop productivity. In fact, improving input use efficiency of fertilizers and nutrients is more important than applying higher doses of fertilizers in Indian agriculture. At present, the nutrient utilization efficiency of many soil nutrients is very low such as 30-50% for nitrogen, 15-20% for phosphorus, 60-70% for potassium, 8-10% for sulfur and 1-2 % for micronutrients. Although crop production in India has increased manifold, unbalanced use of chemical fertilizers has detrimental effects on vital natural resources, especially soil and water. To address such issues, the Government of India implemented the National Mission for Sustainable Agriculture (NMSA) in 2014–15 during the 12th Five Year Plan.

National Mission for Sustainable Agriculture is one of the major components of Soil Health Management (SHM). It aims to promote integrated nutrient management through soil test based balanced application of primary, secondary macronutrients and micronutrients in combination with organic manures and biofertilizers. Under the Soil Health Management (SHM) component, the Central Government launched the Soil Health Card (SHC) Scheme on 19 February, 2015 to encourage site specific and soil test-based integrated nutrient management to promote nutrient use efficiency has started. It facilitates judicious application of bio-fertilizers and organic manures as well as chemical fertilizers to maintain soil health and maintain crop productivity.

Soil Health Card is a scheme of the Government of India promoted by the Department of Agriculture and Cooperation under the Ministry of Agriculture and Farmers Welfare. Soil Health Card Scheme ("Swasth Dhara Khet Hara") was launched by the Honorable Prime Minister, Government of India on 19th February, 2015 from Suratgarh, District Sri Ganganagar, Rajasthan. Soil Health Card Scheme was conceptualized, designed and envisioned to promote integrated nutrient management, i.e. application of biofertilizers based on soil fertility to maintain soil health, crop productivity and overcome fertility constraints. and balanced and judicious use of fertilizers with locally available organic fertilizers. Soil Health Card is an excellent way to protect the health of Mother Earth by accurately measuring soil quality and ensuring the use of proper fertilizers and ensure accurate measurement of soil character and components and increases awareness about environment friendly agriculture.

Soil Health Card is a printed report. It consists of 12 parameters, namely nitrogen, phosphorus, potassium (primary nutrients); Sulfur (secondary nutrient); Zinc, Iron, Copper, Manganese, Boron (micronutrients); and condition of the soil with respect to pH, EC, organic carbon (physical parameters). Based on this, the soil health card also indicates the fertilizer recommendations and soil amendments required for the farm. Sustainable agriculture is a method of farming that is being done for future generations. This long-term approach to agriculture combines efficient production with wise

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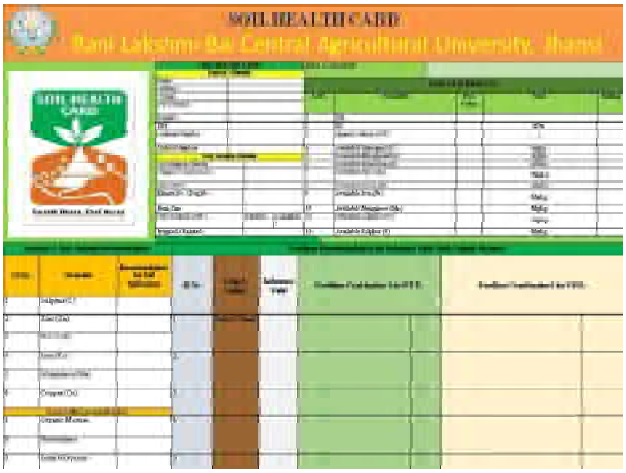

management of the earth's resources. It is expected that, over time, sustainable agriculture will do the following:

- Will meet human needs for food and fiber.
- To protect the natural resource base and prevent degradation of soil and water quality.
- To use non-renewable resources efficiently.
- Using natural biological cycles and controls.
- To ensure the economic survival of farming and the well-being of farmers and their families.

Soil Health Card: How to read the condition of our soil?

Soil Health Card is a printed report card issued to farmers every 2-5 years after testing their soil in laboratories. Here grid based sampling method is followed and the grid size for irrigated and rainfed areas is 2.5 hectares and 10 hectares respectively. Soil samples are collected using GPS and revenue maps.

Base of Fertilizer Recommendation

Fertilizer recommendations are made based on low, medium, high and very high soil test calculations (Table 1). The rating is as follows:

Concluding Remarks:

Soil Health Card raises awareness about soil health and eco-friendly agriculture by accurately measuring soil quality and ensuring use of proper fertilizers. According to a study conducted by the National Productivity Council (NPC) in 2017, this Soil Health Card Scheme has led to increased awareness among farmers as well as a decline of 8-10% in the use of chemical fertilizers, resulting in improved efficiency in the farming system. There has been high stability. Therefore, the crop yield has also increased by about 5-6%. Soil Health Card Program is an innovative step towards improving soil health for healthy crop growth.

Table 1: Parameters and limitations in the soil health card

S. No.	Nutrient	Low	Medium	High
1.	pH	< 6.5 (acidic)	6.5 7.5 (neutral)	>7.5 (alkaline)
2.	EC	< 4.0 (normal)	> 4.0 (saline)	-
3.	Organic Carbon (%)	< 0.5	0.5-0.75	>0.75
4.	Nitrogen (kg/ha)	< 280	280-560	>560
5.	Phosphorus (kg/ha)	< 10	10-25	>25
6.	Potassium (kg/ha)	< 120	120-280	>280
7.	Sulfur (mg/kg)	< 10 (Deficient)	> 10 (Sufficient)	
8.	Zinc (mg/kg)	< 0.6 (Deficient)	> 0.6 (Sufficient)	
9.	Iron (mg/kg)	< 4.5 (Deficient)	> 4.5 (Sufficient)	
10.	Copper (mg/kg)	< 0.2 (Deficient)	> 0.2 (Sufficient)	
11.	Manganese (mg/kg)	< 2.0 (Deficient)	> 2.0 (Sufficient)	
12.	Boron (mg/kg)	< 0.5 (Deficient)	> 0.5 (Sufficient)	

Microorganisms abundance enhances the soil fossil

Umesh Pankaj

In the nature, plants are part of a rich ecosystem including numerous and diverse microorganisms in the soil. Microorganisms live in complex communities of interacting species that impact life on earth and geochemical processes in the environment. Soil microbial population continues to be involved in improving the bioavailability of soil-borne nutrients. Soil carbon is produced directly by the growth and death of plant roots as well as indirectly by the transfer of carbon-rich compounds from roots to soil microorganisms. The article focuses on soil organic matter derived from microorganisms makes a larger contribution to the persistent soil organic matter pool than plant residues. This soil carbon helps in water and oxygen flow towards to root and nourish the plant. Organic matter prevents the loss of vital nutrients from the soil and increases the activity of healthy microorganisms, which in turn promotes plants health. In natural ecosystems, most nutrients such as N, P, and S are bound in organic molecules and are therefore minimally bioavailable for plants. To access these nutrients, plants are dependent on the growth of soil microbes such as bacteria and fungi, which possess the metabolic machinery to depolymerize and mineralize organic forms of N, P, and S.

Formation of soil organic matter by the action of microorganisms

It is well known that human activity since the industrial revolution has resulted in a significant increase in atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases (GHGs) as a outcome of continuous input into the atmosphere. Consequences this the Earth's climate is changing rapidly. What is perhaps less appreciated is that natural and managed soils are an important source and sink for atmospheric CO_2. The amount of carbon in soils represents a large portion of the carbon found in the planet's terrestrial ecosystems. The total carbon in terrestrial ecosystems is approximately 3170 gigatons (1 GT = 1 petagram = 1 billion metric tons). About 80% (2500 GT) of this quantity is found in soil. Soil carbon can be either organic (1550 Gt) or inorganic carbon (950 GT). The latter consists of elemental carbon and carbonate materials such as calcite, dolomite and gypsum. The amount of carbon found in living plants and animals is relatively small compared to that found in soil (560 GT). The soil carbon pool is about 3.1 times larger than the atmospheric pool of 800 GT. The ocean alone has a large carbon pool of about 38,400 GT of carbon which found mostly in inorganic forms. Soil organic matter is composed of soil microbes including bacteria and fungi, decaying materials of once-living organisms such as plant and animal tissues, fecal materials, and the products of their decomposition. Soil organic matter is composed of organic compounds that are highly rich in carbon. Soil organic carbon (SOC) levels are directly related to the amount of organic matter contained in the soil. Soil organic carbon levels result from the interaction of several ecosystem processes, the major ones being photosynthesis, respiration, and decomposition. Photosynthesis is the fixation of atmospheric CO_2 into plant biomass. Soil organic carbon input rates are determined primarily by a plant's root biomass, but also includes litter accumulated from plant shoots. Soil carbon is produced directly by the growth and death of plant roots as well as indirectly by the transfer of carbon-rich compounds from roots to soil microorganisms. For example, many plants form symbiotic relationships between their roots and specialized fungi called mycorrhizae in the soil. The roots provide the energy to the fungus in the form of carbon while the fungus provides the plant with often limited nutrients such as phosphorus and micronutrients. Decomposition of biomass by soil microorganisms results in the loss of carbon from the soil as CO_2 due to microbial respiration, while a small portion of the original carbon is retained in the soil through the formation of humus, a product that often carbon-rich soils are characterized by their dark color (Figure 1). Humus is highly complex, and this resistance to decomposition causes it to persist for a long time in the soil. Plant debris is less complex, resulting in a much shorter residence time in the soil. Other ecosystem processes that can cause carbon loss include soil erosion and leaching of dissolved carbon into groundwater. When carbon inputs and outputs are in balance with each other, there is no net change in soil organic carbon levels. When carbon input from photosynthesis exceeds carbon loss, subsequently organic carbon levels in soil increase over time.

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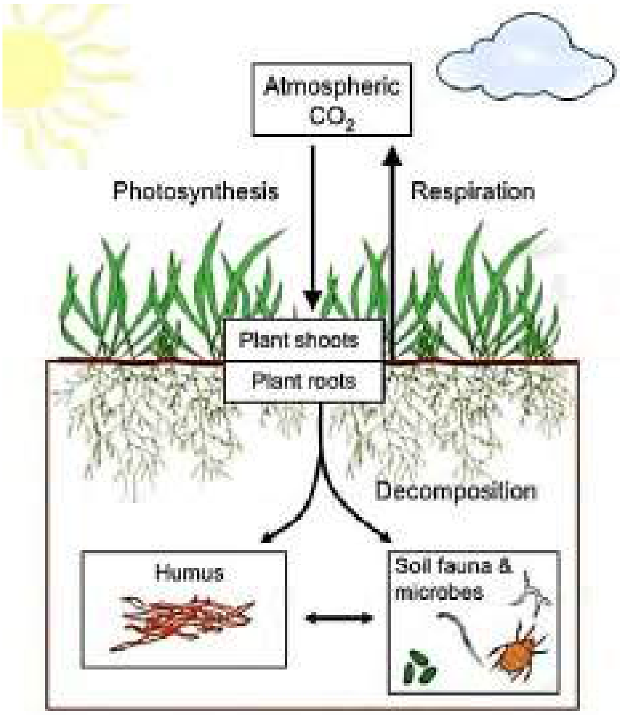

Figure 1. The process by which soil organisms and microorganisms produce humus from the decomposition of roots and root products, which is a long-term store of soil organic carbon that is regulated by carbon input from photosynthesis and carbon loss by respiration.

Role of microorganisms and soil organic matter in agriculture:

To understand the dynamics of soil microbial communities, it is important to know their distribution, composition and abundance. The number of bacteria in the soil (10^8 - 10^9 nos. /g of soil sample) is approximately 100 times higher than the fungal population (10^5 - 10^6 nos./g of soil sample). However, most soil microorganisms are still unidentified, and their functions are not well known. A portion of the population of microorganisms has the ability to promote plant growth by continuously secrete microbial products in plant rhizosphere. This type of bacteria is known as plant growth promoting rhizobacteria or plant growth promoting bacteria (PGPB). Some part of micro-organisms populations are involved in carbon and nutrients fixation and also reacting with abiotic conditions in the soil alternatively form humus. Microorganisms play an important role in biogeochemical cycles and are essential for soil functions, particularly soil organic matter decomposition and nutrient (such as nitrogen and phosphorus) cycling, and thus provide important ecosystem services. Micobial nitrogen fixation in the root zone, photosynthesis and cellular metabolism in plant during respiration are also affected by humus.

By definition, soil organic matter (SOM) is a heterogeneous mixture of living biota, mainly micro-organisms, and inanimate organic matter (fresh and partially decomposed remains of plant, animal and microbial origin). There is evidence that soil organic matter derived from microorganisms makes a larger contribution to the persistent soil organic matter pool than plant residues. This soil carbon helps in water and oxygen flow towards to root and nourish the plant. Organic matter prevents the loss of vital nutrients from the soil and increases the activity of healthy microorganisms, which in turn promotes plants health. Humus contains many nutrients and minerals which improve soil health and fertility by increasing water holding capacity. Carbon is most important for healthy soil conditions, and humus is about 60 percent carbon content. There are six essential nutrients that plants need in their soil: phosphorus, potassium, magnesium, sulfur, calcium, and nitrogen. Nitrogen is one of the most important of the six that need of every plant. Humus also plays an important role in the improvement of soil structure. Ideal soil contains humus and has a granular and loose structure. Clay soil is extremely dense and has minimal space between the mineral particles and by adding humus to it gives the loose texture to the soil. In sandy soils, humus helps to maintain moisture and nutrient levels.

Water Conservation Agriculture: The Need of Current Hour

Sandeep Upadhyay

Water and land are two major resources of agriculture and they need to be conserved. In Bundelkhand region, there is very shortage of water resources as the soil is shallow enough and being rugged and rocky in nature. Uneven and scanty rainfall is making agriculture in Bundelkhand very difficult. Here it has been recorded 41 percent less rainfall in June 2023. Farmers are facing troubled by the low crop yield due to hard work and more investment. To find out the explanation for this, the World Meteorological Organization (WMO) had predicted that the year 2024 could be hotter than the year 2023, which after looking at the records; year 2023 was really the hottest year among other years. El Nino has resulted in increased extreme events such as heat waves, droughts, wildfires, heavy rainfall and floods in some areas. Sustainable agriculture will happen only by adopting water conservation management methods. Farmers should prevent soil erosion by leveling the fields slope with strong bunds. Improve the soil as much as possible and adopt the right method of irrigation. Use micro irrigation or drip irrigation. Farmers should use hot climate tolerant varieties as per scientist's recommendation. No communication gap should be there among agricultural scientist's bodies and farmers; so Whats-App groups, advisories issued and training workshops with them from time to time in newspapers and TV-Radio channels being issued and organized. Front line demonstrations taking place in different village. It is very important to stay connected.

Let us consider about the Earth. Among the solar system, there is water on the Earth itself. About 71 percent of the surface is covered with water, but fresh pure water is only 3 percent of the total water; 97 percent of the water on Earth is in the oceans, which is salty. Of the 3 percent fresh water, 2 percent is frozen in the form of ice caps and glaciers, that is, we can use only 1 percent of the water for our daily needs which is found in reservoirs, ponds, springs and rivers etc. Currently, 83 percent of these water resources are being used in the agricultural sector, but based on the increasing demand in other areas, its availability for agricultural use is estimated to reduce to 68 percent by the year 2050. According to Water Aid India's State of India's Water 2019 report, about 1654 liters of water is required to produce 1 kg of wheat, similarly 2800 liters of water is required to produce 1 kg of rice.

Fig: Award-winning poster high-lighting the Importance of Land and Water resources on World Soil Day 2023.

Fig: Kisan Mitra Fertile Soil Health Made from Earthworms

Fig: Salinity soil problem caused by severe waterlogging

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Fig: Use irrigation making ridge and furrows.

Fig: Provide support by making ridges in the maize and irrigate the crop.

Fig: Avoid surface irrigation to save water.

Fig: Use as far possible Drip irrgation.

Fig: Use ferti cum seed drill machine. Sow in lines, apply fertilizer and conserve moisture with the zero-till ferti-drill.

Fig: Grow tuberous crops among the trees by applying mulch.

Fig: In-situ Soil moisture conservation trial at the Research Block University

Fig: Research field visit and inspection by higher officials at the Research Block university

There is very shortage of water resources in Bundelkhand region. Untimely and scanty rainfall, lack of shallow soil depth with rough and rocky plateau land, the farming of Bundelkhand is completely rainfed in nature. There has been a 41 percent decrease in rainfall in Bundelkhand in June 2023 and the crop of November was also sown late due to insufficient rainfall and irregularity of weather. Overall, meteorologists are calling it El Nino weather effect but farmers are troubled by low crop yield due to hard work and investment. To know the reason for this, the World Meteorological Organization (WMO) predicted that the year 2024 could be hotter than the year 2023, which after looking at the records, it was found that 2023 is also the hottest year among other years. This is the El Nino weather effect which will result in an increase in extreme events like heat waves, drought, forest fires, heavy rains and floods in some areas, which will have major impacts and are visible.

The main problem faced in the development of agriculture is the uncertainty of water supply due to which the crop productivity of farmers is continuously increasing. Here in this area, it is not only necessary to start sustainable agriculture, but it is also necessary to adopt conservation management methods as per the geographical situation, among which leveling of slopes and embankment are the main ones. Therefore, you should also level your land and then make a strong embankment around the field so that soil erosion is stopped. As a result of the ridges, more and more rain water gets absorbed into the soil and the moisture can be used by the plants in summer. Improve the soil, adopt the right method of irrigation. Avoid surface irrigation, which uses excess water. Use micro irrigation or drip irrigation. Due to proper covering on the soil, its organic matter will not decrease, it will not be oxidized by the heat of strong sunlight, that organic matter will not get degraded. Because the amount of organic matter in the soils of Bundelkhand is less than normal. The organic level can be increased with this organic matter only when proper attention is paid to water conservation. More and more trees will be planted and agriculture will have to be done with the help of forestry. In the research block of the Central Agricultural University, the ginger crop grown among the trees by applying mulch is giving double the yield. According to scientific estimates, by burning one tonne of stubble and grass, 6 kg nitrogen, 2 kg phosphorus, 15 kg potash, 2 kg sulfur and a lot of organic humus is destroyed in one go. Be it forest fire or burning of stubble, no fire should be allowed to occur above the ground.

Farmer brothers, the temperature and moisture in different types of soils of Bundelkhand have been continuously monitored at different places and it has been found that the ongoing pulses and oilseed crops are better than the crops of Shri Anna class Millets which require less fertilizer and less water and may be more appropriate. Rakar soil of Bundelkhand has low water holding capacity and less organic matter and Mar soil has high water holding capacity and more organic matter. In Parva soil, crops like jowar, urad, moong, groundnut and sesame do well with less irrigation water, whereas in Rakar soil, wheat, linseed and in Mar soil, crops like wheat, gram, pulses, oilseeds do well with more water. Both Parva and Rakar soils are suitable for Shri Anna Millets category.

Farmer brothers, you also have to understand that having more water resources and providing more irrigation will improve crop productivity and soil fertility, this is not true, crop productivity and quality rather reduces. Research experiences of soil scientists in this regard have also revealed an interrelationship between the introduction of irrigation and the spread of waterlogging and soil salinity. The situation is such that even the projects started in the post-independence period have developed serious water logging and soil salinity problems. In many irrigation projects, water logging and salinity have occurred so rapidly that farmers and environmentalist aware people across the country have started the Save Soil Movement.

In the Bundelkhand agriculture system, sowing of submerged paddy will also have to be avoided. Direct sowing of paddy saves 20 percent water and labor in aerobic rice. Only strains and varieties selected for dry areas will have to be used in sowing. There are more possibilities of increasing the productivity of Kharif maize. Kharif maize is very sensitive to excess water and hence it has to be grown in ridges. In mixed farming, pulse crops are mainly grown among grain crops like wheat, barley along with gram, peas and lentils. Do not give priority or give less priority to oilseeds like wheat and mustard along with cereals, the reason is that both these crops together increase the demand for more irrigation of the land and chemical fertilizers. Gram along with wheat is absolutely suitable for the land of Bundelkhand. Gram along with wheat is to be sown by furrow-furrow method i.e. ridge-furrow method. 4 rows of wheat are to be sown in the groove of the row drain and 2 rows are to be sown on both sides of the ridge on the ridge, so that irrigation water will remain available to the wheat in the deep furrows. Gram will not be harmed by excess water and this will also help in inter-cropping activities like weed control. There will be convenience. There are many benefits in this mixed farming like this method of farming makes proper use of nutrients from different surfaces of the land, improves the soil structure, stops land erosion, increases the yield per unit area at low production of one crop. The second crop definitely gives some production. It has also been found through experiments and tests that in the case of single crop sowing, the fertility of the land gets reduced, which does not happen in mixed farming. 30 to 40 percent nitrogen requirement of wheat is that of gram. Pulses complete the crop and the next crop also benefits.

It is beneficial to start the cultivation of lentils with initial light irrigation in such land which is new or in which the yield is continuously decreasing and there is shortage of water. Nitrogen fixing symbiotic bacteria are found in very small nodes of its fine roots which increases nitrogen in the soil. The organic matter also increases due to the fine roots and as a result the water holding capacity also increases. Scientifically, nitrogenous chemical fertilizers are not given in the cultivation of lentils or other pulses of this category, it is correct to plant Rhizobium culture, but during the initial growth of pulses crop, less quantity of nitrogenous chemical fertilizers are required in weak and light sandy soils in a few weeks. For example, 15 to 20 kg per hectare should be applied through basal dose.

Many concept test results for improved farming by saving land and water are being tested through the research work of the university. Rani Lakshmi Bai Central Agricultural University is always with all the farmers of Bundelkhand. Under the guidance and constant supervision of Hon'able Vice Chancellor Dr. A.K. Singh and direction of Director Extension Education Dr. S.S. Singh, scientists bodies are performing out different types of Front Line Demonstrations in different villages so that the knowledge of good seeds, fertilizers and agricultural methods must reach the farmers and they can get educated. Various trainings workshops are also being organized for their happiness. Our able guide Director Education Dr. Anil Kumar and Director Research Dr. SK Chaturvedi both providing high level academic research work along to the different states students. To filling the gap between agricultural scientists and farmers, advisories are being issued through Whats-App groups time to time in newspapers and TV-Radio channels. Farmers are requested to stay connected.

Conclusion

Conservation of Bundelkhand's agriculture is only possible by adopting sustainable agriculture and water conservational techniques; otherwise the agricultural nature will deteriorate in the face of natural calamities. It is absolutely necessary that for the healthy health of all, the farmers of Bundelkhand should also adopt farming as per the importance of natural resources.

Agroforestry is the Backbone of Sustainable Agricultural Development

Ram Prakash Yadav, M.J. Dobriyal, Prabhat Tiwari, Garima Gupta and Rakesh Kumar

Globally sustainable agriculture is the need of the hour for sustainable development considering multifarious issues faced by humans. There are limited options available that can provide solutions to challenges facing the world and agroforestry is one of the promising of them. It is a multidimensional approach for sustainable development and can address social, environment and economic development. Agroforestry augment diversification, improve soil health, conserve water resources, prevent climate change, increase biodiversity and provide additional sources of income to farmers. Agroforestry rebuilds natural ecosystems, thereby building climate resilience diversified and sustainable production. Therefore, agroforestry is the promising solution to the various global problems.

Introduction

Agroforestry has emerged as a promising approach for sustainable agriculture. Agroforestry is a sustainable farming practice that combines trees and shrubs with crops and/or livestock. Agroforestry is a multi-dimensional land use system has attracted attention that provides environmental, social and economic sustainability, which are the three central pillars of sustainable development, and these issues facing agriculture today. The agroforestry aims to improve soil health, conserve water resources, prevent climate change, increase biodiversity and provide additional sources of income for farmers. Trees provide shade, fodder for animals, manure and moisture to the soil. Agroforestry rebuilds natural ecosystems, thereby building climate resilience. It facilitates diversification and sustainable production thereby improving social, economic and environmental conditions for all land users.

Agroforestry also promotes biodiversity by providing a variety of habitats for wildlife, as well as supporting beneficial insects that can help control pests and diseases. A diversity of crops and trees in an agroforestry system can also help promote natural pest and disease management, reducing the need for synthetic pesticides and herbicides. Trees such as fruit trees, nut trees, or timber trees can provide a valuable source of income along with traditional crops. This can help increase farmers' resilience to economic shocks and provide a more stable source of income in the long term.

According to the World Agroforestry Centre, agroforestry can increase crop yields by 50% and sequester 3.5 tonnes of carbon per hectare per year. This optimizes the benefits that arise from the biological interactions that arise when trees and shrubs are mixed with crops and livestock. The United Nations' Bruntland Report of 1987 (WCED, 1987) states that sustainable agriculture must be able to meet the present needs of society without compromising the ability of future generations to meet their own needs. The Food and Agriculture Organization (FAO) defines sustainable agriculture as "the management and conservation of the natural resource base, and the orientation of technological and institutional change to meet and sustain human needs for present and future generations". Such development conserves land, water, plant and animal genetic resources, is environmentally non-destructive, technically suitable, economically viable and socially acceptable.

FAO (2014) have proposed five principles for sustainable agriculture that cover all three pillars, viz., 1) improving resource use efficiency, 2) preserving, protecting and enhancing natural ecosystems, 3) protection and 4) improve and protect rural livelihoods and social well-being 4) enhance the resilience of people, communities and ecosystems, and 5) promote good governance of both natural and human systems.

Agroforestry and Climate Change

These practices provide socio-economic and environmental benefits and promote sustainable land-use which helps to shift to a low carbon economy. A shift from agriculture to agroforestry could increase soil organic carbon by an average of 34%, while a conversion from grassland to agroforestry could increase soil organic carbon by 10%. Carbon offsetting with agroforestry has the potential to provide financial incentives to sequester carbon using this land management strategy and create financial diversification and security for the farmer. Agroforestry can help reduce climate change and generate carbon credits in the

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following ways: **Carbon sequestration:** Since trees absorb carbon dioxide from the atmosphere, agroforestry practices help sequester carbon and store it in the soil and tree biomass. This can generate carbon credits that can be sold in carbon markets. **Emission Reduction:** Agroforestry practices help reduce emissions by improving soil health and reducing the need for synthetic fertilizers and pesticides. This helps reduce emissions from agriculture and generate carbon credits and **Co-benefits:** Agroforestry practices provide co-benefits such as increased biodiversity, improved soil health and climate resilience, thereby providing socio-economic benefits to farmers.

Agroforestry and sustainable agriculture

By integrating trees and crops in innovative ways, agroforestry can help improve soil health, promote biodiversity and mitigate the effects of climate change, while also providing a source of income diversification for farmers. There are many agroforestry practices that can be used to promote sustainable agriculture.

Agri-Silvi System: In this practice, rows of trees are planted between rows of crops, providing shade and protection from wind to the crops. Trees also help improve soil health by fixing nitrogen and increasing organic matter. Farming of turmeric with neem planation in semiarid region of Bundelkhand is the example of this system.

Silvopasture: This practice combine forestry and the grazing of domesticated animals on pastures, rangelands or farmland, forage crops, and livestock on the same piece of land. Trees provide shade and shelter to animals, while animals help control weeds and provide nutrients to the soil. Example of this is *Holoptelea integrifolia* and BN hybrid grass in semi-arid region of Bundelkhand.

Agrosilvopastoral systems: These are characterized by domestic gardens in which animals are scattered on the land as well as crops used for grazing after the crops have been harvested Home gardening (agroforestry in home gardens) is the example of this that integrates fruit trees, vegetables and medicinal plants in a home garden setting.

Neem-turmeric agroforest structure and layers

For the purpose of our analysis and proposed agroforestry standards, we summarize the broad regenerative agriculture goals: 1) Soil: Contribute to soil fertility and health as well as soil formation. 2) Water: Increase water infiltration, water retention and clean and safe water runoff. 3) Biodiversity: To enhance and conserve biodiversity. 4) Ecosystem health: capacity for self-renewal and resilience and 5) Carbon: Separator of carbon.

We first identify four interrelated characteristics of regenerative agroforestry, which can be achieved through different agroforestry practices. Due to the complexity of agroforestry systems compared to monoculture, as well as the wide range of potential applications in different environments and agricultural sites. According to our definition a regenerative agroforestry system should be highly integrated, densely planted, multi-storey and include multiple species. We propose these characteristics as key criteria for a regenerative agroforestry standard as follows: **1) Integration:** Presence of trees, shrubs and perennials integrated into the agricultural system. Perennials are more resilient to weather extremes and other environmental variations, providing greater flexibility than annual crops. There is evidence that perennials, with more extensive and deeper root systems, can reduce erosion to a greater extent than annual crop systems. **2) Density:** Plants per unit area (horizontal structure). Higher plant density builds soil by increasing the production of organic matter, which can be left in place to add organic matter and mulch to the soil through management of leaf fall, root senescence and pruning/ cutting. Higher density plantings can increase soil holding capacity and reduce erosion, as well as potentially increase biodiversity within agroecosystems **3) Multi-storey:** Layered structure and levels represented in root systems (vertical structure). The agroforests have higher total light interception than single-layer canopies, and hence higher total primary production of biomass (higher photosynthetic conversion). The aboveground structure of agroforests with diverse species composition is paralleled by root systems that occupy different soil depths and together form a network that efficiently captures nutrients before they are leached away by water, and **4) Multiple species:** The number of families, genera, species and varieties of plants over time (temporal succession). Increasing species diversity increases the overall biodiversity of the system. Having a large number of species also provides resilience by ensuring that the ecological niche is occupied even after weather extremes and other disturbances.

Challenges

Agroforestry can help increase the efficiency, productivity and sustainability of systems. By providing farmers with the right information, it helps promote the long-term sustainability of agriculture and support the livelihoods of farmers and their communities. Despite the above mentioned opportunities, there are challenges in implementing agroforestry practices. Limited technical assistance, less awareness and understanding, and capacity building, financing issues, and land ownership issues can all create challenges for the establishment of agroforestry systems.

Conclusion

Agroforestry provides a range of benefits to sustainable agriculture, including improved soil health, biodiversity, climate change mitigation and income diversification. Thus, it represents a promising approach to farming that can help promote long-term sustainability and resilience for farmers and their communities.

Harnessing modern technology for climate resilient agriculture

Piyoosh Kumar Babele

Climate adaptation in agriculture is becoming increasingly important as climate change increases extreme weather events and threatens food and nutrition security. This strategy focuses on modifying agricultural practices to resist various environmental changes, including drought, floods and rising temperatures. Climate resilient agriculture is critical to protecting livelihoods, food security, biodiversity and infrastructure from the worsening impacts of climate change. Incorporating cutting- edge agricultural technologies is essential to solve the climate issues. Using precision farming, power sensors, AI-powered analytics and smart irrigation systems increases resource efficiency, reduces environmental impact and increases crop resilience. These developments support sustainable food production, risk mitigation and farmer's adaptation to climate change. Promoting accessible information systems and digital literacy is important to empower people and communities in the digital age. This involves providing instruction and training on how to use digital technologies, the Internet, and information resources. Initiatives to enhance the capacity of farmers and provide them with the necessary training and knowledge to adapt to the changing environment and use sustainable practices are also important.

Introduction

Climate adaptation in agriculture is becoming increasingly important as climate change increases extreme weather events and threatens food security. Climate adaptation focuses on modifying agricultural practices to resist various environmental changes, including drought, floods and rising temperatures. It is important to explore how agricultural technologies are enhancing climate resilience in the agricultural sector and the transformative impact of modern technology in reducing climate change risks and enhancing sustainability practices. It is also important to highlight applications for a more resilient and sustainable future.

Incorporating cutting-edge agricultural technologies is essential to solve climate issues. Using precision farming, power sensors, AI-powered analytics and smart irrigation systems increases resource efficiency, reduces environmental impact and increases crop resilience. Furthermore, the integration of nanotechnology and omics data can be used to develop new crop varieties with improved yield, disease resistance, and stress tolerance, as well as to identify new targets for crop improvement. Here we are highlighting the exciting area of using modern agricultural technology to strengthen our agricultural systems against climate-related threats, which can move us towards a sustainable future.

Understanding Climate Adaptation in Agriculture

The ability to anticipate, tolerate, adapt and recover from the negative impacts of climate change is called climate adaptation. This includes implementing policies and practices that improve the ability to cope with climate-related hardships such as extreme weather, rising temperatures, sea level rise, and others. Climate resilient agriculture is critical to protecting livelihoods, food security, biodiversity and infrastructure from the worsening impacts of climate change.

Climate change has substantial impacts on agriculture, due to the disruption of traditional growing seasons and increased frequency of extreme weather events. Rising temperatures, prolonged drought and extreme heat have reduced crop yields and threatened food security. Unpredictable rainfall patterns and more frequent floods that cause soil erosion and reduced agricultural productivity provide difficulties for the production and supply of food around the world. By using resilience measures in various sectors, including agriculture, water management and urban design, societies can reduce vulnerability, reduce economic losses and promote sustainable development. This will ensure a more secure and sustainable future for future generations.

Agricultural technology solutions for climate resilience

1. *Weather forecasting and climate data analysis*

Weather forecasting involves estimating short-term atmospheric variables such as temperature, precipitation, and wind patterns, to aid daily planning and decision making. Computer models are used to analyze meteorological data from satellites, weather stations, and other sources to produce forecasts.

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However, to understand climate variability and change, climate data analysis looks at long-term trends and patterns. To find patterns in temperature, precipitation, and other climate changes, climatologists examine historical data. Using this data, many industries-including agriculture, water resources, and urban planning can better understand the impacts of climate change, develop ways to mitigate its effects, and create policies that are climate-resilient.

2. *Precision farming and smart irrigation systems*

Precision farming is a cutting-edge farming method that maximizes crop yields using technology such as GPS, sensors and drones. Farmers can precisely manage fertilizers, pesticides and irrigation by gathering real-time data on soil conditions, the amount of moisture present and plant health. This reduces wastage and increases productivity.

Similar technology is used by smart irrigation systems to water crops precisely based on their needs, conserving water resources and reducing runoff. These cutting-edge technologies improve resource efficiency, increase yields and support sustainable agriculture, which ultimately helps provide food security and protect the environment.

3. *Crop monitoring and disease detection through Artificial Intelligence (AI)*

Artificial intelligence (AI) and machine learning are used to evaluate and analyze data from multiple sources, including satellite imaging, drones, and sensors for crop monitoring and disease identification. AI algorithms can identify trends, anomalies and disease symptoms in crops at an early stage, enabling farmers to take quick action such as altering irrigation and fertilizer levels or carrying out targeted pest management. By minimizing the use of chemicals and maximizing resource allocation, this technology helps promote sustainable agricultural practices by preventing crop damage, increasing yield predictability, and preventing crop losses.

4. *Sustainable Soil and Nutrient Management*

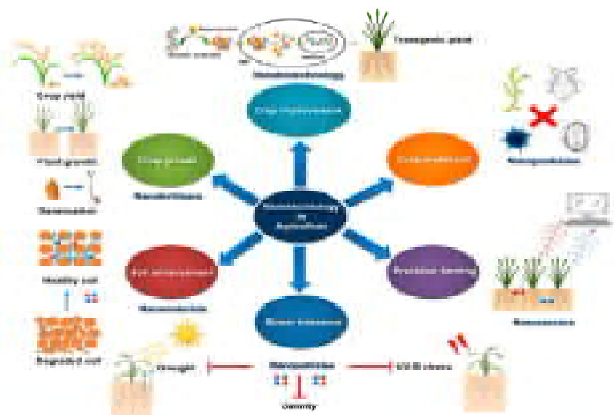
Sustainable methods of managing soil and nutrients are essential to preserving soil health, increasing crop productivity, and promoting environmental protection. To improve soil fertility and structure, this strategy uses techniques such as crop rotation, cover crops, and incorporation of organic matter. Reduce nutrient runoff and pollution by accurately applying nutrients, composting, and reusing organic waste. Farmers can use these sustainable practices to ensure long-term soil productivity, reduce their reliance on synthetic fertilizers, and help mitigate climate change by storing carbon in healthy soils. Technologies such as soil moisture sensors, remote sensing and weather forecasting make it possible to effectively schedule irrigation during drought.

Innovative uses of nanotechnology in agriculture

Nanotechnology is technology operating at the nanoscale, between 1 and 100 nanometers. It is the analysis and application of extremely small things. It can be used in many science related fields, such as chemistry, biology, physics, materials science and engineering. Nanotechnology, due to its extremely small size, has brought multifaceted benefits in the field of agriculture and also helps in farming and agriculture. It has brought with it various applications like nano biosensors, nano fertilizers, nanotube irrigation facilities, nano treatment processes for soil health improvement. Its use in precision farming using nano materials like nano-tubes, nano-biosensors has increased the production in farming. The most important aspects related to agriculture where nanotechnology is applied are: (1) Nano-fertilizers and pesticide delivery. (2) Slow and controlled release of nanoparticles with organic fertilizers to improve soil health. (3) Genetic modification at the nanoscale to increase crop productivity. (4) Use of nano biosensors for rapid detection of pathogens and other disease causing viruses and bacteria.

Nano bioremediation and nanofibers are still under research and development for genetic manipulation of crops, fruits and vegetables. It has shown the way to a promising future for farmers practicing organic farming and genetically modified farming. Nano-biotechnology has been an important area for the Government of India which launched a National Nano Mission in 2007 that looks at the use of nanotechnology in various sectors. Following are some of the strategies devised for sustainable farming using agricultural nanotechnology: (1) Controlled Green Synthesis of Nanoparticles. (2) Understanding of nanoparticles produced by root endophytes and mycorrhizal fungi, which play important roles in plant productivity and disease management. (3)

Interaction of nanoparticles with plant systems such as transport system of nanoparticles inside the plant body. (4) Critical assessment of negative side effects of nanoparticles on different environmental conditions. (5) Development of portable and user-friendly nano-biosensors for rapid analysis of soil, plants, water and pesticides.



Integration of multi-omics and systems biology for innovation

The integration of omics data in crop plant breeding has led to tremendous progress in the development of new crop varieties with desirable traits such as increased yield, improved disease resistance, and increased nutritional value. The integration of diverse omics datasets from different databases provides a comprehensive understanding of the underlying biological processes and interactions affecting plant traits. Machine learning algorithms and multi-omics data integration have emerged as powerful tools to analyze and interpret omics data, enabling the development of predictive models that can accelerate the breeding process and improve the reproductive performance required for traditional breeding methods. Can reduce time and resources. These models can identify genetic factors underlying desirable traits and predict the performance of different varieties under specific environmental conditions, allowing more efficient and effective selection and crossing of plants.

However, integration of omics data faces several challenges, including the vast amount of data generated by different omics technologies, the complexity of integrating multiple omics data sets, and the need for advanced systems biology, computational tools to analyze and interpret these data. and the need for expertise. Additionally, ethical and social considerations associated with the use of omics data in crop breeding cannot be ignored. The development of new crop varieties with desirable traits can have significant impacts on the environment, local communities, and the broader agricultural system. Therefore, transparent and inclusive decision-making processes that involve all stakeholders, including farmers, consumers and policy makers, are essential.

Extension of agricultural technologies to rural communities

The affordability and accessibility of technology are important determinants of how it is adopted across different industries. Successfully integrating traditional and modern farming practices requires a combination of tried and true agricultural knowledge and cutting-edge technology and processes. Farmers can increase production, save resources and promote sustainable agriculture for the future by combining traditional knowledge of regional ecosystems and sustainable practices with contemporary developments in precision farming, irrigation and crop management. If farmers want to improve agricultural practices and production they must receive training and expand their skills. Workshops, courses and extension programs educate students on cutting-edge methods of farming and technology as well as contemporary practice. By giving farmers the necessary knowledge and skills, we can help drive rural development, while also enabling farmers to adapt to changing conditions, increase yields and ensure food security. Promoting accessible information systems and digital literacy is important to empower people and communities in the digital age. This involves providing instruction and training on how to use digital technologies, the Internet, and information resources. People can gain access to important knowledge, educational resources and job prospects by improving their digital literacy. If the digital divide could be eliminated, everyone would be able to participate in the global information economy, make intelligent decisions, and improve their general quality of life. Capacity building and training programs aim to improve the capabilities, skills and knowledge of people and organizations. These courses provide specialized instruction in a variety of subjects, including project management, technical skills, and leadership. Capacity building encourages personal and professional progress, strengthens institutions and promotes sustainable development by providing critical resources and information to participants. These programs are particularly important to empower communities, allowing them to successfully address issues and promote good change in their respective industries.

Conclusion

Tackling the problems caused by climate change and pursuing sustainable agriculture requires a diverse strategy that uses cutting-edge technologies and empowers people. Farmers can promote climate resilience, optimize resource management and increase crop production by integrating agricultural technologies solutions. Initiatives to enhance the capacity of farmers and provide them with the necessary training and knowledge to adapt to the changing environment and use sustainable practices are also important. Increasing information availability and bridging the digital divide empowers communities and supports inclusive growth. The integration of nanotechnology and omics data into crop plant breeding is an important step toward increasing crop productivity and improving global food security. Addressing the challenges associated with integration of omics data will require collaboration and coordination among researchers, policy makers, and stakeholders in the agriculture sector. The benefits of omics data integration in crop breeding are enormous, and it is essential that efforts are made to leverage these technologies for the well-being of humanity. The secret to a more sustainable and resilient future for agriculture and the planet as a whole lies in jointly embracing these ideas.

Regulation in excessive agrochemical usage: Need of Hour

Gunjan Guleria, Anusuiya Panda, Yogeshwar Singh, Shiv Vendra Singh, Garima, Vanpala Alekhya, Praveen H, Pusuluri Pawan Kumar, Ankush Raj

Pesticides encompass various compounds like insecticides, herbicides, rodenticides, etc. India has seen a reduction in pesticide use since 1990, but its high usage still negatively impacts society, leading to pesticide poisoning and diseases. The World Health Organization and the United Nations estimate around 1 million cases of human pesticide poisoning globally annually, resulting in 20,000 deaths. Although developing countries use only 20% of pesticides worldwide, they experience a majority of pesticide-induced deaths due to inadequate safety measures, enforcement of standards, and knowledge about the dangers of pesticides. To minimize risks, it is essential to follow safety precautions like wearing protective clothing, reading labels for toxicity awareness, and disposing of chemicals properly. If pesticide exposure occurs, seek medical help immediately and dispose of chemical containers in a designated area, not in ditches or ponds.

Introduction

Pesticides include a wide range of compounds, including, insecticides, fungicides, herbicides, rodenticides, mollsucicides, nematicides, plant growth regulators, and others. More than half of the pesticides used globally are in Asia. India ranks 12th globally in pesticide use and third in Asia after China and Turkey. In the present study, different types of pesticides in India and the world, pesticide use patterns and detailed pesticide consumption data were collected, organized and summarized. About 70% of the total population is employed under the agriculture sector which is the most important sector of the Indian economy. Pesticides and fertilizers are major integral parts of modern agriculture. India's share in global pesticide use is only 1%. Ideally a pesticide should be fatal to targeted insects, but not to species, including humans. Unfortunately, this is not the case, hence the controversy over the use and misuse of pesticides. Under the saying, "If a little is good, a lot will be better" is the large-scale use of these chemicals has played with humans and other life forms. It is evident that India uses small quantities of pesticides per hectare cropland area, but uncontrolled and haphazard pesticide use is responsible for the presence of high pesticide residues in both natural and physical environments. In India, the main use of pesticides is for cotton crop (45%), followed by paddy and wheat. Pesticides threaten 64% of the world's land. In seven decades, the consumption of pesticides has increased 45 times. They are harming human health and the environment. The amount of pesticides is also being used in the production of cereals and vegetables, due to which many types of diseases are spreading among people. About 3 million pesticides are used in farms globally. A large percentage of these seep into the ground, which damages the earth as well as harms our health.

Use of pesticides

In India the consumption of pesticides per hectare is the lowest in the world at 1 kg/hectare, while in the UK it is 5-7 kg/hectare and in China 13 kg/hectare. In India, about 40% of the total cultivated land is treated with pesticides and about 65-70% of the cultivated land treated with pesticides is irrigated. Since 1990 to 2021, in India, an average of 65% of fiber crop area is treated with pesticides, followed by fruits (50%), vegetables (46%), spices (43%), oilseeds (28%) and pulses (23%). In India herbicides are used 10%, insecticides 76%, fungicides 13% and worldwide herbicides are used 30%, insecticides 44%, fungicides 21%. (Koli and Bhardwaj, 2018). Fig. 2 shows that Brazil was the world's largest user of pesticides in 2021. This was close to United States of America, the second largest user. The next three users – Indonesia, China, Argentina– all had similar applications levels. Among different countries India is one of the country in which pesticides use is reduced since 1990 to 2021 but still pesticide use is very high in India which is affecting Indian community (Fig. 2). Some of the examples of countries which reduced pesticide use since 1990 till 2021 are India (-18%), Sweden (-20%), Switzerland (-1%) etc. Some of the examples of countries which increased the pesticide use since 1990 till 2021 are Brazil (+1,307%), China (+62%), Americas (+191%), Europe (+1%), Bangladesh (+1,125%), Australia +255%, Sri Lanka (+157%) (FAO Stat, 2023).

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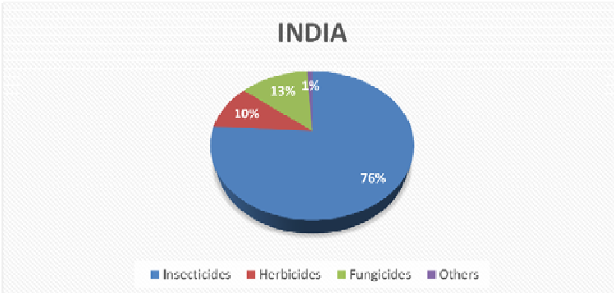
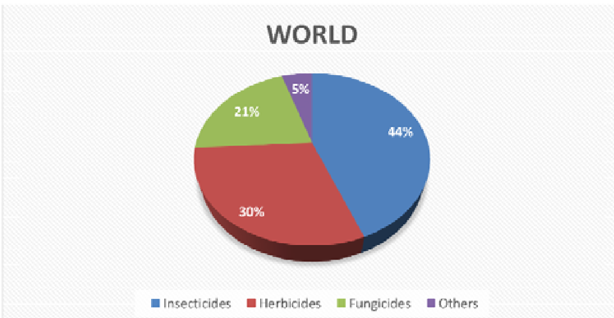


(a)



(b)

Fig.1(a) Pesticides use in India & (b) Pesticides use in World

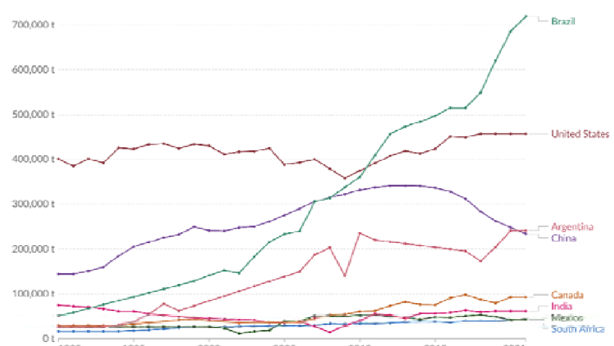


Fig. 2: Pesticide use, 1990 to 2021 (Tonnes of pesticide consumption per year)

Source: Food and Agriculture Organization of the United Nations (2024)

Effects of pesticides

1. The highest price is being paid for human pesticide poisoning and diseases.| Currently the World Health Organization and the United Nations - Report estimates that there are 1 million cases of human pesticide poisoning in the world every year, and there are about 20,000 deaths.

2. Although developing countries use only about 20% of all pesticides. Most pesticide-induced deaths in the world occur there. Often in developing countries, inadequate occupational and other safety, inadequate enforcement of standards, poor labeling of pesticides, illiteracy, inadequate protective clothing and facilities for workers and generally laundry facilities are insufficient knowledge of the dangers of pesticides.

3. Widespread and unscientific use of agrochemicals results in serious health effects of pesticide residues in food products. For humans and animals, although agriculture has an impact on the environment and human health, chemicals are reported from all over the world, the effects are comparatively greater. In developing economies, serious disclosures have long-term and acute health impacts.

4. Through runoff from treated plants and soil, pesticides can reach surface water.

Precautions required for the safe use of pesticides

- The label in the container should be carefully read and aware of the toxicity.
- Chemicals should also be sprayed to control pests or weeds when the loss in crop yield is economically visible.
- Read the procedure of using the sprinkler properly and use the appropriate spray water according to the problem.
- Before making the solution, wear rubber gloves in hands, shoes on feet, rubber coat, glasses and gas masks if necessary.
- Wood should be used to make the solution and any part of the wounded body should be washed thoroughly with water.
- After spraying, remove any pesticides left in the tank and expose them to the chemical. Do not attempt to clean the sprayer nozzle from the mouth.
- Ensure that appropriate protective clothing is available at the site of chemical spraying.
- Chemical Protective Clothing/Use equipment such as eye tools, gloves, shoes/gumboots, masks, aprons, coats, etc.
- When using agrochemicals, if the effect is on the body, immediately go to the doctor and take the chemical container with you.
- It should be thrown into pits dug on wasteland.
- Never empty the tank in irrigation canals or ponds.

Conclusion

In the agricultural environment leading to modernity *viz.*, farmers use fertilizers, pesticides and other chemicals for good crop yield. Care should be taken in their use, otherwise it, causes many problems by reaching the body through breathing, skin or food. Many chemicals cause irritation in the skin of hands and feet, blisters or sores. There are also some chemicals that release gas that can enter the body and cause irritation in the eyes, nose, and mouth. It can also cause nervousness, fainting and suffocation due to excessive burning. In order to assess the fate of a pesticide in a soil environment, the dynamics of individual processes as well as- the combined effects of all processes must be assessed. The fate of pesticides in the environment is controlled by retention, transformation and transport processes and the interaction of these processes. Just as transformation processes determine how long pesticides can remain in the environment, transport processes determine where pesticides are located. Because pesticides are toxic, there is natural concern about the impact of their presence in the environment on human health and environmental quality. The fate of a pesticide determines its availability and effectiveness for pest control, as well as its potential adverse effects on organisms and other environmental components.

Agri-Innovation

1. **Captive maturation, induced breeding and larval rearing of grey mullet Mugil Cephalus by** Dr. A.S. M. Kailasam, *et al.*, ICAR- Central Institute of Brackish water Aquaculture Chennai

   Captive reproduction of grey mullet Mugil Cephalus is standardized using broodstocks conditioned in a tank system on the east coast and using farm-reared broodstock on the west coast and have completed the fry production.

2. **DDW55 (Karan Manjari):** Biofortified durum wheat variety ICAR-Indian Institute of Wheat & Barley Research, Karnal

   Recommended for Madhya Pradesh, Gujarat, Rajasthan and Chhattisgarh. Average yield: 35.6 q/ha. Yield potential: 56.5 q/ha. Zinc content in cereals: 43.3 ppm Pasta score: 6.3/10 Title: 64 days. Weight of thousand grains: 52.0 g, number of irrigations required: 1-2. Maturity: 116 days Plant height: 82. DW55 is a bold seeded variety that has excellent pasta forming quality and is highly tolerant to the stress of housing, heat and drought.

3. **NINFET Sathi: Accelerated Retting Technology of Jute by** Dr. Deb Prasad Ray, *et al.*, ICAR-National Institute of Natural Fiber Engineering and Technology Kolkata

   NINFET-Sathi has revolutionized the concept of jute retting at the farmer's level by producing 8-10.5% higher yield and 1-1.5 grade improvement within 10-12 days over the conventional retting of 20-25 days without affecting the environmental components. By adopting the technology, farmers can generate an additional income of Rs. 16,000 to Rs. 20,000/- per ha. Over 50000 farmers covering 12000 ha under jute cultivation across various jute growing areas of West Bengal, Bihar, Assam, Odisha and Andhra Pradesh have adopted the technology during 2020-23.

4. **Mustard: Pusa Double Zero Mustard 33 by** Dr. A.S. D. K. Yadav, *et al.*, ICAR-Indian Agricultural Research Institute, New Delhi

   Indole quality [Low in erucic acid (0.58% in oil) and glucosinolates (15.17 ppm in seed meal) in comparison to >40.0 % erucic acid and >120.0 ppm glucosinolates in popular varieties]. Seed yield: 26.4 q/ha. Oil content: 38.0%. Maturity: 141 days. Suitable for Rajasthan (North and Western parts), Punjab, Haryana, Delhi, Western Uttar Pradesh Plains of Jammu & Kashmir and Himachal Pradesh.

5. **Genetically improved freshwater prawn Macro brachium rosenbergii, 'CIFA-GI Scampi' 13 Gen by** Dr Bindu R Pillai, *et al.*, ICAR- CIFA, Bhubaneswar

   CIFA-GI SCAMPI is a genetically improved and fast-growing strain of freshwater prawn *Macrobrachium rosenbergii* developed through selective breeding. The average daily growth recorded in the farmer's field was 0.26g/day. This fast-growing strain of scampi could help the farmers in getting higher production and income, as it has exhibited 53% higher cumulative growth and 68% higher yield compared to non-GI scampi after 13th generation. Multi-location performance trials of GI scampi in carp-scampi polyculture system were evaluated in farmers' ponds in Odisha, West Bengal, and AP during 2021 and 2022. In 2021-2022 themselves, the scampi production in the country has shown a remarkable 2.5-fold increase from 8,303 to 21,317 t.

6. AI-DISC (Artificial Intelligence-based Disease Identification System for Crops) by Dr. Sudeep Marwaha, et al., ICAR-Indian Agricultural Statistics Research Institute, New Delhi

   AI-DISC has a user-friendly Android-based user interface for the stakeholders. Automatic image-based detection of diseases of crops using highly optimized Al-based models. Identifies 50 diseases across 19 major crops. Crop protection-related advisory for the respective identified disease as prescribed by the domain experts of the participating universities. The decisions are derived from the model developed based on 1.5 lakhs images of crop diseases in natural background stored in the national plant disease image repository.

7. **Button Mushroom Variety NBS 5-59 by** Dr. Shwet Kamal, *et al.*, ICAR -Directorate of Mushroom Research, Solan

   High yielding. Pure white. Browning resistant. Very thin gill. Late gill opening. High dry weight

8. **Wheat: DBW 327** by Dr. CN Mishra *et al.*, ICAR-Indian Institute of Wheat & Barley Research, Karnal

Contains high zinc (40.6 ppm) in comparison to 30.0-32.0 ppm zinc in popular varieties. Average grain yield: 79.4 q/ha. Maturity: 155 days. Suitable for early sown irrigated conditions in rabi. Suitable for Punjab, Haryana, Delhi, Rajasthan Western Uttar Pradesh (excluding Kota & Udaipur division) (except Jhansi division). Jammu and Kathua district of Jammu & Kashmir, Paonta Valley and Una district of Himachal Pradesh and Tarai region of Uttarakhand.

9. **Women Friendly Multipurpose Integrated Vertical Nutri-Farming System (IVNFS) for Vegetable Production with Mushroom and Poultry by** Dr. Tania Seth *et al.*, ICAR-Central Institute for Women in Agriculture, Bhubaneswar

   The IVNFS model is a low cost, durable structure of iron that can be used for round the year vegetable cultivation, mushroom cultivation and poultry rearing. The vertical farming approach provided opportunity to grow multiple commodities in a single structure and limited space.

10. **DNA barcode, multiplex PCR and qPCR assay for diagnosis of pathogens infecting pulse crops to facilitate safe exchange and healthy conservation of germplasm** by Dr. Aradhika Tripathi, *et al.*, ICAR-National Bureau of Plant Genetic Resources, New Delhi

    Highly sensitive and specific multiplex PCR and PCR protocol for the rapid detection of *A. alternata, F. oxysporumf sp. ciceris, R. solani*, causing diseases in pulse crops. The DNA barcodes and diagnostics developed are suitable for quick and reliable detection of these pathogens during quarantine processing and field diagnostics.

11. **Inactivated low pathogenic avian influenza (H9N2) vaccine for Chickens by** Dr. C. Tosh, et al. ICAR-National Institute of High Security Animal Diseases, Bhopal

    First indigenously developed low pathogenic avian influenza (H9N2) vaccine in India. Passed the sterility, safety and efficacy testing in experimental trials in SPF and laboratory conditions. The vaccine is effective for control of the infections with H9N2 in chickens.

12. **DBW316 (Karan Prema) by** ICAR-Indian Institute of Wheat & Barley Research, Karnal

    A New wheat variety from ICAR-Indian Institute of Wheat & Barley Research, Karnal. DBW 316 (Karan Prema), is a new high yielding bread wheat variety released for cultivation under late sown conditions in North Eastern Plain Zones (NEPZ) which covers ‘Eastern Uttar Pradesh, Bihar, Jharkhand, Orissa, West Bengal, Assam and Plains of North-Eastern States. DBW 316 is tolerant to terminal heat stress, wheat rusts, wheat blast and foliar blights. DBW 316 has high end-use quality for chapati, bread with high protein content (13.2%), high bread loaf volume (593 ml). Recorded potential yield level of 68 q/ha with av. yield of 41 q/ha under late sown conditions.

13. **Karan Varuna (DBW372) by** ICAR-Indian Institute of Wheat and Barley Research, Karnal

    A New wheat variety from ICAR-Indian Institute of Wheat and Barley Research, Karnal. This variety is recommended for cultivation under irrigated early sown conditions of NWPZ covering states of Punjab, Haryana, Delhi, Rajasthan (except Kota & Udaipur divisions) and Western Uttar Pradesh (except Jhansi division), parts of Jammu & Kashmir (Jammu & Kathua distt.) and parts of Himachal Pradesh (Una dist. & Paonta valley) and Uttaranchal (Tarai region). It has shown yield potential of 84.9g/ha with average yield 75.3 q/ha across states and years. Being a high input responsive genotype it performed better under early sown conditions. DBW372 has high protein content (12.2%), high bread loaf volume (540ml), high biscuit spread factor (8.2) & high grain zinc content (40.8 ppm).

14. **Karan Vrinda (DBW371) by** ICAR-Indian Institute of Wheat & Barley Research, Karnal

    New Wheat variety developed by ICAR-Indian Institute of Wheat & Barley Research, Karnal. Recommended for cultivation under irrigated early sown conditions of NWPZ covering the states of Punjab, Haryana, Delhi, Rajasthan (except Kota & Udaipur divisions) & Western Uttar Pradesh (except Jhansi division), parts of Jammu & Kashmir (Jammu & Kathua distt.) & parts of Himachal Pradesh (Una dist. And Paonta valley) and Uttaranchal (Tarai region). The average yield of DBW 371 is 75.9 q/ha and being a high input responsive genotype it performs better under early sown conditions. Bolder grains (46gTKW), lowest phenol content (2.8), high protein content (12.2%) high grain Fe (45ppm) and Zn (40ppm) content.

15. Sree Hira

A new elite variety of taro for Odisha. Sree Hira, a new elite taro (*Colocasia esculenta* (L.) Schott.) variety suitable for rainfed upland & irrigated medium and lowland conditions of Odisha Bhubaneswar is developed by the Regional Station, ICAR-CTCRI, Bhubaneswar. The variety is a clonal selection, the plants are semi-erect, medium plant type with green petioles and leaf blades. It is tolerant to taro leaf blight disease. It bears 12-16 cormels per plant which are long elliptical with plant v brown skin and white flesh colour with good palatability, mealiness, and aroma. The average weight of each cormel is 60-100 g. The cormel yield is 16-20 t/ha, with maturity at 180 days after planting. The farmers can get a net return of Rs 2.5-2.7 lakhs/ha by cultivating Sree Hira.

(Source: ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram)

16. Karan Vaidehi (DBW370) New Wheat Variety Developed by ICAR-Indian Institute of Wheat & Barley Research Karnal

Recommended for cultivation under irrigated early sown conditions of NWPZ covering states of Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions) and Western Uttar Pradesh (except Jhansi division), parts of Jammu & Kashmir (Jammu and Kathua distt.) and parts of Himachal Pradesh (Una dist. and Paonta valley) and Uttaranchal (Tarai region). The average yield 74.9 q/ha, moderate plant height (99 cm), bolder grains (41gTKW) and matures in 150 days. Best chapati quality score (8.3/10), lower phenol content (3.6), high protein content (12.0%), and high biscuit spread factor (8.2).

Compiled by: **Dr Govind Vishwakarma**
TRA, Fruit Science

Swachh Bharat Abhiyan

स्वच्छ भारत

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ORGANIC FARMING GAINS MOMENTUM

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