INTEGRATED PLANT NUTRITION MANAGEMENT PRACTICES

Paving the Path to Resilient Agriculture

Abstract

INM practices play a pivotal role in modern agriculture by enhancing soil health, conserving resources, and ensuring food security. Embracing INM principles is critical for sustainable and resilient farming systems.

INM Devision

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Unlocking Agricultural Sustainability: The Power of Integrated Nutrition Management (INM)

Integrated Nutrient Management (INM) is a holistic approach to maintaining soil fertility and plant nutrient supply at optimal levels to sustain desired crop productivity. This practice involves combining various sources of plant nutrients in an integrated manner, aiming to enhance agricultural productivity, promote soil health, and mitigate environmental concerns. INM is a vital component of modern agricultural practices, addressing challenges such as declining factor productivity, escalating input costs, soil degradation, and environmental issues. By fostering a harmonious balance between chemical fertilizers and organic sources, INM contributes to sustainable agricultural systems, making it a cornerstone of environmentally conscious farming.

INM stands as a beacon of sustainable agriculture, redefining the way we approach crop cultivation, soil health, and ecological harmony. INM is a comprehensive strategy that optimizes soil fertility and plant nutrient supply through a harmonious blend of diverse nutrient sources. In an age marked by evolving environmental challenges and shifting agricultural paradigms, INM emerges as a vital tool in fostering productivity while safeguarding our precious ecosystems.

At its core, INM seeks to strike an equilibrium between crop productivity and ecological well-being. It emphasizes the integration of chemical fertilizers, organic manure, biofertilizer and other natural sources to achieve optimal nutrient balance. By minimizing the excessive use of chemical fertilizers, INM offers a pathway to environmental sustainability. This approach embodies the ethos of good agricultural practices, nurturing soil health, sustaining agricultural output, and enhancing the resilience of farming communities.

1. Soil Health Challenges

The decline in nutrient use efficiency and agricultural productivity is a direct consequence of deteriorating soil health. Climate change further exacerbates this situation. Soil health is essential for retaining and releasing water and nutrients, supporting root growth, maintaining a healthy biotic habitat, resisting degradation, and mitigating environmental pollution.

- **Low Soil Organic Carbon:** A shortage of organic carbon in Indian soils hampers soil vitality. Incorporating organic manures or compost enhances soil organic carbon, vital for nutrient cycling, carbon sequestration, and soil structure improvement. Balanced fertilization can elevate soil organic carbon by 6 to 100% and boost carbon sequestration by 20-600 kg ha-1 yr-1, depending on soil, crop, and climate.
- **Imbalanced Nutrient Use:** India's nutrient ratio (6.5:2.4:1.1) deviates from the ideal (4:2:1). Nutrient deficiencies have emerged due to continuous nutrient mining, inadequate organic manure addition, and micronutrient scarcities. This imbalance impedes fertilizer response and crop productivity, leading to a worrisome decline in fertilizer response ratio over the years.
- **Low Nutrient Use Efficiency:** Nutrient use efficiency in Indian soils is suboptimal, ranging from 30-50% (N), 15-20% (P), 60-70% (K), 8-10% (S), and 1-2% (micronutrients). Unutilized nitrogen leads to groundwater pollution, while P and K losses occur through soil erosion.

2. Importance of INM: Enhancing Sustainability and Soil Health

INM is a response to the challenge of sustaining agricultural productivity amidst increasing constraints. Long-term studies, particularly in India, have underscored the benefits of integrating chemical fertilizers with organic manure and biofertilizers . This approach not only boosts productivity but also lends stability to crop production. Furthermore, INM contributes to soil quality improvement by acting as a source of energy, organic carbon, and available nitrogen for soil microbes. This, in turn, enhances soil microbial activity and nutrient cycling, thus improving overall soil health.

2.1 Elevating Soil Health:

Long-term studies conducted in India have spotlighted the transformative potential of INM. The synergistic use of chemical fertilizers, organic manure, FOM and biofertilizers not only elevates crop productivity but also nurtures soil health. As a source of energy, organic carbon, and available nitrogen, INM fosters the growth of beneficial soil microorganisms. This, in turn, enriches soil quality and promotes a robust ecosystem within the soil. The enduring effects of INM ripple through subsequent crop cycles, amplifying its positive impact over time.

2.2 Balancing Ecology and Economics:

INM's effectiveness lies in its ability to harmonize economic viability with environmental stewardship. By combining nutrient sources and optimizing their utilization, INM strikes a delicate balance. This not only enhances yield and profitability but also reduces the environmental burden arising from excessive chemical fertilizer use. The practice encourages the recycling of agricultural waste, reducing pollution and conserving resources—a win-win for both farmers and the planet.

2.3 Resilience in Action:

Coordinated efforts by the Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) have illuminated INM's potential. Balanced fertilizer application, such as 100% NPK+FYM+ FOM/LFOM, emerges as a linchpin in sustaining soil quality and productivity. The detrimental impact of relying solely on urea becomes evident, underlining the need for a holistic nutrient management approach. From reutilizing phosphorus to addressing specific nutrient deficiencies, INM adapts to diverse agro-ecological contexts, contributing to a resilient agricultural landscape.

2.4 Elevating Nutritional Profiles

Integrated Nutrient Management (INM) extends its prowess to the realm of nutrition. Notably, the cultivation of finger millet grains showcases INM's power to enhance the content of calcium, magnesium, and crude proteins—essentials for human health.

2.5 Towards a Greener Tomorrow:

INM does not stop at enhancing crop yields; it extends its benefits to the environment as well. Through soil carbon sequestration, INM combats climate change and fosters a more sustainable future. Its ability to reduce greenhouse gas emissions while ensuring productive yields positions INM as a potent ally in addressing the challenges of our time.

3. Key Goals of INM: Achieving Balance and Eco-Friendly Practices

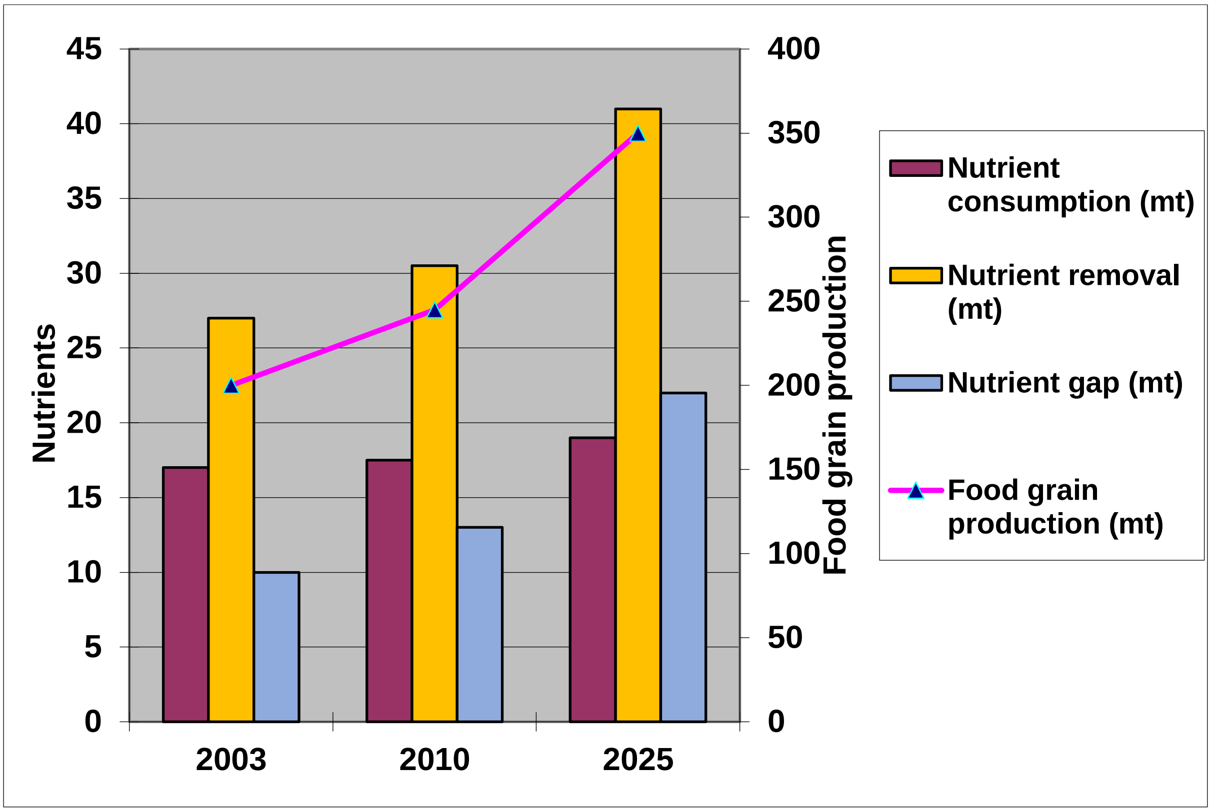
The central aim of INM is to establish an ecologically sound practice by leveraging the synergistic properties of chemical fertilizers and organic sources. By creating a judicious combination of these inputs, INM seeks to reduce the excessive use of chemical fertilizers while ensuring soil fertility, optimizing yields, maximizing profitability, and minimizing environmental pollution through agricultural waste recycling.

3.1 Balancing Nutrient Inputs:

A primary goal of INM is to strike a balance between the application of chemical fertilizers and organic nutrient sources. The overreliance on chemical fertilizers can lead to soil degradation, nutrient imbalances, and environmental pollution. The graph presented below, covering the years from 2003 to 2025, provides essential insights into the dynamics of fertilizer consumption, nutrient removal, nutrient gap, and food grain production. Let's break down these terms and their significance:

Figure 1

Fertilizer consumption and food grain production



3.1.1 Fertilizer Consumption: This refers to the quantity of fertilizers, including major nutrients like nitrogen (N), phosphorus (P), and potassium (K), that are applied to agricultural fields. It's measured in metric tons (mt). Fertilizers are crucial for providing essential nutrients to crops, enhancing their growth, and ultimately increasing agricultural productivity.

3.1.2 Nutrient Removal: Nutrient removal represents the actual amount of nutrients (N, P, and K) taken up by crops during their growth cycle. It's also measured in metric tons (mt). This metric is vital because it indicates the nutrients that are depleted from the soil due to crop cultivation.

3.1.3 Nutrient Gap: The nutrient gap is the difference between nutrient consumption and nutrient removal. In other words, it quantifies the shortfall or excess of nutrients applied compared to what crops actually utilize. If the nutrient gap is positive, it suggests over-application of nutrients, while a negative gap indicates a deficiency in nutrient supply.

3.1.4 Food Grain Production: This metric measures the total production of food grains, typically in metric tons (mt). Food grains are a staple source of nutrition for billions of people worldwide, making this an essential component of agricultural output.

Here's a detailed analysis of the graph from 2003 to 2025:

- **Fertilizer Consumption (Nutrient Consumption in mt):** The graph shows a progressive increase in fertilizer consumption over the years, from approximately 150 mt in 2003 to around 400 mt in 2025. This upward trend signifies the growing reliance on fertilizers to meet the nutrient demands of crops.
- **Nutrient Removal (Nutrient Removal in mt):** In parallel with fertilizer consumption, nutrient removal also experiences a steady rise. In 2003, nutrient removal was around 250 mt, and by 2025, it reaches roughly 400 mt. This demonstrates that crops are absorbing more nutrients from the soil due to increased agricultural productivity.
- **Nutrient Gap (Nutrient Gap in mt):** The nutrient gap is the disparity between nutrient consumption and nutrient removal. In 2003, the nutrient gap was about 100 mt, indicating a surplus of nutrients in the soil. However, as the years progress, this gap narrows and even turns negative, signifying that the nutrient supply falls short of what crops require. By 2025, the nutrient gap is nearly -50 mt, emphasizing the need for more precise nutrient management to maintain soil fertility and crop productivity.
- **Food Grain Production (Food Grain Production in mt):** Food grain production steadily climbs from approximately 150 mt in 2003 to over 350 mt in 2025. This substantial increase reflects the growing importance of agriculture in sustaining food security as the global population continues to rise.

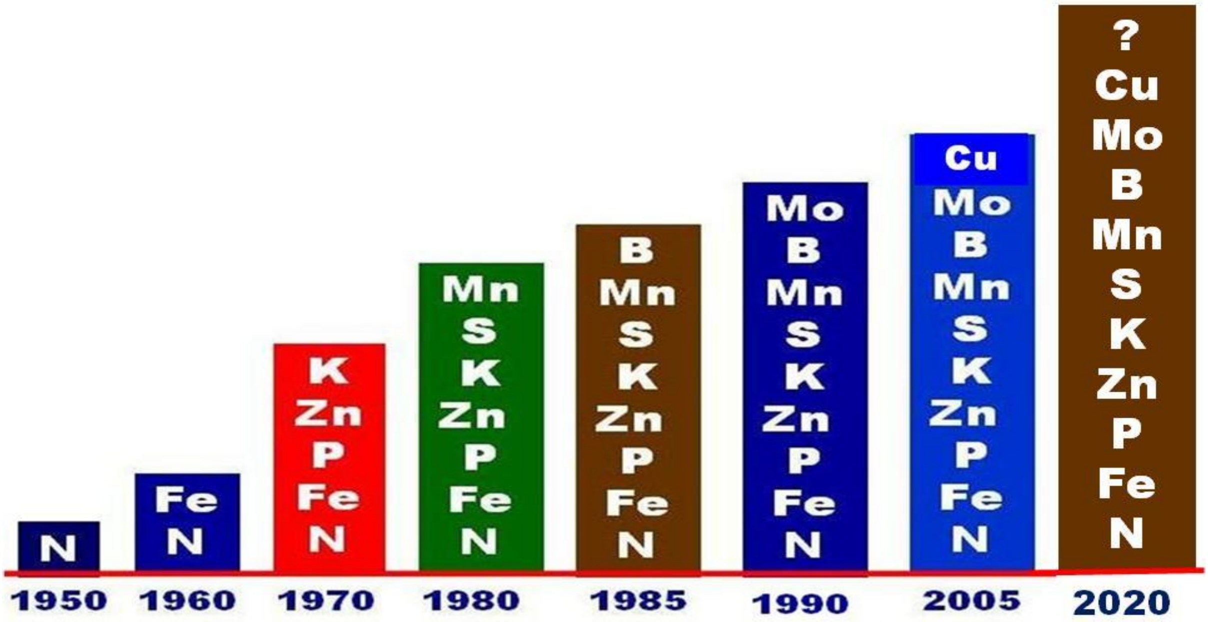
The graph illustrates the critical relationship between fertilizer consumption, nutrient removal, nutrient gap, and food grain production. While increased fertilizer usage has led to higher crop yields, it's essential to address the nutrient gap to ensure sustainable agriculture. Careful nutrient management practices are crucial for maintaining soil health, maximizing crop productivity, and meeting the food demands of a growing world population. INM emphasizes the judicious integration of diverse nutrient sources, reducing the excessive use of chemical fertilizers while harnessing the benefits of organic manures, green manures, and biofertilizers.

3.2 Enhancing Soil Health:

INM's overarching goal is to improve soil health by fostering an environment conducive to beneficial soil microorganisms and nutrient availability. **The progressive expansion of nutrient deficiencies** underscores the urgent need for a multifaceted approach to soil and nutrient management in Indian agriculture. This includes promoting of balanced fertilizer and use of Organic sources, such as organic manures and green manures, conducting widespread soil testing, encouraging sustainable farming practices, and advocating for policies that prioritize long-term soil health. Addressing nutrient deficiencies is not only vital for sustaining agricultural productivity but also for ensuring food security and the well-being of India's rural communities.

Figure 2

Progressive expansion in the occurrence of nutrient deficiencies in India between 1950 to 2020



The figure 2 graph depicting the progressive expansion in the occurrence of nutrient deficiencies in India from 1950 to 2020 illustrates a critical trend in the country's agriculture. The graph covers a span of seven decades, from 1950 to 2020, providing a long-term perspective on nutrient deficiencies in Indian soils. This historical context is crucial for understanding how agricultural practices and policies have evolved over time.

The graph shows a steady and concerning increase in the occurrence of nutrient deficiencies in Indian soils during this period. Nutrient deficiencies refer to inadequate levels of essential elements like nitrogen (N), phosphorus (P), potassium (K), and various micronutrients (e.g., iron, zinc, manganese) necessary for plant growth. This implies that soils are becoming progressively depleted in vital nutrients such as nitrogen (N), phosphorus (P), potassium (K), and possibly micro and secondary nutrients like iron (Fe), zinc (Zn), manganese (Mn), and others.

Nutrient deficiencies can have a detrimental impact on agriculture. They lead to reduced crop yields, poor crop quality, increased vulnerability to pests and diseases, and lower overall agricultural productivity. This, in turn, affects food security and the livelihoods of millions of farmers

To address this growing problem and sustain agricultural productivity, the use of micro and secondary nutrients alongside major nutrients is deemed essential. This emphasizes the need for a balanced approach to nutrient management. While major nutrients are critical, the inclusion of micro and secondary nutrients becomes crucial in preventing deficiencies and maintaining soil fertility.

The primary goal of addressing these nutrient deficiencies is to sustain agricultural productivity. Soil nutrient deficiencies can lead to reduced crop yields, poor crop quality, and, ultimately, food insecurity. By taking measures to correct nutrient imbalances, such as applying appropriate fertilizers and soil amendments, India can safeguard its agricultural output and ensure a stable food supply.

3.3 Minimizing Environmental Impact:

Eco-friendliness lies at the core of INM's objectives. The excessive use of chemical fertilizers can result in soil and water pollution, negatively impacting ecosystems and human health. By integrating organic sources and reducing chemical inputs, INM mitigates the release of harmful pollutants, conserving water quality and maintaining a healthy environment.

3.4 Sustaining Agricultural Productivity:

INM aims to ensure sustainable agricultural productivity by maintaining soil fertility and optimizing nutrient availability. The judicious use of nutrient sources prevents soil exhaustion and nutrient imbalances that can lead to yield fluctuations. By nurturing soil health, INM supports consistent and reliable crop yields, contributing to food security and economic stability.

3.5 Resilience to Climate Change:

As climate patterns shift, agriculture faces new challenges. INM offers a strategy to enhance crop resilience through improved soil quality. Organic sources incorporated in INM, such as organic manures and cover crops, increase the soil's water-holding capacity and nutrient retention, making crops more resilient to water stress and extreme weather events.

4. Strategies for Enhanced Nutrient Management:

4.1 Soil Testing: Accurate soil testing is fundamental for prescribing optimal nutrient quantities. Portable digital soil test kits supplement traditional testing, aiding distribution of soil health cards, fertilizer recommendations, and geo-referenced soil fertility maps.

4.2 Balanced & Integrated Nutrient Management: Long-Term Fertilizer Experiments reveal the superiority of balanced nutrient applications with organic manures in enhancing soil quality and yield sustainability. Balanced NPK application, conjunctive nutrient use, and sole organic nutrient treatments outperform chemical fertilization.

4.3 Organic, Liquid Fermented and Bio Fertilizers: Technologies for producing organic manures and effective biofertilizers promote nutrient-rich soil and improved plant health. Biofertilizers increase productivity, reduce chemical fertilizer usage, and enhance nutrient use efficiency by 15-25%.

4.4 Crop Residue Recycling: Incorporating crop residues into the soil prevents adverse impacts on soil quality and sustains production systems. Inclusion of rice residue and FYM is particularly promising for maintaining soil organic carbon and system sustainability.

4.5 Nutrient Use Efficiency Enhancement: Adhering to the 5R approach (right kind, rate, time, place, and method of fertilizer application) optimizes nutrient use efficiency. Additional tools like leaf color charts, nitrification inhibitors, and slow-release fertilizers further contribute to efficiency.

5. The Role of Balanced fertilization

The vitality of soil in sustaining life on Earth is undeniable. The intricate relationship between soil health and human health underscores the importance of balanced fertilization for sustainable agricultural productivity. This note delves into the significance of organic manure, farm yard manure, fermented organic manure and liquid fermented organic manure and its impact on soil quality, nutrient use efficiency, and agricultural sustainability.

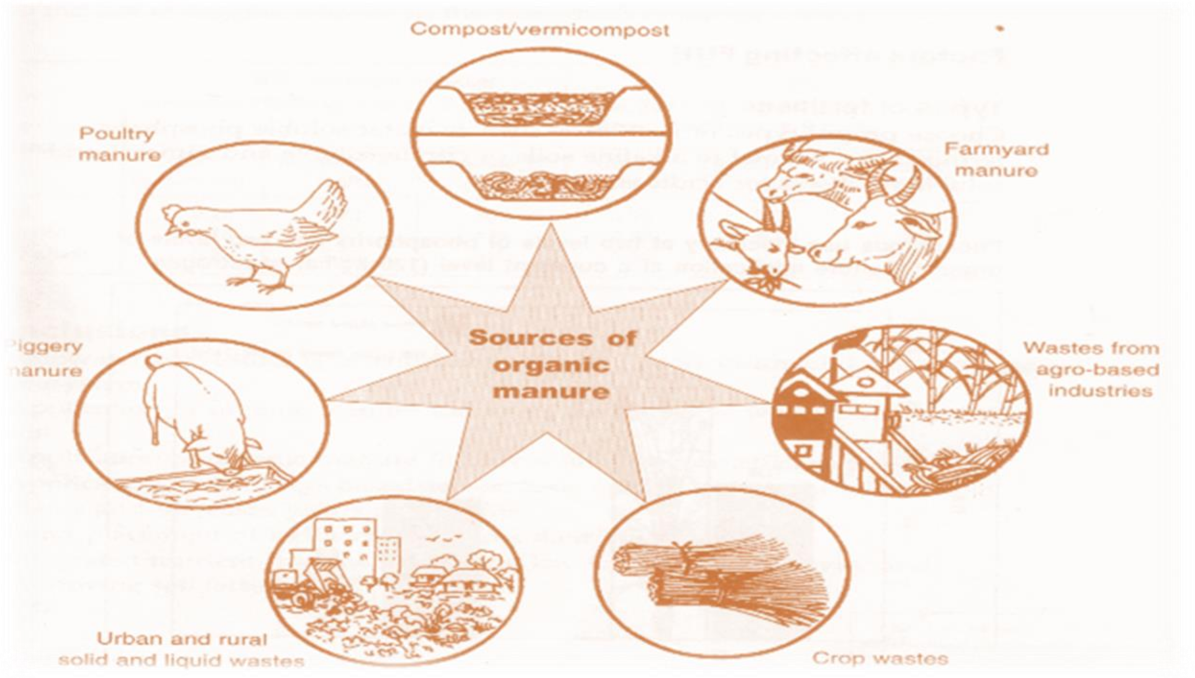
5.1 Introduction of Organic Manure

Organic manures are essential components of sustainable agriculture. They are derived from organic materials, typically of plant or animal origin, and serve as valuable sources of nutrients for crops. These manures not only provide essential nutrients but also improve soil structure, enhance microbial activity, and contribute to long-term soil fertility.

Key Organic Manure Sources: Here are some of the key organic manures with its primary and micro nutrients value:

Figure 3

DIFFERENT SOURCES OF ORGANIC MANURE FOR INTEGRATED NUTRIENT MANAGEMENT



5.1.1 **FYM (Farm Yard Manure):**

- Primary Nutrients (%): N (1.00), P (0.54), K (0.90)
- Micronutrients (mg/kg): Fe (2600), Zn (57), Mn (250), Cu (2.5), B (2.1), Mo (0.7)

5.1.2 **Pig Manure:**

- Primary Nutrients (%): N (1.88), P (2.13), K (0.67)
- Micronutrients (mg/kg): Fe (1200), Zn (50), Mn (70), Cu (8.9)

5.1.3 **Poultry Manure:**

- Primary Nutrients (%): N (1.89), P (1.90), K (1.60)
- Micronutrients (mg/kg): Fe (1400), Zn (90), Mn (210), Cu (7.1), B (5.0)

5.1.4 **Goat/Sheep Manure:**

- Primary Nutrients (%): N (0.65), P (0.50), K (0.03)
- Micronutrients (mg/kg): Fe (2570), Zn (150), Mn (61), Cu (4600)

5.1.5 **City Compost:**

- Primary Nutrients (%): N (1.50), P (0.50), K (1.00)

- Micronutrients: Fe (400), Zn (560), Mn (150), Cu (15), B (9)

5.1.6 **Sewage Sludge:**

- Primary Nutrients (%): N (2.40), P (1.20), K (0.002)
- Micronutrients: Fe (2459), Zn (262), Mn (643), Cu (9), B (0.6)

5.1.7 **Press Mud:**

- Primary Nutrients (%): N (1.20), P (1.96), K (2.20)
- Micronutrients (mg/kg): Fe (1140), Zn (94), Mn (450)

5.1.8 **Green Manure (Sesbania):**

- Primary Nutrients (%): N (2.25), P (0.37), K (140)
- Micronutrients (mg/kg): Fe (17), Zn (80), Mn (3.2), Cu (20), B (0.2)

5.1.9 **Azolla:**

- Primary Nutrients (%): N (4.03), P (0.29), K (1.70)

Table 1

Average nutrient content of organic manures

Organic Manure	Primary nutrients (%)			Micronutrients (mg/kg)					
	N	P	K	Fe	Zn	Mn	Cu	B	Mo
FYM	1.00	0.54	0.90	2600	57	250	2.5	2.1	0.7
Pig	1.88	2.13	0.67	1200	50	70	8.9	-	-
Poultry	1.89	1.90	1.60	1400	90	210	7.1	5.0	-
Goat / sheep	0.65	0.50	0.03	-	2570	150	61	4600	-
City compost	1.50	0.50	1.00	-	400	560	150	15	9
Sewage sludge	2.40	1.20	0.002	-	2459	262	643	9	0.6
Press mud	1.20	1.96	2.20	1140	94	450	-	-	-
GM(Sesbania)	2.25	0.37		140	17	80	3.2	20	0.2

Azolla	**4.03**	**0.29**	**1.70**	-	-	-	-	-	-

5.1.10 **Average Nutrient Content of Crop Residues:**

These residues are the remnants of harvested crops and can be incorporated into the soil to recycle nutrients. Here are some examples:

- **Rice Straw:**
    - N (0.58%), P_2O_5 (0.23%), K_2O (1.66%)
- **Wheat Straw:**
    - N (0.49%), P_2O_5 (0.25%), K_2O (1.28%)
- **Sorghum Stalks:**
    - N (0.50%), P_2O_5 (0.23%), K_2O (2.17%)
- **Pearl Millet Stalks:**
    - N (0.65%), P_2O_5 (0.75%), K_2O (2.50%)

These crop residues serve as valuable sources of nutrients and organic matter when returned to the soil.

Table 2

Average nutrient content of crop residues

Crop -residues	Nutrients content (%)		
	N	P_2O_5	K_2O
Rice straw	0.58	0.23	1.66
Wheat straw	0.49	0.25	1.28
Sorghum stalks	0.50	0.23	2.17
Pearl millet stalks	0.65	0.75	2.50

Maize stalks	**0.59**	**0.31**	**1.31**
Average pulses	**1.60**	**0.15**	**2.00**
Groundnut	**1.60**	**0.23**	**1.37**
Other oilseeds	**0.80**	**0.21**	**0.93**
Pigeonpea	**1.10**	**0.58**	**1.28**
Chickpea	**1.19**	**0.36**	**1.25**
Sugarcane trash	**0.35**	**0.04**	**0.50**

Understanding the nutrient content of these organic manures and crop residues is essential for developing effective nutrient management plans. Farmers and researchers can tailor their fertilizer and organic matter application based on the specific nutrient requirements of crops and the existing soil nutrient status. This targeted approach not only optimizes crop yields but also promotes sustainable agriculture by reducing nutrient imbalances and environmental impacts.

3.1.11 **Nutrient Content of Some Oilseed Cakes:**

Oilseed cakes are valuable byproducts of oil extraction from seeds and serve as excellent sources of nutrients for crops. The table highlights the nutrient content of select oilseed cakes, specifically focusing on nitrogen (N%), phosphorus (P2O5%), and potassium (K2O%).

Table 3

Nutrient content of some oil seed cakes

Oil cake	**N %**	**P_2O_5 %**	**K_2O %**
Caster	**5.8**	**1.8**	**1.0**

Cotton seed	**3.9**	**1.8**	**1.6**
Karanj	**4.0**	**1.0**	**1.3**
Neem	**5.2**	**1.0**	**1.4**
Niger	**4.8**	**1.8**	**1.3**
Safflower	**4.8**	**1.4**	**1.2**
Linseed	**5.5**	**1.4**	**1.2**

These oilseed cakes contain varying levels of nitrogen, phosphorus, and potassium, which are essential nutrients for plant growth and development. When incorporated into the soil or used as organic fertilizers, oilseed cakes can enhance soil fertility and contribute to healthier crop yields. Farmers and agriculturists can use this data to make informed decisions about the application of oilseed cakes to meet specific nutrient requirements in their agricultural systems.

5.2 Fermented and Liquid Fermented Organic Manure

FOM and LFOM, or Fermented Organic Manure and Liquid Fermented Organic Manure, are valuable agricultural inputs derived from the decomposition and fermentation of organic materials. These organic materials can include a variety of biodegradable waste sources, such as crop residues, animal dung, kitchen waste, and other organic matter. FOM and LFOM are rich in essential nutrients like nitrogen, phosphorus, and potassium, making them effective supplements to enhance soil fertility and crop productivity.

5.2.1 **Types of FOM and LFOM**

There are two primary types of Fermented Organic Manure:

- **Solid Fermented Organic Manure (FOM)**: FOM is the solid residue obtained after the fermentation and decomposition of organic materials. It is typically applied to the soil as a solid substance. Its nutrient content depends on the type and composition of the organic materials used in its preparation.

- **Liquid Fermented Organic Manure (LFOM)**: LFOM, on the other hand, is the liquid extract obtained during the fermentation process. LFOM can be applied directly to the soil or used as a foliar spray. Like FOM, its nutrient content varies based on the source materials and the fermentation process.

5.2.2 **Benefits of FOM and LFOM**

- **Nutrient-Rich**: FOM and LFOM are rich sources of essential nutrients, including nitrogen, phosphorus, potassium, and micronutrients. They provide a balanced nutrient profile for crops, promoting healthy growth.
- **Improved Soil Structure**: These organic manures enhance soil structure and increase its water-holding capacity, making the soil more conducive to root growth and nutrient uptake.
- **Enhanced Microbial Activity**: FOM and LFOM promote the growth of beneficial soil microorganisms, which contribute to nutrient cycling and soil health.
- **Sustainable Farming**: Utilizing these organic manures reduces the dependence on synthetic fertilizers, contributing to sustainable and environmentally friendly farming practices.

5.2.3 **Issues and Challenges with FOM and LFOM**

- **Variable Nutrient Content**: The nutrient content of FOM and LFOM can vary depending on the source materials and the fermentation process. This variability can make it challenging to precisely determine nutrient application rates.
- **C/N Ratio**: Maintaining the right Carbon-to-Nitrogen (C/N) ratio is crucial for efficient decomposition and nutrient release. If the C/N ratio is too high, nitrogen immobilization can occur, limiting its availability to plants.
- **Application Timing**: Determining the optimal timing for FOM and LFOM application to match crop nutrient demand can be complex and requires careful planning.

5.2.4 **Dos and Don'ts of FOM and LFOM**

Dos:

- **Mixing with Recommended Fertilizers**: FOM and LFOM are most effective when used in conjunction with recommended doses of synthetic fertilizers tailored to crop needs.
- **Balanced pH**: Maintain the pH of FOM and LFOM within the range of 6.5 to 7.5 for optimal nutrient availability.
- **Application Timing**: Apply FOM 7-10 days before sowing for best results.

Don'ts:

- **Avoid Foliar Sprays**: FOM and LFOM should not be applied as foliar sprays but should be incorporated into the soil.

5.2.5 **FOM/LFOM Recommended Packages of Practices**

Here's a table summarizing the recommended packages of practices for important crops

Table 4

Crop Wise FOM/LFOM Recommended Packages of Practices

Crop	**Recommended Practices**
Rice	• Application of FOM (Bio-slurry enriched and stabilized to 2.1% N) @ 2.5 t/ha during nursery preparation and @ 1.25 t/ha after transplanting along with recommended dose of fertilizers (RDF). • In direct-seeded rice, liquid FOM is recommended @ 1.25 t/ha along with RDF.
Wheat	• Soil application of FOM (dried bio-slurry) @ 6-8 t/ha, 10 days before sowing, along with the recommended dose of fertilizers for sustainable productivity. • FOM should be applied before the last plough and ploughed into the soil.
Maize	• Application of FOM @ 4 to 6 t/ha along with 80% of the recommended dose of fertilizers (150 kg N/ha, 60 kg P_2O_5/ha, 30 kg K_2O/ha) for optimum productivity.
Pea	• For optimum green pod yield of pea, application of FOM (with 2.8% N) and urea in a 1:3 ratio is recommended. This practice improves microbial activity in the soil.
Okra	• For optimum productivity of okra crop, FOM application @ 5 t/ha is recommended along with the recommended dose of fertilizers (100 kg N/ha, 60 kg P_2O_5/ha, 40 kg K_2O/ha).
Spinach	• Application of 25% of recommended nitrogen through FOM and 75% recommended nitrogen through fertilizer produced optimum yield of spinach. FOM needs to be mixed in soil at least 15-20 days before sowing, and side or top dressing or fresh FOM application needs to be avoided.
Baby Corn	• Application of FOM @ 3 t/ha along with the full recommended dose of fertilizer (150 kg N/ha, 60 kg P_2O_5/ha, 20 kg K_2O/ha) is recommended for optimum production of baby corn. Spray of 0.3% iron is recommended

• Crop	• Recommended Practices
	along with the above practice. After application of FOM, the field needs to be ploughed and ridges and furrows formed at a spacing of 45 cm x 25 cm.

These recommended practices aim to optimize crop yield while using FOM effectively to enhance soil fertility and microbial activity. It's important to note that the success of these practices may vary depending on local conditions and specific crop varieties. Farmers should consider local factors and consult with agricultural experts for the best results.

FOM and LFOM play a crucial role in sustainable agriculture by providing a rich source of organic nutrients that enhance soil fertility and crop productivity. Their benefits include improved nutrient availability, enhanced soil structure, and support for beneficial soil microbes. However, challenges related to nutrient variability, C/N ratios, and application timing need to be addressed for their effective use. By following recommended dos and don'ts and tailoring application to specific crop requirements, farmers can harness the full potential of FOM and LFOM.

6. Scientific Research and INM Implementation

6.1 Long-term Fertilizer Experiments (LTFEs)

In the realm of agricultural research, the quest for optimal nutrient management practices is an ongoing pursuit to ensure sustainable crop productivity and food security. Among the multitude of strategies, the combination of inorganic fertilizers, represented by Nitrogen, Phosphorus, and Potassium (NPK), and the incorporation of organic matter through Farm Yard Manure (FYM), has emerged as a noteworthy contender. These two components, when synergistically applied to the soil, have consistently demonstrated their potential to significantly boost crop yields. The Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) have jointly conducted **Long-term Fertilizer Experiments (LTFEs)** across diverse soil types and cropping systems. This comprehensive study delves into the results obtained from Long-Term Fertilizer Experiments (LTFE) to explore the profound impact of NPK and FYM on crop productivity at various experimental locations.

The findings of these experiments have consistently highlighted the positive impact of balanced fertilizer use in maintaining soil quality. Below data is derived from Long Term Fertilizer Experiments (LTFE) conducted at various locations. These experiments are instrumental in assessing the impact of different nutrient management practices on crop productivity, specifically within the soybean/maize-wheat system.

Here is explanation of table:

Control: This treatment represents the baseline where no specific nutrient management practices are applied. In Ranchi, soybean yields are approximately 605 kg/ha, while wheat yields are 692 kg/ha. Similarly, in Jabalpur, soybean yields are 814 kg/ha, and wheat yields are 1238 kg/ha. In Palampur, maize yields are 287 kg/ha, and wheat yields are 381 kg/ha.

100% N: This treatment involves the application of 100% of the recommended nitrogen (N) fertilizer. Results vary by location; for instance, in Ranchi, soybean yields increase to 293 kg/ha, while wheat yields increase to 386 kg/ha. In Jabalpur, soybean yields reach 1024 kg/ha, and wheat yields reach 1668 kg/ha. In Palampur, maize yields improve to 2004 kg/ha, and wheat yields reach 4850 kg/ha.

100% NP: This treatment entails the application of 100% of the recommended N and phosphorus (P) fertilizers. Notable increases in productivity are observed.

100% NPK: This treatment involves the application of 100% of the recommended N, P, and potassium (K) fertilizers. The impact is even more pronounced.

NPK + FYM Treatment: In this treatment, a combination of NPK fertilizers and FYM is applied to the soil. The results show that this approach consistently leads to the highest crop yields across all locations.

- In Ranchi, soybean yields reach 1867 kg/ha, and wheat yields are 3327 kg/ha.
- In Jabalpur, soybean yields average 2004 kg/ha, and wheat yields reach 4850 kg/ha.
- In Palampur, maize yields improve to 4660 kg/ha, and wheat yields reach 3102 kg/ha.
- In Ludhiana, maize yields are 3805 kg/ha, and wheat yields reach 4987 kg/ha.
- In New Delhi, maize yields reach 2421 kg/ha, and wheat yields reach 4867 kg/ha.
- In Udaipur, maize yields average 3410 kg/ha, and wheat yields reach 4374 kg/ha.

NPK + Lime: This treatment combines the application of N, P, K fertilizers with lime. In Ranchi, soybean yields are 1795 kg/ha, and wheat yields are 3170 kg/ha. In Palampur, maize yields reach 4112 kg/ha, and wheat yields reach 2854 kg/ha.

CD 5%: The CD 5% represents the coefficient of variation at 5%, indicating the variability in the data.

Table 5

Effect of nutrient management on average productivity of soybean/ maize-wheat system under LTFE at different locations

Treatments	**Ranchi**	**Jabalpur**	**Palampur**
	1972 to 2006-09	**1972 to 2006-09**	**1999-2006-09**

Crop	Soybean	Wheat	Soybean	Wheat	Maize	Wheat
Control	605	692	814	1238	287	381
100 % N	293	386	1024	1668	221	267
100 % NP	870	2449	1652	4071	2004	1635
100 % NPK	1496	2795	1818	4419	3237	2294
NPK + FYM	1867	3327	2004	4850	4660	3102
NPK + Lime	1795	3170	-	-	4112	2854
CD 5%	212	390	282	441	706	502

Treatments	Ludhiana		New Delhi		Udaipur	
	1972 to 2009		1995 to 2009		1997-2009	
Crop	Maize	Wheat	Maize	Wheat	Maize	Wheat
Control	899	1206	1221	2381	1900	1907
100 % N	1891	2999	1552	4076	2458	3112
100 % NP	3376	4123	1781	4524	2837	3610
100 % NPK	3217	4769	2185	4524	3042	3879
150% NPK	4188	4850	2380	4765	3133	4331

NPK + FYM	**3805**	**4987**	**2421**	**4867**	**3410**	**4374**
CD 5%	**234**	**251**	**184**	**271**	**181**	**207**

Certainly, the combined use of NPK (Nitrogen, Phosphorus, and Potassium) and Farm Yard Manure (FYM) has consistently demonstrated significant increases in crop yields across various experimental locations.

The use of NPK in conjunction with FYM enhances nutrient availability and organic matter content in the soil. This combination promotes optimal conditions for plant growth, ensuring that crops receive both essential macro and micronutrients along with organic matter for improved soil structure and microbial activity. As a result, this treatment consistently produces the highest yields compared to other nutrient management practices.

Observation 1:

Soil organic status in long term fertilizer experiments: The Soil Organic Status in Long-Term Fertilizer Experiments (LTFE) is a crucial aspect of sustainable agriculture research. Over the years, these experiments have provided invaluable insights into how different nutrient management practices impact the organic content of soils. The table shared in the presentation compiles data from various LTFE locations, offering a comprehensive view of how soil organic status evolves in response to different fertilization strategies.

This analysis goes beyond immediate crop yields and delves into the long-term effects of nutrient management on soil health. Soil organic matter is a key determinant of soil quality, influencing factors such as water retention, nutrient availability, and microbial activity. Understanding how different fertilization approaches affect soil organic status is essential for devising sustainable agricultural practices that promote both crop productivity and long-term soil health.

Table 6

Soil organic status in long term fertilizer experiments

Locations	**Initial**	**NP**	**NPK**	**NPK+FYM**
Ludhiana	**2.2**	**3.3**	**3.6**	**5.2**
New Delhi	**4.4**	**3.9**	**4.4**	**5.5**

Udaipur	**6.9**	**7.1**	**7.8**	**8.9**
Jagtial	**7.9**	**10.0**	**10.0**	**101**
Jabalpur	**5.7**	**6.5**	**7.4**	**9.6**
Akola	**4.6**	**4.9**	**5.1**	**6.8**
Coimbatore	**3.0**	**6.7**	**7.0**	**9.8**
Palampur	**7.8**	**9.4**	**9.7**	**13.0**
Bangalore	**4.6**	**4.7**	**4.9**	**5.7**
Pantnagar	**15.0**	**8.5**	**8.7**	**16.0**
Barrackpore	**7.0**	**4.7**	**4.6**	**6.8**
Ranchi	**4.5**	**3.8**	**3.9**	**4.5**
Raipur	**6.2**	**6.4**	**6.5**	**7.0**

Observation 2:

Effect of nutrient Management on Soil Microbial Biomass Nutrients: In the context of sustainable agriculture and soil health, assessing the impact of nutrient management on soil microbial biomass nutrients is of paramount importance. The Ranchi location, as part of the Long-Term Fertilizer Experiments (LTFE), provides valuable insights into this aspect. This study specifically investigates how different nutrient management strategies affect soil microbial biomass nutrients in Ranchi.

The table provided in the presentation showcases the concentrations of key microbial biomass nutrients - carbon (C), nitrogen (N), and phosphorus (P) - under various nutrient management treatments. These treatments include a Control group, 100% N application, 100% NP application, 100% NPK application, and 100% NPK application along with Farm Yard Manure (FYM).

The findings are illuminating:

- **Carbon (C) Concentration**: The control group registers a microbial biomass C concentration of 176 mg/kg. This value is significantly lower than the treatments involving nutrient application. Among the nutrient management treatments, the 100% NPK + FYM treatment records the highest microbial biomass C concentration at 231 mg/kg. This indicates that the integration of NPK fertilizers with FYM contributes to higher soil microbial biomass C levels.
- **Nitrogen (N) Concentration**: Nitrogen is a critical element for soil microorganisms, and its availability impacts microbial activity. In the Control group, the microbial biomass N concentration is 16.4 mg/kg. The 100% NPK + FYM treatment exhibits the highest microbial biomass N concentration at 21.0 mg/kg. This signifies that the combined application of NPK and FYM enhances soil microbial biomass N levels, likely promoting more robust microbial communities.
- **Phosphorus (P) Concentration**: Phosphorus is another essential nutrient for microbial growth. In the Control group, the microbial biomass P concentration is 1.3 mg/kg. The 100% NPK + FYM treatment demonstrates the highest microbial biomass P concentration at 8.2 mg/kg. This suggests that the synergy between NPK and FYM application significantly augments soil microbial biomass P levels, potentially fostering a more nutrient-efficient microbial population.

Table 7
Effect of nutrient Management on Soil Microbial Biomass Nutrients in Ranchi

Treatment	Microbial biomass nutrients (mg kg^{-1})		
	SBM-C	SBM-N	SBM-P
Control	176	16.4	1.3
100% N	129	10.1	1.1
100% NP	153	13.8	4.7
100% NPK	183	18.8	7.5

100% NPK+FYM	**231**	**21.0**	**8.2**

Overall, the data from Ranchi highlights the positive influence of nutrient management on soil microbial biomass nutrients. Specifically, the incorporation of NPK fertilizers, along with FYM, emerges as a potent strategy for enhancing microbial biomass C, N, and P concentrations. These findings underscore the importance of balanced nutrient management practices not only in promoting crop productivity but also in nurturing the vital soil microbial community that plays a pivotal role in nutrient cycling and soil health maintenance.

6.2 The Power of Balance

The results from LTFEs illuminate the significance of balanced nutrient management. Employing a 100% NPK+FYM blend fosters sustained soil quality, a key indicator, compared to imbalanced nutrient application observed across LTFE locations. Moreover, the use of urea alone emerges as detrimental to soil health.

6.3 Nutritional Excellence Through Integration

The efficacy of integrated nutrient management (100% NPK + FYM/Lime) extends beyond yield. This approach elevates the nutritional quality of crops, as demonstrated by finger millet grain's enhanced content of calcium, magnesium, and crude proteins.

6.4 Micronutrient Mastery

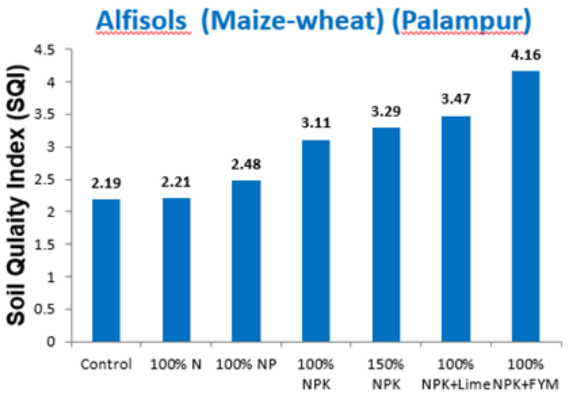
Intricate inclusions of vital micronutrients, such as sulfur and zinc, spotlight their pivotal role in specific regions. The Tarai belt's rice-wheat productivity serves as a prime example where these micronutrients form the bedrock for success.

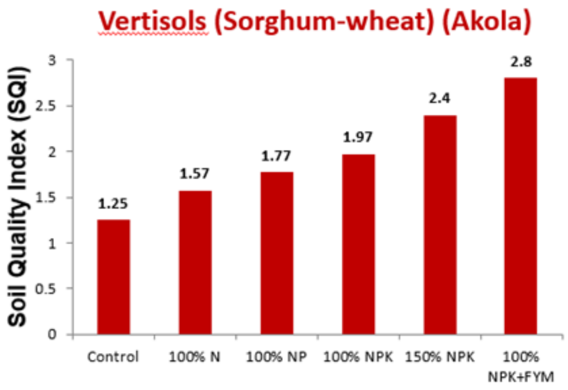
6.5 Nurturing Soil Vitality

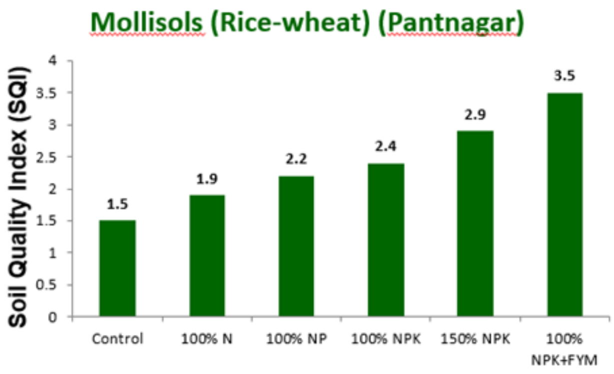
INM's reverberations echo through diverse soils and cropping systems. A discernible improvement in soil quality is evident, setting the stage for heightened carbon sequestration capabilities. This, in turn, strengthens the landscape's resilience against climate change impacts.

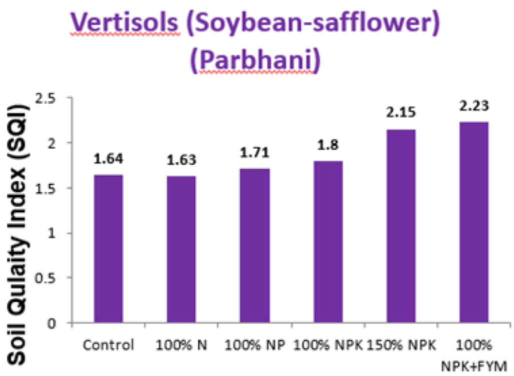
The INM is helpful in increasing the soil quality on different soils and in various cropping systems as shown below.

Figure 4
Soil Quality Index in different crops and soils under LTFE









The culmination of ICAR and SAUs' collaborative endeavors illustrates a roadmap toward agricultural resilience. By maintaining balanced nutrient applications, integrating micronutrients, elevating crop nutritional content, and fostering enhanced soil vitality, INM emerges as the holistic pathway to thriving agriculture.

These experiments underscore the indispensable role of balanced nutrient management in fostering both soil quality and agricultural productivity.

7. Recommended Integrated Plant Nutrition Service Package (IPNS) Crop and Region Wise

Integrated Nutrient Plant Nutrition Service (INPS) embodies a comprehensive approach that harnesses the combined potential of diverse nutrient sources to counteract nutrient depletion, bolster soil health, and sustain optimal crop productivity. It orchestrates a harmonious synergy between various sources of plant nutrients, seamlessly merging inorganic fertilizers, organic manure, green manure, and biofertilizers. This methodic integration is geared towards mitigating soil nutrient imbalances and fostering a holistic agricultural ecosystem.

By synergizing the benefits of these multifaceted nutrient inputs, INPS strives to maintain the delicate equilibrium of soil nutrient content. It addresses the challenge of preventing nutrient exhaustion over time while fostering the growth of robust crops. This approach isn't confined to a singular source of nutrients; rather, it recognizes the symbiotic potential of combining diverse nutrient origins. In doing so, INPS embodies an environmentally conscious approach that capitalizes on organic materials and biofertilizers to fortify the soil structure, enhance nutrient availability, and propel sustainable crop cultivation practices.

Outlined below are the region-specific and crop-oriented Integrated Plant Nutrition Service (IPNS) recommendations to be adopted:

Table 8

Integrated Plant Nutrition Management Packages Recommendations For Various Crops Region Wise

Western Himalayan Region		
Cropping System	**Generalized fertilizer recommendation**	**Integrated Plant Nutrition Service package (IPNS)**
Rice – Wheat	Rice : 120 kg N+ 40 kg P_2O_5 Wheat : 120 kg N + 80 kg P_2O_5 + 40 kg K_2O	Rice : 40 kg N + FYM/Green Manure @ 15 t/ha + 20 kg Zinc sulphate (in Zn deficient soils) Wheat : 120 kg N + 80 kg P_2O_5 (through SSP) + 40 kg K_2O
Maize – Wheat	Maize: : 120 kg N + 60 kg P_2O_5 + 40 kg K_2O Wheat : 120 kg N + 60 kg P_2O_5 + 30 kg K_2O	Maize : 60 kg N + 30 kg P_2O_5(through SSP) + 20 kg K_2O + 10 t FYM + fresh Eupatorium/ Lantana Mulch @ 10t/ha Wheat : 80 kg N + 30 kg P_2O_5 (through SSP) + 15 kg K_2O
Liming @3-4 q/ ha in furrows at the time of sowing for soils having pH<5.5		
Eastern Himalayan Region		
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**
Rice – Rice	Rice : 60 kg N + 30 kg P_2O_5 + 25 kg K_2O Rice : 80 kg N + 40 kg P_2O_5 + 20 kg K_2O	Rice : 20 kg N + 20 kg P_2O_5 + 15 kg K_2O +FYM/GM @ 10t/ha + Azolla @ 10t/ha + 20 kg Zinc Sulphate once in 3 years + 5 kg borax + 1 kg ammonium molybdate + 5 kg copper sulphate Rice : 60 kg N + 40 kg P_2O_5 25 kg K_2O + Azolla @ 10t/ha

Rice- wheat	Rice : 80 kg N + 40 kg P_2O_5 + 50 kg K_2O Rice : : 80 kg N + 40 kg P_2O_5 + 30 kg K_2O	Rice : 40 kg N + 20 kg P_2O_5 + 40 kg K_2O + FYM@5t/ha/GM + Azolla @ 10t/ha + 20 kg Zinc Sulphate once in 3 years + 5 kg borax + 1 kg ammonium molybdate + 5 kg copper sulphate Rice : 50 kg N + 20 kg P_2O_5 + FYM @ 5t/ha
Rice – Mustard	Rice : 80 kg N + 40 kg P_2O_5 + 50 kg K_2O Mustard : 40 kg N + 20 kg P2O5 + 30 kg K_2O + 10 kg S	Rice : 40 kg N + 30 kg P_2O_5 (through SSP) + 40 kg K_2O + FYM/GM @ 10t/ha + Azolla @ 10t/ha + 20 kg Zinc Sulphate once in 3 years + 5 kg borax + 1 kg ammonium molybdate + 5 kg copper Sulphate Mustard : 20 kg N + 10 kg P_2O_5 (through SSP) + 25 kg K_2O
Rice – Potato	Rice : 80 kg N + 40 kg P_2O_5 + 25 kg K_2O Potato : 100 kg N + 100 P_2O_5 + 50 kg K_2O	Rice : 40 kg N + 20 kg P_2O_5 + 15 kg K_2O + Azolla/GM @ 10t/ha + 20 kg Zinc Sulphate once in 3 years + 5 kg borax + 1 kg ammonium molybdate + 5 kg copper sulphate Potato : 50 kg N + 50 kg P_2O_5 + 30 kg K_2O + FYM@ 10t/ha + seed treatment with *Azotobacter* and PSB
Lower Gangetic plain		
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**
Rice – Rice	Rice : 80 kg N + 60 kg P_2O_5 + 40 kg K_2O Rice (HYV) : 120 kg N + 80 kg P_2O_5 + 60 kg K_2O	Rice : 60 kg N + 40 kg P_2O_5 + 30 kg K_2O + FYM/GM @ 10t/ha + 20 kg Zinc Sulphate Rice : 90 kg N + 80 kg P_2O_5 + 60 kg K_2O + Azolla @ 10t/ ha

Rice – Wheat	Rice : 80 kg N + 60 kg P_2O_5 + 40 kg K_2O Wheat: 120 kg N + 60 P_2O_5 + 60 kg K_2O	Rice : 40 kg N + 45 kg P_2O_5 + 30 kg K_2O + FYM/GM @ 10t/ha + Azolla @ 10t/ha/BGA @ 10 kg/ha + kg Zinc Sulphate Wheat: 90 kg N + 45 P_2O_5 + 45 kg K_2O
Jute – Rice – Potato	Jute : 40 kg N + 20 kg P_2O_5 + 40 kg + K_2O Rice : 60 kg N + 30 kg P_2O_5 + 30 kg K_2O Potato : 180 kg N + 80 kg P_2O_5 + 120 kg K_2O	Jute : 30 kg N + FYM @ 5t/ha Rice : 30 kg N + 30 kg P_2O_5 + 30 kg K_2O + Azolla @ 10t/ha/BGA@ 10 kg/ha + 20 kg Zinc Sulphate Potato : 150 kg N + 40 kg P_2O_5 + 100 kg K_2O + FYM@ 5t/ha + seed treatment with *Azotobacter* and PSB
	Middle Gangetic plain	
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**
Rice – Wheat	Rice : 100 kg N + 60 kg P_2O_5 + 40 kg K_2O Wheat: 120 kg N + 80 P_2O_5 + 40 kg K_2O	Rice : 50 kg N + 30 kg P_2O_5 + 20 kg K_2O + Green Manure (greengram/stover) 20 kg Zinc Sulphat (in calcareous soils) Wheat: 90 kg N + 60 P_2O_5 + 30 kg K_2O + FYM@ 10t/ha OR Rice : 75 kg N + 45 kg P_2O_5 + 30 kg K_2O + BGA @ 15 kg/ha + FYM @ 10 t/ha + 20kg Zinc Sulphate (in calcareous soils) Wheat : 100 kg N + 65 kg P_2O_5 + 30 kg K_2O
Maize – Wheat	Maize : 100 kg N + 60 P_2O_5 + 30 kg K_2O + 40 kg S and 16 kg borax (in calcareous soil) Wheat : 120 kg N + 80 P_2O_5 + 40 kg K_2O	Maize : 90 kg N + 60 P_2O_5 (through SSP) + 30 kg K_2O + GM + 16 kg borax (in calcareous soil) Wheat : 90 kg N + 60 kg P_2O_5 + 30 kg K_2O + FYM@ 10t/ha

Groundnut-Pigeonpea intercropping	Groundnut: 10 kg N + 50 P_2O_5 + 20 kg K_2O Wheat: 10 kg N + 50 P_2O_5 + 20 kg K_2O	100% RDF + lime @2 t/ha + FYM@2 t/ha + Soil water conservation measure (furrows between groundnut and pigeon pea rows)
Upper Gangetic plain		
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**
Rice – Wheat	Rice : 120 kg N + 60 kg P_2O_5 + 40 kg K_2O + 20 kg Zinc Sulphate Wheat : 120 kg N + 60 kg P_2O_5 + 40 kg K_2O + 40 kg S	Rice : 90 kg N + 30 kg K_2O + FYM/GM (Sesbania/ Leucaena Lopping) @ 10t/ha Wheat : 90 kg N + 60 kg P_2O_5 (through SSP) + 30 kg K_2O
Maize – Wheat/ Mustard	Maize : 100 kg N + 60 kg P_2O_5 + 40 kg K_2O Wheat : 120 kg N + 60 kg P_2O_5 + 40 kg K_2O Mustard : 80 kg N + 50 kg P_2O_5 + 40 kg K_2O	Maize : 50 kg N + 20 kg K_2O + FYM @ 10t/ha Wheat : 120 kg N + 60 kg P_2O_5 (through SSP) + 40 kg K_2O Mustard : 60 kg N + 40 kg P_2O_5 (through SSP) + 30 kg K_2O
Sugarcane – Potato	Sugarcane (Autumn planting) : 180 kg N + 60 kg P_2O_5 + 40 kg K_2O Potato (Intercropping) : 180 kg N + 60 kg P_2O_5 + 80 kg K_2O	Sugarcane(Autumn planting) : 100 kg N + 45 kg P_2O_5 + 30 + Sulphitation pressmud/ GM + Incorporation of Potato foliage. Potato (Intercropping): 135 kg N + 20 kg P_2O_5 + 60 kg K_2O + FYM 2 10 t/ha + seed treatment with Azotabacter and PSB * (In case of ratoon crop, incorporate sugarcane frash along with only 75 kg N)

Sugarcane – Wheat	Sugarcane(Autumn planting) : 180 kg N + 60 kg P_2O_5 + 40 kg K_2O Wheat(Intercropping) : 120 kg N + 60 kg P_2O_5 + 60 kg K_2O	Sugarcane(Autumn planting) : 135 kg N + 45 kg P_2O_5 + 30 t (FYM/ Sulphitation pressmud) /GM (Sesbania /Sunhemp/cowpea @ 10 t/ha Wheat (Intercropping) : 80 kg N + 40 kg P_2O_5 + 40 kg K_2O *(In case of ratoon crop, incorporates sugarcane frash along with only 75 kg N)

Trans Gangetic Plain		
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**
Rice/ Maize/Bajra – wheat	Rice: 120 kg N + 60 kg P_2O_5 + 60 kg K_2O + 20 kg Zinc Sulphate Maize: 120 kg N + 60 kg P_2O_5 +30 kg K_2O + 20 kg Zinc Sulphate Bajra : 90 kg N + 60 kg P_2O_5 Wheat: 180 kg N + 60 kg P_2O_5 + 30 kg K_2O	Rice: 60 kg N + 30 kg K_2O + FYM/poultry manure/GM @ 10 t/ha Maize: 70 kg N + FYM/GM (Sesbania/ cowpea) @ 10t/ha Bajra: 60 kg N + 30 kg P_2O_5 FYM @ 10 t/ha Wheat: 150 kg N + 30 kg P_2O_5 (through SSP) + 30 kg K_2O + *Azotobactor/Azospirillium* + PSB
Cotton–wheat	Cotton: 120 kg N + 30 kg P_2O_5 + 30 kg K_2O Wheat: 180 kg N + 60 kg P_2O_5 + 30 kg K_2O	Cotton: 120 kg N Wheat: 150 kg N + 30 kg P_2O_5 (through SSP) + 30 kg K_2O + *Azotobactor/Azospirillium* + PSB

Eastern Plateau & Hills		
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**

Rice –Winter Maize/Wheat/Pulses	Rice : 60 kg N+ 30 kg P_2O_5 + 30 kg K_2O + 20 kg Zinc Sulphate Winter Maize : 120 kg N + 60 kg P_2O_5 + 30 kg K_2O Wheat : 120 kg N + 60 kg P_2O_5 + 40 kg K_2O Pulses : 20 kg N + 40 kg P_2O_5 + 20 kg K_2O + Rhizobium + 20 kg S + micronutrient Mixtures	Rice : 30 kg N + 15 kg P_2O_5 (through SSP) + 15 kg K_2O + FYM/GM @ 10t/ha + 15 kg BGA Winter Maize : 100 kg N + 45 kg P_2O_5 (through SSP) + 20 kg K_2O Wheat : 90 kg N + 45 kg P_2O_5 (through SSP) + 30 kg K_2O Pulses : 10 kg N + 20 kg P_2O_5 (through SSP) + FYM @ 2.5t/ha + Rhizobium + 500 g PSB
Liming @3-4 q/ ha in furrows at the time of sowing for soils having pH<5.5		
Central Plateau & Hills		
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**
Rice-Wheat/Mustard	Rice : 100 kg N+ 30 kg P_2O_5 + 40 kg K_2O Wheat : 120 kg N + 60 kg P_2O_5 + 40 kg K_2O Mustard : 60 kg N + 30 kg P_2O_5 + 20 kg K_2O	Rice : 75 kg N + FYM/Green Manure @ 5t/ha Wheat : 90 kg N + 45 kg P_2O_5 + 30 kg K_2O Mustard: 30 kg N + 15 kg P_2O_5 + 10 kg K_2O FYM @ 10 t/ha.
Soybean - Wheat	Soybean : 20 kg N+ 60 kg P_2O_5 + 20 kg K_2O + B Wheat : 120 kg N + 60 kg P_2O_5 + 40 kg K_2O	Soybean : 10 kg N+ 25 kg P_2O_5 (through Boronated SSP) + 4t FYM+ Rhizobium + 25 kg Zinc Sulphate in alternate years Wheat : 90 kg N + 45 kg P_2O_5 (through SSP)

Rice – Gram	Rice : 100 kg N+ 30 kg P_2O_5 + 30 kg K_2O Gram : 20 kg N+ 40 kg P_2O_5 + 20 kg K_2O +Rhizobium	Rice : 25 kg N+ 15 kg P_2O_5 + pulse crop residue Incorporation + BGA @ 10 kg/ha/Azolla @ 10t/ha Gram : 10 kg N+ 20 kg P_2O_5 + Rhizobium + 5t FYM + 500 PSB
Soybean-Chickpea (Rainfed system)	Soybean: 20 kg N+ 60 kg P_2O_5 + 20 kg S Chickpea: 30 kg N+ 60 kg P_2O_5	100% RDF + 2 t/ha FYM to soybean and 50% RDF to chickpea
Liming @3-4 q/ ha in furrows at the time of sowing for soils having pH<5.5		
Western Plateau & Hills		
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**
Soybean – wheat	Soybean : 20 kg N + 60 kg P_2O_5 + 20 kg K_2O + B + S Wheat : 120 kg N + 60 kg P_2O_5 +40 kg K_2O	Soybean : 10 kg N + 25 kg P_2O_5 (through SSP)+ 4 t FYM + Rhizobium + 25 kg Zinc Sulphate in alternate year Wheat: 90 kg N + 45 kg P_2O_5 (through SSP)
Cotton – Fallow/Pigeon pea/wheat	Cotton : : 100 kg N + 50 kg P_2O_5 + 50 kg K_2O Pigeon pea : : 20 kg N + 40 kg P_2O_5 + 20 kg K_2O + Rhizobium + 20 kg S + Micronutrient Mixture Wheat : 120 kg N + 60 kg P_2O_5 + 30 kg K_2O	Cotton : : 50 kg N + 25 kg P_2O_5 + 25 kg K_2O + seed treatment with *Azotobacter* + 4 t FYM / in situ Green manuring (cowpea) followed by mulching with subabul loppings . Pigeon pea : : 10 kg N + 20 kg P_2O_5 (through SSP) + 10 kg K_2O + FYM @ 2.5 t/ha + Rhizobium + 500 g PSB Wheat : : 90 kg N + 30 kg P_2O_5 (through SSP) + 30 kg K_2O + *Azotobactor / Azospirillium* + PSB

Green gram-Safflower (Rainfed)	Safflower: 40 kg N + 50 kg P_2O_5	Incorporation of green gram stalk before sowing of safflower along with 75% RDF of safflower + Soil moisture conservation measure (Summer ploughing and inter-culture with blade hoe)
Fallow-sunflower (Rainfed)	Sunflower: 60 kg N +80 kg P_2O_5 + 50 kg K_2O	100% RDF+FYM @ 2 t/ha +Soil moisture conservation measure (Opening furrow after every 6 rows)
Southern plateau and Hills , East Coast Plains and Ghats and West Coast Plains Regions		
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**
Rice-Rice	Rice : 100 kg N+ 30 kg P_2O_5 + 30 kg K_2O Rice : 120 kg N + 60 kg P_2O_5 + 40 kg K_2O	Rice: 75 kg N +15 kg. P_2O_5 + 15 kg. K_2O+ FYM/Green Manure @ 5t/ha Rice: 90 kg N + 60 kg P_2O_5 + 40 kg K_2O + 40 kg. K_2O+Azolla @ 10 t /ha BGA @ 10 kg / ha + 20 kg Zinc Sulphates
Rice – Pulses	Rice : 100 kg N+ 30 kg P_2O_5 + 30 kg K_2O Pulses : 20 kg N + 40 kg P_2O_5 +2 0 kg K_2O + Rhizobium	Rice: 25 kg N+ 15 kg K_2O + pulse crop residue incorporation + BGA @ 10 kg /ha/Azolla @ 10 t/ha Pulses: 10 kg N + 20 kg P_2O_5 + 10 kg K_2O + Rhizobium + 2.5 T FYM + 500 g PSB
Fallow-Sunflower (Rainfed)	Sunflower: 60 kg N +80 kg P_2O_5 + 50 kg K_2O	Sunflower:100% RDF+FYM @ 2 t/ha +Soil moisture conservation measure (Opening furrow after every 2 rows)
Castor monocropping (Rainfed)	Castor: 60 kg N +80 kg P_2O_5 + 40 kg K_2O + 20 kg S	Cowpea incorporation after first picking and 75% RDF of castor
Liming @3-4 q/ ha in furrows at the time of sowing for soils having pH<5.5		
Gujarat plains & Hills Regions		
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**

Groundnut/ wheat/ Mustard	Groundnut : 20 kg N + 40 kg P_2O_5 + 60 kg K_2O Wheat : 120 kg N + 60 kg P_2O_5 + 30 kg K_2O Mustard : 60 kg N + 30 kg P_2O_5 + 20 kg K_2O	Groundnut : 15 kg N + 30 kg P_2O_5 (through SSP) +45 kg K_2O + Gypsum @ 250 kg / ha in furrow + 25 kg Zinc Sulphate + 1 kg Boron Wheat: 70 kg N + 30 kg P_2O_5 (through SSP) + 20 kg K_2O + Azotobactor/Azospirillium + PSB Mustard : 30 kg N + 15 kg P_2O_5 (through SSP) + 10 kg K_2O + FYM @ 10 t/ ha
Cotton – Castor	Cotton: 100 kg N + 40 kg P_2O_5 + 40 kg K_2O Castor (irrigated) : 40 kg N + 60 kg P_2O_5	Cotton : 50 kg N + 25 kg P_2O_5 + 25 kg K_2O + seed treatment with *Azotobacter* + 4 t FYM Castor (irrigated) : 25 kg N + 50 kg P_2O_5 (through SSP)+ 1 t castor seed cake/FYM @ 5t/ha + seed treatment with Azospirillium and PSB @ 5 kg/ha
	Western Dry Regions	
Cropping System	**Generalized fertilizer recommendation**	**IPNS package**
Kharif Pulses – Fallow	Kharif pulses : 20 kg N + 40 kg P_2O_5 + 20 kg K_2O + Rhizobium	Pulses : 10 kg N + 20 kg P_2O_5 +10 kg K_2O + Rhizobium + 2.5 t FYM
Pearmri millet – mustard	Pearl millet : 50 kg N + 30 kg P_2O_5 + 15 kg K_2O Mustard : 60 kg N + 30 kg P_2O_5 + 20 kg K_2O + S	Pearl mrimillet : 25 kg N + 20 kg P_2O_5 (through SSP)+ 10 kg K_2O + *Azotobacter/ Azospirillium* Mustard : 45 kg N + 20 kg P_2O_5 (through SSP)+ 15 kg K_2O + FYM @ 5 t/ha

Fallow-Mustard (Rainfed)	Mustard: 80 kg N + 40 kg P_2O_5 + 20 kg S	Green manuring with Sesbania and FYM @ 2 t/ha + 75% RDF
Maize-Raya (Rainfed)	Maize : 80 kg N + 40 kg P_2O_5 Raya : 37 kg N + 20 kg P_2O_5	100% RDF + S @ 20 kg/ha + Soil moisture conservation Measures (summer ploughing + maize residue application on surface)

Note: The above recommendations are general guidelines. It is essential to consider soil test results, crop variety, climatic conditions, and specific regional factors for precise nutrient management.

8. Government's policy initiatives

Government of India is implementing several schemes for promotion of integrated nutrient management to ensure higher agricultural productivity and profitability of farming community based on the technology backstopping provided by Indian Council of Agriculture Research (ICAR) and State/Central Agricultural Universities providing requisite technology backstopping to a variety of programmes/schemes being implemented by different Ministries/Departments.

National Mission on Soil Health Card has been launched to provide soil tested based fertilizer recommendation to all the farmers in the country based on the twelve soil parameters. The Government under the component of soil health management of National Mission on Sustainable Agriculture (NMSA) is promoting soil test based balanced and integrated nutrient management in the country through setting up and strengthening of soil testing laboratories, establishment of bio-fertilizer and compost unit, use of micronutrients, trainings and demonstrations. A number of value added fertiliser materials fortified with secondary and micronutrients have been enlisted in Fertilizer Control Order (FCO) to promote balanced and efficient use of fertilisers. Also the customised fertilisers which are crop, soil and area specific show a good promise to maintain soil health by ensuring balanced fertilisation. The Govt. of India took a historical policy decision of introduction of Nutrient Based Subsidy (NBS) on N, P, K and Sulphur containing fertilizers with effect from1st April 2010. Additional subsidy for fertilizers fortified with zinc and boron was paid at the rate of ₹500 and ₹300 per tonne, respectively. It well help in soil health enhancement through balanced and efficient use of plant nutrients including secondary and micronutrients.

The Government under Watershed Management component of Pradhan Mantri Krishi Sinchayee Yojana is promoting Micro irrigation/fertigation. Besides, Govt. of India through Paramparagat Krishi VikasYojana (PKVY) and Mission Organic Value Chain Development for North Eastern Region (MOVCDNER) are promoting organic farming through adoption of village by Cluster Approach and Participatory Guarantee System (PGS) certification. Nearly 2.00 million ha in Indo-Gangetic Plains have been brought under RCTs mainly zero tillage and bed planting through National Food Security Mission (NFSM) and NMSA schemes.

9. Conclusion

In conclusion, the adoption of Integrated Nutrient Management (INM) practices underscores the indispensable role of external nutrient supply in maintaining and enhancing crop productivity. Beyond sustaining yields, it is evident that meticulous nutrient management fosters a multifaceted improvement in soil properties, spanning chemical, physical, and biological aspects. INM's balanced and integrated approach contributes significantly to elevating soil quality. Consequently, INM emerges as the cornerstone for not only sustaining agricultural productivity but also ushering in a positive transformation in soil health. In essence, nutrient management stands as the pivotal key to a sustainable future for agriculture, bridging the nexus between crop yield and soil vitality.[i]

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References:

1. Singh, A., Kumar, A., Singh, S., Singh, A., & Singh, R. (2019). Impact of integrated nutrient management on soil health and crop yield: A review. International Journal of Chemical Studies, 7(3), 2133-2137.
2. ICAR. (2018). Integrated Nutrient Management. Indian Council of Agricultural Research. Retrieved from https://www.icar.org.in/en/content/integrated-nutrient-management
3. Pathak, R., Singh, R., Singh, A., & Singh, M. (2021). Sustainable soil nutrient management for enhancing crop productivity. Soil Science, 166(3), 202-212.
4. Choudhary, M., Sharma, S., Yadav, A., Kumari, S., & Sunda, H. (2020). Impact of integrated nutrient management on soil fertility and crop productivity. Journal of Pharmacognosy and Phytochemistry, 9(7), 73-76.

Appendices:

1. "ICAR- SAU Collaborative Long Term Fertilizer Experiments: Insights and Implications"
2. "Advancing Sustainable Agriculture: The Role of Integrated Nutrient Management"
3. "Unlocking the Potential of INM: A Case Study in Climate-Resilient Agriculture"