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Integrated Nutrient Management (INM) for Profitable and Eco-Friendly Crop Production

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Abstract

Integrated Nutrient Management (INM) combines chemical fertilizers, organic manures, and biofertilizers to optimize nutrient use, enhance soil fertility, and boost crop productivity sustainably. INM improves input efficiency, reduces environmental pollution, and supports long-term agricultural profitability. This approach is vital for maintaining soil health, reducing dependency on synthetic inputs, and ensuring food security under changing climate conditions.

Keywords: *Integrated Nutrient Management, soil fertility, biofertilizers, crop productivity, sustainability act*

1. Introduction

A. Definition of Integrated Nutrient Management (INM)

Integrated Nutrient Management (INM) is a holistic approach that promotes the judicious and efficient use of all sources of plant nutrients chemical fertilizers, organic manures, crop residues, and biofertilizers to maintain soil fertility and productivity. The goal is to achieve optimal crop yields while minimizing negative environmental impacts.

It integrates:

- Chemical fertilizers (NPK and micronutrients) for immediate nutrient needs
- Organic sources like farmyard manure (FYM), compost, and green manure for long-term soil health
- Biofertilizers such as Rhizobium, Azospirillum, and phosphate-solubilizing bacteria (PSB) for biological nutrient enhancement

This system supports both productivity and ecological balance.

B. Importance of balanced nutrient management in agriculture

- Unbalanced fertilizer use leads to nutrient mining, declining yields, and soil degradation.
- Data from the Food and Agriculture Organization (FAO) shows that nutrient imbalance has caused a 30% reduction in potential crop yields in intensively farmed areas.
- Studies show that combined use of organic and inorganic sources increases nutrient use efficiency by 20–25% and improves crop yields by 10–15% compared to chemical fertilizers alone.

- Soil Organic Carbon (SOC) levels decline significantly under exclusive chemical fertilizer regimes, dropping below 0.4% in many agricultural zones—well below the ideal 0.8–1% needed for healthy soils.
- Balanced nutrient application contributes to water retention, root development, and resilience to drought and pests.

2. Concept and Components of INM

A. Use of chemical fertilizers

- Chemical fertilizers supply readily available nutrients such as N, P, and K, supporting immediate crop growth requirements.
- Average nutrient use efficiency remains low: nitrogen (30–40%), phosphorus (15–20%), and potassium (50–60%). This inefficiency highlights the need for integrated approaches.
- Balanced NPK application has shown yield increases of 20–35% in cereals, oilseeds, and pulses under controlled field trials.

B. Role of organic manures (e.g., FYM, compost, green manure)

- Farmyard manure (FYM) provides approximately 0.5% N, 0.2% P_2O_5, and 0.5% K_2O, contributing to improved soil structure and microbial activity.
- Compost adds 15–25 tons/ha of organic matter, boosting water retention by up to 20% and enhancing nutrient-holding capacity.
- Green manures such as dhaincha and sunn hemp fix 80–120 kg N/ha and improve soil organic carbon by 0.2–0.3% over continuous use.

C. Integration of biofertilizers (e.g., Rhizobium, Azotobacter, PSB)

- Rhizobium inoculation enhances biological nitrogen fixation in legumes, adding 50–200 kg N/ha depending on crop species.
- Azotobacter and Azospirillum improve root development and supply 20–40 kg N/ha through atmospheric nitrogen fixation.
- Phosphate-solubilizing bacteria (PSB) increase phosphorus availability by 15–25% and support higher P uptake efficiency.

D. Site-specific nutrient management (SSNM) and soil testing

- SSNM tailors nutrient doses based on crop demand, soil fertility status, and yield targets, increasing fertilizer use efficiency by 25–40%.
- Soil testing reveals critical nutrient deficiencies; surveys show that more than 40% of agricultural soils lack adequate nitrogen and nearly 30% show low phosphorus levels.
- Use of tools such as Nutrient Expert® and GPS-based soil mapping supports precise nutrient application, reducing fertilizer waste by 10–20% while maintaining or improving yields.

3. Benefits of INM

A. Economic benefits

- 1. Improved input-use efficiency
- INM enhances nitrogen use efficiency by 20–30%, phosphorus by 15–25%, and potassium by up to 35%, reducing nutrient losses and maximizing uptake.
- Integrated use of FYM and NPK increases nutrient recovery, leading to better returns per unit of fertilizer applied.
- 2. Reduced cost of production
- Use of on-farm organic resources like compost and green manure cuts chemical fertilizer costs by 25–40%.

- Biofertilizers priced at ₹200–300 per hectare reduce nitrogen input needs by 20–40 kg/ha, saving ₹500–1,000 per hectare.

- 3. Higher crop yields and quality
- Field trials show that combining organics with fertilizers boosts crop yields by 10–25% compared to chemical-only systems.
- Quality improvements include higher protein in cereals, better oil content in oilseeds, and improved grain weight and shelf life.

B. Environmental benefits

- 1. Minimization of nutrient leaching and pollution
- Nitrate leaching reduced by 30–50% under INM due to slower nutrient release from organics and better nutrient synchrony with crop demand.
- INM reduces chemical runoff, preventing eutrophication of water bodies.
- 2. Improved soil health and biodiversity
- Soil organic carbon increases by 0.1–0.3% over 3–5 years under integrated practices.
- INM promotes microbial biomass by 20–40% and supports earthworm activity, improving aeration and nutrient cycling.
- 3. Climate change mitigation (reduced emissions)
- Use of biofertilizers reduces nitrous oxide (N_2O) emissions from soils by 10–15%.
- Organic amendments sequester carbon, with compost and green manure adding 1.5–2.0 tons of carbon per hectare annually.

C. Long-term sustainability of agriculture

- INM prevents soil nutrient mining, restoring balance in multi-cropped systems.
- Long-term experiments (e.g., over 20 years) show sustained or improved productivity under INM while chemical-only systems experience yield stagnation.
- Improved soil structure, moisture retention, and biological activity ensure resilience against climate variability and pest outbreaks.

4. Strategies and Practices for Implementing INM

A. Soil health assessment and nutrient budgeting

- Soil testing reveals macro and micronutrient deficiencies; nearly 55% of cultivated soils test low in nitrogen, 42% in phosphorus, and 44% in sulfur.
- Nutrient budgeting based on soil test values and crop demand improves fertilizer efficiency by 20–35%.
- Inclusion of micronutrients like zinc and boron in plans increases crop productivity by 8–15% in deficient soils.

B. Crop rotation and diversification

- Rotating cereals with legumes improves nitrogen availability through biological fixation (up to 100–150 kg N/ha per season).
- Diverse cropping systems reduce pest pressure by 20–40% and improve nutrient cycling.

- Inclusion of pulses in rotation raises soil organic matter by 0.1–0.2% over 3–4 years.

C. Use of locally available organic resources

- On-farm biomass, FYM, compost, and crop residues reduce reliance on external inputs by 30–50%.
- Application of 5–10 t/ha of compost or FYM contributes 20–40 kg N, 10–20 kg P, and 20–30 kg K per hectare.
- Green manure crops such as Sesbania and sun hemp fix atmospheric nitrogen and improve soil microbial populations.

D. Adoption of precision agriculture tools

- Tools like Leaf Color Chart (LCC), GreenSeeker, and Nutrient Expert® guide real-time nutrient application, improving nitrogen use efficiency by 15–30%.
- GPS and GIS-based soil mapping enables site-specific nutrient management, reducing over-application and losses.
- Use of drip fertigation increases nutrient uptake and saves water by 30–50%.

E. Farmer training and awareness programs

- Demonstration programs and field schools improve INM adoption rates by 40–60%.
- Studies show trained farmers use 15–25% fewer inputs while maintaining or increasing yields.
- Capacity-building initiatives led by Krishi Vigyan Kendras (KVKs) and research institutes reach over 1 million farmers annually.

5. Case Studies and Examples

A. Success stories from different regions or crops

- In Punjab, integrated use of NPK with FYM and green manure in rice-wheat systems increased yields by 18% and improved soil organic carbon from 0.36% to 0.58% in 6 years.
- Maize farms in Madhya Pradesh using biofertilizers (Azospirillum + PSB) with 75% recommended NPK recorded 14% higher yields and 22% lower input costs compared to 100% NPK alone.
- Sugarcane growers in Maharashtra using press mud, compost, and chemical fertilizers achieved a 20% increase in cane yield and improved juice quality (Brix value up from 17.8 to 19.1).
- In Eastern Uttar Pradesh, green gram integrated with Rhizobium and 50% recommended nitrogen boosted pod yield by 23% and saved ₹1,200 per hectare in fertilizer cost.

B. Comparative analysis: Conventional vs. INM-based farming outcomes

- Long-term trials by ICAR show INM-based wheat plots maintain stable yields over 15 years, while conventional plots show yield decline of 0.3–0.5 t/ha.
- Soil pH under chemical-only fertilization dropped from 6.9 to 5.8 in 10 years, while INM plots maintained near-neutral pH (6.7–7.0).
- Net returns under INM in rice-wheat systems are consistently 12–20% higher due to better input efficiency and reduced nutrient loss.
- Integrated systems show 25–40% more microbial biomass carbon and 15–25% better water-holding capacity compared to chemical-only practices.

6. Challenges and Limitations

A. Limited availability of organic inputs

- Average availability of farmyard manure is only 3–5 tons/ha against the requirement of 10–12 tons/ha for effective soil improvement.
- Only 30% of crop residues are recycled back into the soil; the rest is burned or used as fodder and fuel.
- Composting infrastructure remains underutilized, and efficient collection of biomass is lacking in most rural regions.

B. Lack of awareness and training among farmers

- Survey data show over 55% of farmers are unaware of proper biofertilizer use or benefits of integrated practices.
- Only 18% of smallholders have access to soil health cards or formal nutrient management training.
- Adoption rate of INM practices remains below 25% in rainfed areas due to limited outreach and demonstration efforts.

C. Inadequate infrastructure for biofertilizer production and distribution

- Current biofertilizer production meets only 10–15% of national demand.
- Nearly 40% of biofertilizer units operate below capacity due to lack of skilled labor, quality control, and storage facilities.
- Shelf life and strain viability issues reduce effectiveness, especially under poor storage and transportation conditions.

D. Policy and institutional gaps

- Subsidies favor chemical fertilizers, with over ₹1.75 lakh crore allocated annually, while support for organic inputs remains limited.
- Lack of uniform standards for compost and biofertilizers leads to inconsistent product quality.
- Coordination gaps between agricultural departments, extension agencies, and input suppliers slow down technology transfer.

7. Policy Support and Recommendations

A. Government schemes and subsidies for INM promotion

- National Mission on Sustainable Agriculture (NMSA) promotes INM through soil health management and organic input use.
- Soil Health Card Scheme has tested over 22 crore soil samples, guiding balanced nutrient application.
- Paramparagat Krishi Vikas Yojana (PKVY) supports organic farming clusters and provides ₹50,000 per hectare over 3 years, including inputs like compost and biofertilizers.

B. Research and extension services

- Indian Council of Agricultural Research (ICAR) and State Agricultural Universities have developed over 30 INM crop-specific packages.
- Krishi Vigyan Kendras (KVKs) conduct over 70,000 on-farm trials and demonstrations annually, covering INM practices across agro-climatic zones.
- Advisories on micronutrient deficiencies, precision application, and integration methods have improved fertilizer use efficiency by 15–25%.

C. Public-private partnerships

- Agri-input companies collaborate with ICAR and state departments to develop fortified

compost, enriched biofertilizers, and farmer training modules.

- PPP models have expanded custom hiring centers and organic input distribution in over 120 districts, improving access for smallholders.
- Digital platforms like eNAM and mobile apps assist farmers with INM guidance and timely input availability.

D. Need for integrated policy frameworks

- Unified fertilizer subsidy policies are required to bring organic inputs and biofertilizers on par with chemical fertilizers.
- Mandatory quality standards for compost and biofertilizers must be enforced under the Fertilizer Control Order (FCO).
- State-specific INM promotion strategies aligned with cropping patterns, soil health status, and climatic conditions can enhance adoption and impact.

Conclusion

Integrated Nutrient Management enhances crop productivity, reduces input costs, improves soil health, and ensures environmental sustainability making it essential for profitable and eco-friendly agricultural development.

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