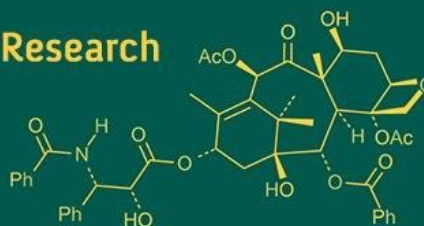


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Integrated nutrient management for sustainable mungbean production: A review of the opportunities and challenges

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Abstract

This review paper delves into the comprehensive analysis of the influence of integration of organic & inorganic nutrient management on mungbean cultivation. Through a meticulous examination of existing literature, this review synthesizes the outcomes of diverse organic, inorganic and its combine fertilization approaches, encompassing vermicompost utilization, FYM, biofertilizers (Rhizobium and PSB), Leaf compost, integration with inorganic fertilizer (as. Phosphates, potassic, micronutrients) and incorporation and their consequential effects on mungbean growth, yield, and soil quality. The review elucidates the underlying mechanisms by which organic nutrients modulate mungbean physiology and productivity, underscoring the significance of sustainable agricultural methodologies. The synthesis of findings underscores the potential of organic nutrient management to augment mungbean yield, ameliorate soil fertility, and foster environmental sustainability. Several research demonstrated that INM increases crop yields when compared to conventional approaches, improves water-use efficiency and the economic benefits to farmers, while boosting grain quality, soil health, and sustainability. In conclusion, the paper identifies research gaps and advocates for future investigations to refine organic nutrient management practices for the sustainable advancement of mungbean cultivation.

Keywords: Sustainable farming, organic inputs, integrated nutrient management, mungbean cultivation

Introduction

Mungbean (*Vigna radiata* L. Wilczek) is one of the most extensively farmed, protein-rich crops belonging to the leguminous family. Mungbean is a rich source of carbohydrates (56.72 g), protein (21-24 g), fat (1.31 g), minerals (3.48 g) such as calcium (124 mg), phosphorous (326 mg), iron (4.42 mg), fiber (4.11 g) and supplies a good amount of energy (334 kcal) (Gopalan et al., 2002; Dhakal et al., 2015) ^[11, 9]. Availability of pulses per capita per day is only 39.4 g against the minimal requirement of 104 g as suggested by nutritional experts of World Health Organization/Food and Agriculture Organization (Nandania, 2005; Directorate of Economics and Statics, 2011). Mungbean is widely cultivated in many Asian countries (Concentrated mainly in India, China, Pakistan, Bangladesh and some Southeast Asian countries) as well as in dry regions of southern Europe and warmer parts of United States and Canada (Dahiya et. al., 2015) ^[8]. Mungbean production in India is predicted to reach 5.5 million hectares by 2022, yielding 3.17 million tonnes at a productivity of 570 kg per hectare. Mung beans alone account for 10% of pulse production and 16% of total area. According to the AICRPR's Annual Report (2022-23) on Kharif pulses, the dominant contributors to Mung bean cultivation in terms of area and production are Rajasthan (46% and 45%, respectively), with Madhya Pradesh (9% and 14%), Maharashtra (9% and 8%), Karnataka (9% and 6%), Odisha (5% and 4%), Bihar (4% and 5%), Tamil Nadu (4% and 3%), Gujarat (3% and 4%), Andhra Pradesh (3% for both), and Telangana (2% for both). (IIPR, 2022) ^[2].

The usage of artificial fertilizers, however, may also have detrimental effects on the soil and overall agricultural output. The delicate balance of nutrients in the soil can be upset by chemical fertilizers, which can result in a reduction in the health of the soil. As a result, the soil's capacity to sustain plant growth may decline, which could lead to decreased productivity. Additionally, the usage of chemical fertilizers may promote the accumulation of dangerous elements in the soil,

including pesticides, which may be poisonous to humans, animals, and even plants. Chemical fertilizers also have the potential to harm drinking water supplies by leaching into groundwater. Some micronutrients will not become yield-limiting elements over time, because even organic fertilizers may not be able to supply all micronutrients in levels required for a high yield of a crop or harvest system. With a rapidly growing global population, the demand for efficient food for each people has become a primary aim. More than 250 million tonnes of food grains will be required in the twenty-first century due to high population growth. To meet this necessity for food goods, most farmers have chosen to utilize a large amount of inorganic chemical fertilizers that boost production but also degrade soil health, which indirectly generates stress in natural resources, making it possible to meet future food security needs. Long-term food security necessitates a delicate balance between enhancing crop output, preserving soil health, and ensuring environmental sustainability. Meena Millo and Reddy Vishnuvardhan Kanala (2021) [27]. The term "Integrated Nutrient Management" (INM) refers to the efficient and sufficient supply, use, or inspection of all the main components of plant nutrient resources, composition of chemical fertilizers in combination with compost, animal manures, and green manures. To enhance soil fertility, health, and productivity, use legumes in cropping systems, biofertilizers, crop residues, recyclable debris, and other readily available nutrient resources. Currently, there is a rising demand for organic food. Due to their leguminous nature, mung beans require minimal nitrogen. Soil organic matter has a significant impact on the soil microbial population, thereby improving crop growth and yield. The roots of mung beans host symbiotic rhizobia bacteria, facilitating the conversion of atmospheric nitrogen into soil-available forms. Organic manures contain both micro and macro nutrients, enhancing soil fertility, infiltration rate, porosity, water holding capacity, carbon content, cation exchange capacity, and reducing bulk density. Organic sources provide an optimal substrate for microbial proliferation, ensuring a favorable nutritional value and favorable soil physical characteristics. (Kishor et al. 2021) [21].

Concept of INM

INM is a practice that blends traditional and modern methods of fertilizer application and nitrogen management. The concept of INM is based on a number of factors, including nutrient property harmony, a balance between crop nutrient demands, what type of nutrient is generally available in soil and in the farmer's hand, how information and skills about the most suitable nutrient can be harmonized in combination, and which materials can be safely used to increase nutrient-use efficiency. Furthermore, it is a process and a way of safely disposing organic wastes, as well as an effective method of recycling wastes into high-quality compost. The major components of the INM concept are as follows: raising farmer awareness about the value of INM techniques, asking them to abandon the excessive use of chemical fertilizers, and encouraging them to focus on long-term plans for sustainable agriculture. Furthermore, instead of focusing just on profit, producers must consider environmental implications and produce safe food. It must constantly be recalled that food safety is highly valued by

many customers, regardless of price, and that adopting such methods can increase farmer profits.

Components of INM

Integrated Nutrient Management (INM) is a holistic approach that combines the use of various nutrient sources and management practices to optimize nutrient supply to crops, maintain soil fertility, and ensure environmental sustainability. Below are the key components of INM, along with relevant references that provide detailed information on each aspect.

Key Factors of Integrated Nutrient Management (INM)

- 1. Use of Organic Fertilizers:** Organic fertilizers such as farmyard manure (FYM), green manures, compost and crop residues help in maintaining soil organic matter, improving soil structure, enhancing microbial activity and promoting nutrient availability over time. Bajwa, I. S., et al. (2015) [3].
- 2. Use of Inorganic Fertilizers (Chemical Fertilizers)** Inorganic fertilizers provide essential macro- and micro-nutrients (such as N, P, K, S, Zn & Fe) that are quickly available to plants. The proper use of these fertilizers, based on soil testing, helps in increasing crop yields. Ghosh, P. K., et al. (2010) [10].
- 3. Bio-fertilizers:** Bio-fertilizers consist of beneficial microorganisms that improve soil fertility by fixing nitrogen, decomposing organic matter, and solubilizing phosphorus. Common examples include Rhizobium, Azotobacter, and Mycorrhiza. Rai, M., & Dastidar, M. G. (2014) [37].
- 4. Soil Testing and Nutrient Diagnosis:** Soil testing is critical for determining the nutrient status of the soil and identifying deficiencies. It helps farmers apply fertilizers at the right time, in the right quantity, and in the right manner, improving nutrient use efficiency. Verma, P. R., et al. (2013) [48].
- 5. Nutrient Recycling and Cycling:** Nutrient recycling involves the return of organic matter and crop residues to the soil to replenish nutrients and improve soil organic matter. This reduces dependency on chemical fertilizers and enhances soil health. Pathak, H., et al. (2011) [33].
- 6. Water and Irrigation Management:** Efficient water management, including practices like drip irrigation and fertigation (fertilizer applied through irrigation), optimizes nutrient uptake while minimizing water and fertilizer waste. Lal, R. (2016) [25].
- 7. Green Manuring and Cover Cropping:** Green manuring involves growing specific crops (typically legumes) to enrich the soil with nitrogen and other nutrients. Cover crops, such as legumes and grasses, prevent soil erosion and improve soil structure. Mollier, A., et al. (2010) [29].
- 8. Balanced Fertilization Practices:** Balanced fertilization involves applying a mix of nutrients (macro and micronutrients) based on crop needs and soil nutrient status, preventing imbalances that can lead to soil degradation or nutrient deficiencies. Sharma, A., & Kumar, A. (2020) [40].
- 9. Soil pH Management:** Soil pH affects nutrient availability. Liming acidic soils or using sulfur to acidify alkaline soils ensures that nutrients are in the

correct chemical forms for plant uptake. Ghosh, P. K., et al. (2010) ^[10].

10. Agro-Ecological Practices and Cropping Systems: INM incorporates agro-ecological principles by tailoring nutrient management to specific cropping systems, local climate conditions, and soil types, such as monocropping, intercropping, and agroforestry. Bajwa, I. S., et al. (2015) ^[3].

11. Integrated Soil Fertility Management (ISFM): INM is often closely aligned with ISFM, which integrates various soil management practices, including nutrient application, conservation tillage, and organic amendments, to maximize soil fertility and crop productivity. Lal, R. (2016) ^[25].

12. Crop Residue and Farmyard Manure Management: Recycling crop residues and integrating farmyard manure (FYM) into the soil enhances organic matter content, increases nutrient cycling, and improves soil health. Verma, P. R., et al. (2013) ^[48].

Impact of INM on morpho-physiological symptoms of mungbean

Several studies indicate the beneficial effects of several INM components on growth and developmental indicators. The findings of numerous researchers who have previously worked on mungbean suggested that providing nutrients (macro and micro) through diverse components considerably improves growth and developmental features. In this regard, Soodi *et al.* (1994) discovered that applying 25 kilogram N/ha alone or in conjunction with 50 kg

P2O₅/ha enhances the quantity and dry weight of nodules per plant. Similarly, Mathur *et al.* (2007) reported that treating plants with N and P alone or in combination dramatically increased plant height and branch count. Sharma *et al.* (2003) reported that increasing rates of N and P improved physiological indicators such as crop growth rate, relative growth rate, and photosynthetic efficiency. The combination of organic and inorganic fertilizers with biofertilizers was found to be synergistic and have an additive effect on improving mungbean growth metrics (Prajapati *et al.*, 2016; Singh *et al.* 2017) ^[42]. Vermicompost at 2.5 t/ha, combined with the recommended fertilizer dosage (RDF), increased plant height, dry matter, and root weight (Rajkhowa *et al.*, 2002). Tarafder *et al.* (2020).

Effect of INM on growth of mungbean

This study discovered that 100% RDF + 5 tonnes FYM/ha + Rhizobium and PSB seed inoculation greatly enhanced plant height, dry weight per plant, and the quantity and dry weight of root nodules. Kishor Kaushal, et al. (2021) ^[21]. During the study year, the combination of inorganic fertilizer and organic (F.Y.M, Vermicompost, and Poultry manure) nutrients had a significant impact on plant development characteristics such as plant height, number of branches plant-1, dry weight, and number of nodules plant-1. The results clearly demonstrate that the maximum plant height, number of branches plant-1, dry weight, and number of nodules plant-1 (47.70, 6.33, 18.06, and 13.70 respectively) were recorded with the Treatment T 7, i.e. 75%



Source: https://www.researchgate.net/figure/Components-of-integrated-nutrient-management_fig1_361447099

Poultry manure + 25% D A P which was comparable to Treatment T6 (75% Vermicompost + 25% D A P) and significantly superior to the rest of the treatments, while the lowest values were recorded (plant height - 41.16 cm, number of branches plant-1 - 4.96, dry weight - 15.13 g, and number of nodules plant-1 - 7.03, respectively) with Treatment T1, i.e. RDF. It is possible that the basal application of poultry manure provided all required nutrients, growth hormones, and enzymes to the plant, promoting rapid cell division and, as a result, enhanced plant growth. The results are in collaboration with the research findings given by Singh *et al.* 2017 ^[42].

Influence of INM on yield & yield attributes of mungbean

The subplot treatment of 75% RDF+ rhizobium + PSB produced the highest number of root nodules/plant at 30 and 45 DAS in green gram (5.86, 6.19, 12.49, and 12.94 in 2017 and 2018, respectively), while the lowest values were found in the 75% RDF treatment. Mangarajn *et al.* (2020) ^[26]. Application of 75% recommended dose of NPK along with seed treatment with Rhizobium @ 10 g/kg seed and soil application of PSB and KSB @ 5 kg/ha (T4) was found statistically at par with those obtained in T3 (recommended dose of NPK along with seed inoculation by Rhizobium and

PSB separately @ 10 g/kg seed) and significantly superior to other treatments in terms of the above parameters. Singh R. K. *et al.* (2021) ^[43]. RDF+VC 5 t/ha produced a greater seed and stover yield than RDF and RDF+VC 2.5 t/ha. Seed yield is increased due to the cumulative effect of pod number/plant, pod length, grain number/pod, and seed weight.

Effect of INM on quality of mungbean

The maximum protein content (25.2%) and protein yield (107.6 kg/ha) were obtained with RDF+VC 5 t/ha. This was mostly owing to increased biological synthesis under these treatments, which improves nutrient uptake. Application of Mo + Co in conjunction with biofertilizer resulted in the highest protein content and yield. The minimal protein content and yield were measured under control. A comparable finding was observed by Khan *et al.* (2002) and Jain *et al.* (2007) ^[19, 16]. The combination of biofertilizer, Mo, and Co greatly improved nutrient uptake. The greater uptake with the application of biofertilizers and micronutrients could be owing to the enhanced influence of Rhizobium in nitrogen delivery. (Bhattacharyya and Pal, 2001) ^[5].

Impact of Integrated Nutrient Management on Microorganisms in Soil

Integrated Nutrient Management (INM): is an approach that combines the use of organic, inorganic, and biological fertilizers to optimize soil fertility and enhance plant growth while maintaining environmental sustainability. The primary goal of INM is to improve nutrient use efficiency, soil health, and ecosystem functions. Its impact on soil microorganisms is multifaceted, affecting microbial diversity, abundance, activity, and community structure.

Increased Microbial Diversity and Activity

- **Nutrient Availability:** INM practices can enhance soil fertility by maintaining balanced nutrient levels, which supports the growth and activity of a wider variety of microorganisms. For instance, organic amendments such as compost or manure provide a rich source of organic matter, fostering beneficial microbial populations like bacteria, fungi, and actinomycetes.
- **Microbial Activity:** A balanced nutrient environment resulting from INM can stimulate microbial processes such as nitrogen fixation, organic matter decomposition, and nutrient cycling (Jat *et al.*, 2020) ^[18]. Microbial activity is critical for soil health, as it aids in breaking down organic materials, thus releasing plant-available nutrients.

Soil Microbial Community Structure

- **Balance between Microbial Populations:** The use of both organic and inorganic fertilizers in INM can help maintain a balance in the soil's microbial community, preventing dominance of a single group. For example, long-term use of chemical fertilizers alone may reduce microbial diversity, especially beneficial microbes like mycorrhizae and nitrogen-fixing bacteria, while organic amendments can help restore their populations (Gupta *et al.*, 2021) ^[12].
- **Fungal and Bacterial Populations:** Studies have shown that INM practices promote a favorable balance between soil fungi and bacteria. Organic amendments tend to favor fungal growth, while inorganic fertilizers

might encourage bacterial populations (Singh *et al.*, 2020) ^[45].

Enhanced Soil Fertility and Microbial Resilience

- **Nutrient Cycling:** INM enhances nutrient cycling through better microbial activity, especially in the case of organic amendments like compost, which introduces a variety of microorganisms capable of breaking down organic matter and recycling nutrients (Patra *et al.*, 2016) ^[34]. This leads to a more resilient soil ecosystem, capable of withstanding environmental stresses like drought or disease.
- **Improved Soil Structure:** The inclusion of organic matter in INM can improve soil structure by promoting aggregation. This creates microhabitats that support the growth of diverse microbial populations, enhancing soil health and fertility.

Reduction in Soil Pathogens

- **Suppressive Effects:** Organic amendments and the use of biofertilizers in INM can help suppress soil-borne pathogens by promoting the growth of beneficial microorganisms such as antagonistic bacteria and mycorrhizal fungi (Yang *et al.*, 2017) ^[50]. These microorganisms compete with or inhibit the growth of harmful pathogens, thereby improving soil health.
- **Disease Suppression:** Research has demonstrated that INM can reduce the incidence of soil-borne diseases like root rot and wilt by maintaining a healthy and diverse microbial population (Elmer *et al.*, 2019).

Environmental Sustainability

- **Reduction of Chemical Inputs:** By optimizing nutrient use, INM reduces the dependence on chemical fertilizers, leading to lower environmental pollution and less disturbance to the soil microbial community. Overuse of chemical fertilizers can harm beneficial microbes, reducing soil biodiversity and ecosystem services (Hernandez *et al.*, 2020) ^[14].
- **Sustainability of Agricultural Practices:** INM, through its holistic approach, supports sustainable agriculture by ensuring long-term soil fertility, microbial diversity, and resilience against environmental challenges (Bansal *et al.*, 2021) ^[4].

Challenges of integrated nutrient management: There are several challenges in implementing INM effectively.

Soil Health and Fertility Variability

Challenge: Soil nutrient levels vary across different regions, requiring tailored nutrient management strategies. A one-size-fits-all approach to INM often does not work, as soils in different areas may require different nutrient management practices. Sharma, S., *et al.* (2017) ^[41].

Availability and Cost of Inputs

Challenge: The cost and availability of inputs (such as organic manure, bio-fertilizers, and micronutrients) can be a significant constraint. For smallholder farmers in developing countries, these inputs might be too expensive or unavailable, thus hindering the effective implementation of INM. Natarajan, G., *et al.* (2019) ^[30].

Balancing Nutrient Supply

Challenge: Achieving a balance between organic and inorganic fertilizers can be complex. Excessive use of one type of fertilizer over others can lead to soil degradation, nutrient imbalances, and environmental pollution. Haug, R. & Lee, G. (2018) & Ladha, J.K., et al. (2014)^[13, 22].

Inadequate Infrastructure

- **Limited Access to Inputs:** In many rural areas, access to quality organic fertilizers, bio-fertilizers, and even chemical fertilizers can be limited due to poor infrastructure and underdeveloped agricultural supply chains. Tandon, H. L. S. (1995)^[46].
- **Soil Testing Facilities:** Lack of affordable and accessible soil testing services prevents farmers from assessing the specific nutrient needs of their soils, leading to inefficient nutrient management and potential over-application or under-application of fertilizers. International Fertilizer Association (IFA). (2010)^[15].

Soil and Crop Diversity

- **Variable Soil Types:** Different soil types require different nutrient management approaches. INM needs to be tailored to local soil characteristics, which can complicate its implementation, especially on farms with heterogeneous soils. Vanlauwe, B., et al. (2014)^[47].
- **Crop-Specific Nutrient Needs:** Different crops have different nutrient demands, which means farmers must apply customized nutrient strategies for multiple crops on the same farm. This increases the complexity of nutrient management. Raghupathi, R., & Paliwal, R. (2003)^[36].

Environmental Concerns

- **Over-Reliance on Chemical Fertilizers:** Despite the objectives of INM to reduce the dependency on chemical fertilizers, many farmers still rely on them due to their immediate benefits. This can result in negative environmental impacts, such as soil acidification, nutrient leaching, and water pollution. Lal, R. (2012)^[23].
- **Long-Term Soil Health:** Maintaining soil health over the long term requires balancing organic and inorganic inputs. An imbalance, such as excessive chemical fertilizer use, can degrade soil structure and reduce its fertility. Chivenge, P., et al. (2011)^[7].

Opportunities of Integrated nutrient management

Reduction in Fertilizer Dependency: By using organic fertilizers and bio-fertilizers in combination with inorganic fertilizers, INM can reduce farmers' dependence on synthetic fertilizers. This reduces the economic burden on farmers and helps mitigate the environmental impacts associated with over-reliance on chemical fertilizers. Singh, A., & Yadav, R. L. (2012)^[44].

Increased Crop Productivity: By optimizing nutrient application, INM has been shown to significantly increase crop yields. The balanced approach ensures that crops receive the right nutrients at the right time, leading to more efficient growth and higher productivity. Palaniappan, S. P., & Annadurai, K. (2001)^[31].

Economic Benefits for Smallholder Farmers: INM helps smallholder farmers improve their economic stability by optimizing fertilizer use, increasing crop yields, and

reducing input costs. The use of locally available organic inputs also reduces the need for costly chemical fertilizers. Jat, M. L., et al. (2013)^[17].

Diversification of Income Sources: INM often involves the use of multiple farming systems, such as agroforestry or intercropping, which can diversify farmers' sources of income. For example, incorporating nitrogen-fixing leguminous crops can improve soil fertility while providing additional products like legumes for sale or consumption. Powelson, D. S., et al. (2011)^[35].

Increased Efficiency in Waste Recycling: INM facilitates the recycling of agricultural and organic waste materials, which can be converted into valuable fertilizers through composting or biogas production. This helps reduce waste disposal problems while providing an affordable and sustainable nutrient source for crops. (Lal, R. 2012)^[23].

Conclusion

Integrated Nutrient Management (INM) presents a viable strategy for improving the sustainability of mungbean cultivation by enhancing nutrient use efficiency and reducing environmental repercussions. The integration of both organic and inorganic fertilizers, alongside agronomic practices such as crop rotation, the application of bio-fertilizers, and the use of nutrient-rich inputs, plays a crucial role in preserving soil fertility and fostering robust crop development. The review underscores several significant opportunities for implementing INM in mungbean farming, which include increased nutrient accessibility, improved soil health, more effective pest and disease control, and enhanced yield consistency. The adoption of INM practices can also help diminish the ecological impact of agricultural activities by encouraging environmentally friendly farming methods and decreasing reliance on synthetic fertilizers. Nevertheless, the review points out several obstacles, including insufficient knowledge and training among farmers, restricted access to quality organic fertilizers, and the necessity for tailored nutrient management approaches specific to different regions. Additionally, socio-economic factors, such as the expense of inputs and limited agricultural extension services, frequently impede the broader implementation of INM strategies. To address these challenges, it is essential to promote further research and development, provide targeted extension services, and establish policy frameworks that support sustainable agricultural practices. Initiatives such as training programs, farmer field schools, and awareness campaigns can effectively close the knowledge gap and highlight the advantages of INM. Moreover, fostering a supportive environment for smallholder farmers through subsidies or financial assistance for INM-related inputs could significantly boost its adoption.

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