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A Review of the Impact of Nutrient Management on Indian Mustard

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ABSTRACT

This review explores the impact of various nutrient management practices on mustard (Brassica spp.) cultivation, emphasizing the synergistic benefits of integrating organic and inorganic fertilizers. Mustard is a crucial oilseed crop, and optimizing nutrient supply is essential for maximizing its productivity and quality. Numerous studies have demonstrated that integrated nutrient management (INM), which combines organic sources like farmyard manure (FYM), compost, or green manure with inorganic fertilizers such as urea, diammonium phosphate (DAP), and potash, results in improved crop performance compared to the sole application of either source. The integration of organic and inorganic fertilizers positively influences key growth and yield parameters, including plant height, number of primary and secondary branches, number of siliquae per plant, seeds per siliqua, seed yield, and oil content. Organic amendments improve soil structure, enhance microbial activity, and increase nutrient retention and availability, while inorganic fertilizers provide a rapid and targeted nutrient supply. This combination ensures a balanced and sustained nutrient release throughout the crop growth cycle. Specifically, treatments incorporating farmyard manure with recommended doses of nitrogen, phosphorus, and potassium have shown significant improvements in plant vigor and yield attributes. FYM contributes to the gradual release of macro- and micronutrients and enhances soil health, which is crucial for long-term productivity. Moreover, the oil content in mustard seeds tends to increase under integrated nutrient regimes, making this approach highly beneficial not only for yield enhancement but also for improving the quality of the produce. Overall, integrated nutrient management offers a sustainable pathway to boost mustard cultivation.

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1. INTRODUCTION

India plays a vital role in the global oilseed economy, ranking high in both production and consumption. In the 2018–19 period, rapeseed-mustard cultivation worldwide covered an estimated 36.59imillionihectares (mha), yielding 72.37imillionitonnes (mt) with an average productivity of 1980ikg/ha. Of this, India accounted for approximately 19.8%iof the total cultivation area and contributed 9.8%ito the global output (USDA). Over the years, India has seen a steady rise in productivity from 1840ikg/ha in 2010–11 to 1980ikg/ha in 2018–19. Similarly, total production increased from 61.64imt in 2010–11 to 72.42imt in 2018–19 [1].

Mustard, among other oilseeds, holds immense value in India's food security, industrial applications, and rural economy. It serves as a key source of edible oil, widely used in Indian kitchens, especially in the northern and eastern regions. The seeds are often used to temper curries and pickles, while mustard oil is prized for its sharp flavor and high cooking utility [2–4]. Nutritionally, mustard is rich in essential fatty acids (notably omega-3), antioxidants, and micronutrients such as selenium, magnesium, and

manganese, which are known to promote health and well-being.

Economically, mustard farming supports the livelihoods of millions of Indian farmers. However, production is susceptible to fluctuations due to climatic variability, soil fertility constraints, input costs, government policies, and market price volatility. States like Rajasthan, Uttar Pradesh, Madhya Pradesh, and Haryana are the major producers of mustard, but yields vary widely depending on factors like rainfall, irrigation availability, pest pressure, and adoption of improved cultivation techniques.

To reduce dependency on edible oil imports and ensure domestic sufficiency, recent agricultural initiatives in India aim to promote mustard cultivation. Nonetheless, low adoption of advanced technologies such as high-yielding varieties (HYVs), mechanized farming tools, and precision nutrient management continues to hamper productivity growth.

Among all agronomic practices, nutrient management is particularly critical in influencing mustard growth, seed yield, and oil quality. Each major nutrient plays a specific role in the physiological development of the crop:

- **Nitrogen (N)** is essential for vegetative growth, promoting the development of leaves and stems. When applied judiciously in correct amounts and at appropriate stages, nitrogen enhances biomass accumulation and overall seed yield.
- **Phosphorus (P)** is indispensable for early root development, flower initiation, and seed setting. It also contributes to energy transfer within plant cells, improving the efficiency of nutrient uptake. Deficiency in phosphorus may delay flowering and reduce seed quantity and quality.
- **Potassium (K)** plays a vital role in strengthening plant tolerance against biotic and abiotic stressors such as pests, diseases, and drought. It also aids in seed filling and oil biosynthesis. Low potassium availability can hinder growth, reduce resistance, and impair seed development.
- **Sulfur (S)** is critical for the synthesis of amino acids, vitamins, and chlorophyll. Adequate sulfur availability improves enzymatic activity, promotes healthy foliage, and increases both seed yield and oil concentration. Its deficiency may cause chlorosis, stunted growth, and poor seed formation.

In addition to these macronutrients, micronutrients such as ironi (Fe), zinci (Zn), manganese (Mn), copper (Cu), boron (B), and molybdenum (Mo) are necessary in trace amounts for enzymatic functions, reproductive development, and metabolic processes. Imbalances or deficiencies in these elements can severely impact nutrient uptake, physiological functions, and ultimately crop performance. According to Singh et al. [430], monitoring micronutrient status through soil testing and employing appropriate foliar or soil-based interventions is essential to avoid yield penalties.

Given the diverse agroclimatic conditions and variable soil nutrient profiles across mustard-growing regions in India, a site-specific nutrient management strategy is crucial. Integrated nutrient management (INM), which combines organic inputs like farmyard manure with chemical fertilizers, has shown promising results in improving both yield and soil health.

2. EFFECT OF NUTRIENT MANAGEMENT ON GROWTH OF INDIAN MUSTARD

Several studies have underscored the importance of nutrient management in enhancing the growth and yield of Indian mustard [5] conducted a field trial in Aligarh, Uttar Pradesh, and observed that microbial inoculants significantly improved vegetative and reproductive traits of mustard. The use of *Azotobacter*, whether alone or in combination, led to increased shoot length, fresh and dry biomass, and leaf count per plant, along with higher pod count, seeds per pod, 1000-seed weight, and final seed yield at harvest. The best performance among treatments was recorded when *Azotobacter* was applied singly.

In another study, [6] reported that applying 5 tonnes per hectare (t/ha) of vermicompost combined with 75% of the recommended dose of fertilizers (RDF) resulted in notable improvements in plant height, branching, siliquae per plant, and seed count per siliqua. This treatment produced yield outcomes comparable to those of 10 t/ha farmyard manure (FYM) combined with 75% RDF.

[7] Demonstrated that integrating chemical fertilizers with organic and biological nutrient sources significantly enhanced plant height, branching, siliquae count, seed weight, total seed yield, and oil content. According to [8], vermicompost provides vital nutrients nitrogen, phosphorus, potassium, calcium, magnesium, and trace elements like zinc, copper, and boron which are crucial for photosynthesis and plant metabolism. Additionally, its high humanicide content stimulates secondary metabolite production, such as flavonoids and anthocyanins, which improve plant defense and quality.

[9] observed that applying 100% of the recommended fertilizers (120:40:20:40 kg/ha N:P_2O_5:K_2O:S), along with 10it/ha FYM, 25ikg/ha of $ZnSO_4$, and seed inoculation with *Azotobacter*, resulted in significantly higher values for plant height, total dry matter, leaf area, and seed yield. Similarly, [10] highlighted the effectiveness of fertility treatments on various growth and yield attributes such as plant height, dry matter production, branching, siliquae formation, seeds per siliqua, test weight, and both seed and stover yields. The highest performance was seen with 75%iRDF through FYM and 25% through chemical fertilizers, which was statistically at par with 50%iRDF via FYM and 50% via fertilizers. Notably, stover yield was most improved with 100%iRDF from FYM.

Dual inoculation with *Azotobacter* and phosphate-solubilizing bacteria (PSB) also showed a significant increase in growth and productivity indicators compared to untreated controls. [11] Further confirmed that combining 50%iRDF with FYM and seed treatment using *Azotobacter* enhanced plant height and branching. This combination also improved germination rate, root and shoot lengths, and seed vigor index. Their findings emphasized that even reduced fertilizer inputs, when supplemented with organic manure and biofertilizers, could yield significantly better growth compared to full chemical inputs alone.

3. EFFECT OF NUTRIENT MANAGEMENT ON YIELD ATTRIBUTES AND YIELD OF INDIAN MUSTARD

Numerous studies have highlighted the positive influence of nutrient management strategies on the yield and yield-contributing parameters of Indian mustard. [12] observed that integrating 5it/ha of farm yard manure (FYM) with Azotobacter chroococcum and Azospirillum significantly enhanced key yield traits such as the number of primary and secondary branches, 1000-seed weight, oil percentage, and both seed and straw yields compared to untreated controls.

Similarly, [13] found that combining 75% of the recommended dose of fertilizers (RDF) with 5it/ha FYM and inoculation with Azotobacter and phosphate-solubilizing bacteria (PSB) substantially improved the number of siliquae per plant, seed yield, and oil yield. This integrated treatment also outperformed the control in terms of growth and yield attributes.

[14] Reported the highest mustard grain yield when 100%iRDF was supplemented with vermicompost and biofertilizers. Comparable yields were also recorded with 75% and 100%iRDF in combination with 5 t/ha of vermicompost and biofertilizer. [15] Confirmed similar results, noting the maximum siliquae count and seed yield using 100%iRDF in an integrated nutrient management (INM) approach, followed by treatments with 75% and 50%iRDF under the same INM strategy.

[16] highlighted that organic nutrient sources, including manure and vermicompost, significantly improved siliquae per plant, seeds per siliqua, and seed yield, outperforming both RDF alone and control treatments. [17] Also found notable increases in plant height, branching, siliquae formation, seed weight, yield, and oil content when 100% RDF was applied in combination with 50% FYM, 50% vermicompost, and Azotobacter.

[18] Evaluated the effects of fortified vermicompost and reported a significant increase in mustard yield attributes and seed yield with increasing application rates. Specifically, 6.0it/ha of fortified vermicompost produced a seed yield of 15.65 q/ha, registering improvements of 10.86%, 13.34%, and 79.68% over the 4.0 t/ha, 2.0 t/ha, and control treatments, respectively.

[19] showed that substituting half the nitrogen requirement with organic manure and the remaining half with chemical fertilizers significantly boosted both seed and stover yields, reaching 11.99iq/ha and 43.75iq/ha, respectively. [20] Also reported consistent improvements in yield parameters, protein content, and oil content with increasing vermicompost applications (2–6it/ha), combined with 50 kg N and 40 kg P_2O_5 per hectare. At 6it/ha, yields and nutritional content peaked, with 25.7%iprotein and 40.6% oil.

In a separate study, [21] recorded the highest grain yield (20.78iq/ha) under the T12 treatment, which involved the application of 120 kg nitrogen, 50 kg phosphorus, and 50 kg potassium per hectare. This treatment significantly outperformed the control (T1), which yielded only 10.10iq/ha. The combined application of N, P, and K produced synergistic effects, improving growth, nutrient uptake, and overall productivity.

[22] Demonstrated that coupling RDF with 5.0it/ha of vermicompost led to superior growth and yield performance, achieving a grain yield of 22.75 q/ha. In contrast, RDF applied alone (120:60:40:30 kg/ha of NPKS) yielded just 19.15iq/ha, underscoring the added benefit of integrating organic sources into conventional fertilization regimes.

4. EFFECT OF NUTRIENT MANAGEMENT ON NUTRIENT CONTENT AND UPTAKE OF INDIAN MUSTARD

Extensive research has demonstrated that the type and combination of nutrient applications significantly

influence the nutrient content and uptake in Indian mustard. According to [23], the use of zinc, iron, and enriched farmyard manure (FYM) enhanced the uptake of nitrogen, sulfur, and micronutrients, subsequently increasing the oil and protein content in mustard seeds.

[24], through a field experiment in Rajasthan, compared inorganic fertilizers (60 kg N + 40ikg P_2O_5/ha) with combinations involving 10 t/ha FYM or 5it/ha poultry manure. They reported superior nitrogen and phosphorus uptake in both seed and stover under treatments involving only inorganic fertilizers.

[25] Found a progressive accumulation of sulfur in rapeseed dry matter up to 80 days after sowing, with nitrosulf treatments performing better than elemental sulfur. Sulfur uptake increased dramatically by 286% in seeds and 190% in straw under 0.2% sulfur applied as nitrosulf.

[9] Noted that applying the full recommended dose of fertilizers (120:40:20:40 kg/ha N:P_2O_5:K_2O:S), along with 10 t/ha FYM, 25ikg/ha $ZnSO_4$, and seed treatment with Azotobacter, resulted in the highest nitrogen and phosphorus uptake in mustard.

[26] Reported that sulfur application at 40ikg/ha in the 'Pusa Mahak' mustard variety led to a sulfur-use efficiency of 10.4 kg seed per kg of sulfur. Similarly, [27] showed significant increases in N, P, K, S, Zn, and B uptake when the full RDF was supplemented with 2 t/ha FYM, 40ikg sulfur, 25ikg $ZnSO_4$, 1 kg B, and Azotobacter seed inoculation.

[28], experimenting with boron at 0, 1, and 2 kg/ha on BARI Sarisha-8, observed significant increases in boron, nitrogen, phosphorus, sulfur, and zinc content in both grain and stover, with grain boron rising from 19.96 µg/g to 51.29 µg/g.

Singh and Pal (2011) concluded that integrating RDF (120:17.6:16.6:40 kg/ha N:P:K:S) with FYM, $ZnSO_4$, and Azotobacter provided the highest macro- and micronutrient uptake. [29] Observed that full RDF application maximized nitrogen uptake in stover, while partial RDF substitutions through FYM enhanced seed nitrogen and phosphorus uptake.

[30] Found that using 75%iNPK with 5 t/ha FYM significantly improved nitrogen and phosphorus uptake. The highest available nitrogen (175ikg/ha) and phosphorus (12 kg/ha) were obtained under 100%iNPK, while sulfur availability peaked with 75%iNPK plus FYM.

[31] Noted that applying boron up to 20 kg borax/ha improved concentrations and uptake of boron, iron, manganese, copper, and zinc in mustard plants. [19] reported that combining 50% nitrogen through organic manure with 50% from chemical sources significantly enhanced N and P uptake.

[32] Tested different levels of FYM and mineral nutrients, including sulfur, zinc sulfate, and iron sulfate. Each successive increase in FYM and nutrient levels improved nitrogen content and uptake in mustard seeds and stover.

[33] demonstrated that using 5it/ha FYM with phosphate-solubilizing microorganisms (PSM) and Azospirillum significantly increased nutrient uptake compared to 2.5it/ha FYM or PSM alone. Additionally, raising inorganic nitrogen application from 0 to 80 kg/ha enhanced mustard's nutrient uptake.

[34] Reported maximum total uptake of nitrogen (97.87 kg/ha), phosphorus (21.82 kg/ha), and potassium (152.82ikg/ha) under a combined application of 100% RDF plus 25 kg/ha each of zinc and iron. Mallick and Raj (2015) observed improved phosphorus and sulfur uptake with 60ikg P_2O_5/ha and 20ikg S/ha, while boron application raised phosphorus and sulfur uptake by 12.75% and 12.78%, respectively.

5. EFFECT OF NUTRIENT MANAGEMENT ON QUALITY OF INDIAN MUSTARD

Nutrient management practices play a pivotal role in enhancing the quality attributes of Indian mustard, including oil and protein content. [35] Reported that plots receiving the full recommended dose of fertilizer (RDF) recorded the highest oil content (39.2–39.5%), oil yield (704.9–710.3 kg/ha), protein content (18.1–19.3%), and protein yield (328.9–346.6 kg/ha).

In a field trial conducted on sandy clay loam soils, [36] evaluated the impact of various sulfur application levels (0, 15, 30, 45, and 60 kg S/ha). The highest oil and crude protein contents were recorded at the highest sulfur dose of 60 kg/ha. Singh et al. [37] similarly noted that maximum oil and protein content, as well as their respective yields, were closely associated with elevated levels of nitrogen, sulfur, and zinc.

[38] found that increasing zinc levels from 0 to 8 kg/ha significantly improved mustard oil content, peaking at 36.80% before plateauing at higher levels. [39] observed enhanced oil content in mustard grains with the combined use of 10 t/ha FYM and 45 kg/ha phosphorus, consistent across two cropping seasons.

[40] highlighted the synergistic impact of sulfur and boron in improving protein yield. The maximum protein yield (5.43 q/ha) was obtained with 60 kg

S/ha + 1 kg Fe/ha, followed by 4.95 q/ha with 40 kg S/ha + 1 kg Fe/ha. Additionally, zinc application at 10 kg/ha significantly improved seed yield (20.96 q/ha), oil yield (8.03 q/ha), and protein yield (4.71 q/ha).

[41] Reported that under irrigated conditions, the application of 100% RDF (90 kg N and 40 kg P_2O_5/ha) combined with dual inoculation of Azotobacter and phosphate-solubilizing bacteria (PSB) significantly boosted the oil content and overall quality of the mustard cultivar 'Ashirwad'. [42] further observed that potassium application at 90–120 kg/ha led to the highest oil content, reaching up to 45.1%, and underscoring potassium's vital role in quality enhancement.

6. EFFECT OF NUTRIENT MANAGEMENT ON ECONOMICS OF INDIAN MUSTARD

Nutrient management significantly influences the economic viability of Indian mustard cultivation. [43] found that applying 100% of the recommended nitrogen and phosphorus (NP) through chemical fertilizers during the winter season yielded the highest net returns (₹15,537/ha), benefit-cost (B:C) ratio (2.07), and agronomic efficiency (16.1). Comparable economic gains were observed when applying 50% nitrogen and 100% phosphorus through fertilizers in maize-mustard cropping systems.

[44] reported that integrating 75% of the recommended chemical fertilizers with 6 t/ha of farmyard manure (FYM) resulted in the highest cost of production (₹24,299–₹24,962/ha), net profits, and B:C ratio in mustard cultivar 'Vardan'. Similarly, [45] concluded that applying 150 kg N/ha, 30 kg S/ha, and 0.50 kg Zn EDTA/ha yielded the greatest economic returns and the highest B:C ratio.

[27] observed that applying 100% RDF (120 kg N, 40 kg P_2O_5, 20 kg K_2O/ha), supplemented with 2 t/ha FYM, 40 kg sulfur, 25 kg $ZnSO_4$, 1 kg boron, and seed treatment with Azotobacter, led to the highest economic returns and benefit-cost outcomes. Meena et al. [46] similarly noted the maximum net return (₹36,776/ha) and B:C ratio (2.62) with 100% RDF (80 kg N + 40 kg P_2O_5/ha), outperforming 75% RDF.

[47] demonstrated that using two irrigations alongside 125% RDF significantly increased profitability, achieving net returns of ₹40,441/ha and ₹36,916/ha, with B:C ratios of 4.37 and 3.82, respectively. In terms of sulfur,. [18] reported the highest net income (₹25,913/ha) with 40 kg S/ha, while 60 kg S/ha yielded a maximum seed yield (16.09 q/ha) and net return (₹25,609/ha), though statistically non-significant.

Mallick and Raj (2015) found that maximum returns were achieved with 60 kg P_2O_5/ha (₹40,852.75/ha) and 20 kg S/ha (₹38,477/ha), while the best B:C ratios were seen with 30 kg P_2O_5/ha (2.87) and 20 kg S/ha (2.48). Application of 1 kg B/ha increased net return by 13.9% and B: C ratio to 7.11 over the control.

S [22] observed that combining RDF (120:60:40:30 kg/ha NPKS) with 5 t/ha of vermicompost led to the highest gross return (₹81,575/ha), net profit (₹35,725/ha), and B:C ratio (1.96), significantly outperforming RDF alone, which had the lowest gross income (₹69,419/ha). Treatments involving RDF with FYM at 6 t/ha recorded the lowest net returns and B: C ratios [48, 49].

7. CONCLUSION

This review clearly demonstrates that integrated nutrient management, which combines both organic and inorganic inputs, substantially improves the growth, yield, quality, and economic returns of Indian mustard. The incorporation of recommended doses of NPK fertilizers alongside organic amendments such as farmyard manure (FYM), vermicompost, and biofertilizers including Azotobacter and phosphate-solubilizing bacteria (PSB) consistently outperforms the application of chemical fertilizers alone. Such integrated practices enhance key agronomic parameters like plant height, number of siliquae, seed weight, and oil and protein content, while also contributing to improved soil fertility and biological activity. Moreover, they strengthen plant resilience against abiotic and biotic stresses, reduce dependency on synthetic inputs, and promote more sustainable cropping systems. Given the rising demand for edible oils and the need to reduce import dependence, implementing balanced and sustainable nutrient management strategies is vital. These practices not only ensure optimal mustard productivity but also support long-term soil health, environmental conservation, and economic viability for farmers. Therefore, adopting integrated nutrient management is essential for achieving sustainable mustard cultivation and enhancing the overall performance of oilseed-based cropping systems in India.

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