<u>Review Article</u>

Effect of nutrient management on Indian mustard[*Brassica juncea* (L.)]: A review

ABSTARCT

This review explore the impact of various nutrient management on mustard cultivation. Integrating organic and inorganic fertilizers significantly enhances plant height, branch number, siliquae per plant, seeds per siliqua, seed yield, and oil content. Treatments combining farmyard manure (FYM), vermicompost, and biofertilizers such as Azotobacter and phosphorus-solubilizing bacteria (PSB) with recommended doses of NPK fertilizers showed superior results compared to inorganic fertilizers alone. The application of vermicompost and FYM not only improved nutrient uptake and soil properties but also increased the synthesis of beneficial phenolic compounds, enhancing plant health and pest resistance. This integrated nutrient management approach demonstrates a sustainable method to optimize mustard crop production, ensuring higher yields and better-quality seeds.

Key words: *FYM, growth attribute,integratednutrient management, mustard and yield.*

INTRODUCTION

India holds a significant position in both the production and consumption of oilseeds worldwide. During the 2018-19 period, the global area, production, and yield of rapeseed-mustard were estimated at 36.59 million hectares (mha), 72.37 million tonnes (mt), and 1980 kg/ha, respectively. India contributed 19.8% of the total acreage and 9.8% of the total production worldwide (USDA). Over the past eight years, productivity has significantly increased from 1840 kg/ha in 2010-11 to 1980 kg/ha in 2018-19. Additionally, production has risen from 61.64 mt in 2010-11 to 72.42 mt in 2018-19. **(Anonymous, 2019).**These crops are crucial for generating edible oils, which are essential components of the Indian diet and various industrial processes.Mustard plays a crucial role in the Indian diet, offering both culinary variety and nutritional benefits. Mustard seeds are essential in many regional dishes, often fried in oil to enhance the flavor of curries, pickles, and chutneys. Mustard oil, with its distinctive pungent taste, is commonly used for frying, and as a dressing, especially in northern and eastern India. Nutritionally, mustard seeds and oil are packed with omega-3 fatty acids, antioxidants, and important nutrients like selenium, magnesium, and manganese, which contribute to health and wellness. Economically, mustard is a vital crop in India, providing income for many farmers and bolstering the agricultural sector. However, the specific circumstances surrounding oilseed cultivation in India can vary due to factors such as weather conditions, low fertility levels, soil fertility status, governmental policies, and market dynamics. India grows a variety of oilseeds including soybeans, groundnuts, rapeseed-mustard, sunflower, sesame, and cottonseed.

Mustard production in India has shown variability influenced by multiple factors. Mustard, a significant oilseed crop in the country, is mainly grown for its oil, widely used in cooking and food production. Mustard is primarily cultivated in states like Rajasthan, Uttar Pradesh, Madhya Pradesh, and Haryana. Production levels fluctuate due to factors such as weather conditions, fertility status, soil fertility levels, nutrient recommendations, irrigation availability, pest attacks, and market prices. Recent efforts aim to boost mustard cultivation to reduce reliance on imports and meet domestic oil demand. Limited adoption of modern farming methods like high-yield varieties and mechanization hampers yield improvements.Nutrient management significantly influences mustard production by directly impacting plant growth, development, and eventual yield. Nitrogen is vital for fostering leaf and stem growth in mustard plants. When supplied appropriately, it stimulates robust vegetative development, resulting in increased biomass and yield. Thus, precise nitrogen management, including proper timing and dosage of fertilizers, is crucial for optimizing mustard production. Phosphorus is essential for root development, flowering, and seed formation. It facilitates energy transfer within the plant, improving nutrient uptake and utilization. Adequate phosphorus levels encourage early flowering, enhance seed setting, and boost yield. Insufficient phosphorus can lead to delayed maturity and diminished seed yield. Sufficient potassium enhances resilience to drought, fortifies resistance against pests and diseases, and promotes seed filling and oil content in mustard crop. Potassium deficiency may stunt growth, impair seed development, and reduce yield. As a constituent of essential amino acids and vitamins, sulfur is crucial for protein synthesis, chlorophyll production, and enzyme activation. Ample sulfur improves plant growth, boosts photosynthetic efficiency, and elevates seed yield and oil content. Shortages of sulfur can lead to yellowing, hindered growth, and subpar seed quality. Mustard crops require trace elements like iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), and molybdenum (Mo) for various metabolic and physiological functions. Deficiencies or imbalances in micronutrients can detrimentally affect mustard production by impeding growth, nutrient absorption, and seed yield. Hence, careful management of micronutrients through soil analysis, foliar application, or soil amendments is vital for optimal mustard cultivation. In essence, proficient nutrient management is pivotal for maximizing mustard production, yielding superior quality seeds, and enhancing oil content. Farmers should adopt balanced fertilization practices tailored to soil conditions and crop needs to ensure sustainable mustard cultivation and robust yields.

EFFECT OF NUTRIENT MANAGEENT ON GROWTH OF INDIAN MUSTARD

Hamid *et al.* (2003) conducted an experiment on mustard in Aligarh, UP, and observed that microbial inoculants positively affected vegetative growth (shoot length, fresh and dry weights, and number of leaves per plant) and yield characteristics (pods per plant, seeds per pod, 1000-seed weight, and seed yield) at harvest. The highest values for these parameters were obtained with Azotobacter applied alone, though all inoculant combinations performed better than the uninoculated control. Premi *et al.* (2004) found that applying 5 t/ha of vermicompost along with 75% of the recommended dose of fertilizer (RDF) resulted in the highest plant height, number of primary and secondary branches, siliquae per plant, and seeds per siliqua, ultimately leading to a higher seed yield. This treatment was comparable to using 10 t/ha of farmyard manure (FYM) combined with 75% RDF.Singh *et al.* (2008) found that the integrated use of recommended fertilizers with organic and biological nutrient sources significantly increased plant height, branches per plant, number of siliquae, seed weight per plant, seed yield, and oil yield of mustard. Theunissen *et al.* (2010) observed that vermicompost contains essential plant nutrients such as nitrogen, phosphorus,

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potassium, calcium, magnesium, zinc, copper, and boron. These nutrients positively impact plant nutrition, photosynthesis, and chlorophyll content in leaves, enhancing the nutrient content in various plant parts, including roots, shoots, and fruits. The high humic acid content in vermicompost also promotes plant health by stimulating the synthesis of phenolic compounds like anthocyanins and flavonoids, which can improve plant quality and act as a defense against pests and diseases.Singh *et al.* (2010) found that mean plant height, total dry matter accumulation, leaf area, and seed yield of mustard were higher when 100% of the recommended fertilizers (120:40:20:40 kg/ha $N:P_2O_5:K_2O:S$) were applied along with 10 t/ha of farmyard manure (FYM), 25 kg/ha of $ZnSO_4$, and seed treatment with Azotobacter. Rundala *et al.* (2013) reported that different fertility levels significantly affected all growth parameters, including plant height and dry matter accumulation per plant, as well as yield attributes such as the number of branches per plant, siliquae per plant, seeds per siliqua, and test weight, yield (seed and stover), and net returns of mustard. The highest values for these parameters were recorded with 75% RDF through FYM and 25% through fertilizers, which were comparable to 50% RDF through FYM and 50% through fertilizers, except for stover yield, which was comparable to 100% RDF through FYM and significantly superior to other treatments. Additionally, dual inoculation with Azotobacter and PSB significantly increased plant height, dry matter accumulation per plant, number of branches per plant, siliquae per plant, seeds per siliqua, test weight, seed and stover yield, and net returns compared to the control. Kumar *et al.* (2017) found that applying 50% of the recommended dose of fertilizers along with farmyard manure and Azotobacter (as a seed treatment) resulted in the maximum plant height and number of primary and secondary branches per plant. Significant differences in growth were observed between 100% and 50% of the recommended dose of fertilizers combined with farmyard manure and Azotobacter. The 50% RDF with farmyard manure and Azotobacter also resulted in significantly higher germination percentage, root length, shoot length, and seed vigor index compared to the control.

EFFECT OF NUTREINT MANAGEMENT ON YIELD ATTRIBUTES AND YIELD OF INDIAN MUSTARD

Singh and Sinsinwar (2006) reported that the application of 5 t/ha of farmyard manure combined with Azotobacter chroococcum and Azospirillum significantly increased the number of primary and secondary branches, 1000-seed weight, oil content, and yields of seed and straw in Indian mustard compared to the control. Nagdive *et al.* (2007) observed that the number of siliquae, seed yield, and oil yield of mustard significantly increased with the application of 75% RDF and FYM at 5 t/ha combined with Azotobacter and PSB. This treatment also resulted in higher growth, yield-attributing characters, and seed yield compared to the control. Satyajeet and Nanwal (2007) found the highest grain yield of mustard with the application of 100% of the recommended dose of fertilizer (RDF) along with vermicompost and biofertilizer. Comparable yields were also achieved with 100% RDF and 75% RDF combined with 5 t/ha of vermicompost and biofertilizer. Pal *et al.* (2008) reported the highest number of siliquae and seed yield in mustard using an integrated nutrient management (INM) package with 100% of the recommended fertilizer, followed by treatments with 75% and 50% of the recommended fertilizer level using the same INM package. Ramesh *et al.* (2009) observed that organic nutrient management practices significantly increased the number of siliquae per plant, seeds per siliqua, and seed yield of Indian mustard compared to both the recommended dose of

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fertilizers and the control. Their study focused on the impact of manure and vermicompost on the yield of winter rapeseed. Singh *et al*. (2011) reported that applying 100% of the recommended NPK rates along with 50% farmyard manure, 50% vermicompost, and Azotobacter resulted in the highest plant height, number of branches per plant, number of siliquae per plant, seed weight per plant, seed yield, oil content, and oil yield in mustard. Parihar *et al.* (2014) noted that growth and yield attributes, as well as seed yield in mustard, significantly increased with higher levels of fortified vermicompost. Applying 6.0 t/ha resulted in a seed yield of 15.65 q/ha, representing increases of 10.86%, 13.34%, and 79.68% over applications of 4.0 t/ha, 2.0 t/ha, and the control, respectively. Saikia *et al.* (2013) observed that integrating 50% N from organic manure with 50% N from chemical fertilizer significantly increased the seed and stover yields of mustard. The highest seed and stover yields recorded were 11.99 q/ha and 43.75 q/ha, respectively. Similarly, Kansotia *et al.* (2015) reported that applying vermicompost at rates of 2, 4, and 6 t/ha consistently and significantly increased seed and stover yields, protein content and oil content. Specifically, applying vermicompost up to 6 t/ha along with 50 kg N and 40 kg P□O□ per hectare significantly enhanced yields, protein content (25.7%) and oil content (40.6%).Kumar *et al.* (2015) found that the highest grain yield of 20.78 q/ha in mustard was obtained with the treatment T_{12} (N:120 P:50 K:50), where 120 kg of nitrogen was applied with 50 kg each of phosphorus and potassium. In contrast, the control treatment (T1) recorded a grain yield of 10.10 q/ha. The combination of N, P, and K was superior to their individual applications, showing better yield, growth, uptake, and other parameters due to the synergistic effect of N with P and K.Thaneshwar (2017) found that the combined application of the recommended dose of fertilizer (RDF) and 5.0 t/ha of vermicompost resulted in significantly better growth attributes, yield attributes, and grain yield (22.75 q/ha) for mustard compared to other treatments. The lowest grain yield (19.15 q/ha) was recorded with the RDF treatment alone (120:60:40:30 kg/ha of NPKS).

EFFECT OF NUTRINT MANAGEMENT ON NUTRIENT CONTENT AND UPTAKE OF INDIAN MUSTARD

Various studies have delved into the impact of various nutrients treatments on the nutrient content and uptake of Indian mustard. Meena *et al.* (2008) concluded that the application of zinc iron and enriched farmyard manure (FYM) increased the content of nitrogen, sulfur, and micronutrients by mustard plants, leading to an improvement in both oil and protein content in mustard seeds.Dadheech *et al.* (2009) conducted an experiment on Indian mustard in Rajasthan, examining various nutrient treatments. These treatments included inorganic nutrient sources alone (60 kg N + 40 kg P_2O_5 per hectare), a combination of 10 tons per hectare of farmyard manure (FYM) with inorganic sources, and a combination of 5 tons per hectare of poultry manure with inorganic sources. The findings indicated that the application of inorganic nutrient sources led to a significant enhancement in nitrogen (N) and phosphorus (P) uptake by both seeds and stover, as well as overall nutrient uptake, compared to the combinations involving poultry manure with inorganic sources and FYM with inorganic sources. Simillarly, Bose *et al.* (2009) noted a progressive rise in the total sulfur content within the dry matter of rapeseed up to 80 days after crop growth initiation, particularly when sulfur was administered as nitrosulf or elemental S. They found that the increase was more pronounced with nitrosulf application compared to elemental S. The maximum sulfur uptake by both rapeseed and straw was observed to be 286% and 190% higher respectively compared to the control in treatment with 0.2% sulfur as nitrosulf.

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Futhermore, Singh *et al.* (2010) found that utilizing the recommended fertilizers at 100%, consisting of a ratio of 120 parts nitrogen (N), 40 parts phosphorus pentoxide (P_2O_5), 20 parts potassium oxide (K_2O), and 40 parts sulfur (S) per hectare, alongside farmyard manure (FYM) at a rate of 10 tons per hectare, applying zinc sulfate ($ZnSO_4$) at 25 parts per hectare, and treating seeds with Azotobacter, resulted in the highest nitrogen (N) and phosphorus (P) content, as well as their uptake in both seed and stover of mustard.Thuan and Rana (2010) observed that the utilization of 40 kg/ha of sulfur resulted in an increase in sulfur uptake in seeds and exhibited a beneficial response to sulfur application (kg of seed per kg of sulfur) in 'Pusa Mahak' variety, reaching 10.4 kg. Tripathi *et al.* (2011) found that N, P, K, S, Zn and B content in both seed and stover significantly increased when utilizing the complete recommended dose of fertilizers (120-40-20 kg N-P_2O_5-K_2O ha) in conjunction with 2 tons of Farm Yard Manure (FYM), 40 kg of sulfur (S), 25 kg of zinc sulfate ($ZnSO_4$), 1 kg of boron (B) per hectare, and seed treatment with Azotobacter. This was compared to using only 75% of the recommended fertilizer dose. Hossain *et al.*(2011) carried out a field study involving three levels of boron (0, 1, and 2 kg ha^{-1}) on the BARI Sarisha-8 variety of mustard (*Brassica napus*). They observed that increasing the application rate of boron led to a significant increase in boron and nitrogen concentrations in both grain and stover. Additionally, phosphorus (P), sulfur (S), and zinc (Zn) concentrations showed a significant increase, while potassium (K) concentration remained unchanged in stover. In grain, the concentration of boron increased from 19.96 µg/g in the control to 45.99 µg/g and 51.29 µg/g with the application of 1 kg and 2 kg of boron per hectare, respectively.Singh and Pal (2011) conducted a field experiment on mustard during the winter seasons of 2005-06 and 2006-07, wherein they applied the recommended dose of fertilizers(RDF) at a ratio of (120:17.6:16.6:40) N:P:K:S kg per hectare, alongside 10 tons per hectare of farmyard manure (FYM), 25 kilograms of zinc sulfate ($ZnSO_4$) per hectare, and seed treatment with Azotobacter. The combined application of RDF with FYM, Zn, and Azotobacter resulted in the highest values of nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and zinc (Zn) content, as well as their uptake. Rundala *et al.* (2012) conducted a field experiment on loamy sand soil during the rabi season of 2009-10. They found that varying fertility levels significantly influenced the nutrient uptake of Indian mustard. Application of 100% recommended dose of fertilizer (RDF) resulted in the highest nitrogen uptake by the stover, but this was comparable to the combination of 75% RDF through farmyard manure (FYM) and 25% through fertilizers, as well as 25% RDF through FYM and 75% through fertilizers. On the other hand, the combination of 75% RDF through FYM and 25% through fertilizers showed the highest nitrogen uptake by the seed compared to the control and 100% RDF through FYM. Phosphorus uptake in both seed and stover significantly improved with the application of 75% RDF through FYM and 25% through fertilizers, which was similar to the results obtained with 50% RDF through FYM and 50% through fertilizers. Singh *et al.* (2013) noted that applying 75% of the recommended dosage of nitrogen, phosphorus, and potassium (NPK) along with 5 tons of farmyard manure (FYM) per hectare resulted in significantly increased uptake of nitrogen (N) and phosphorus (P). However, the highest values of available nitrogen (175 kg per hectare) and phosphorus (12.0 kg per hectare) were observed under sole application of 100% NPK.Choudhary and Bhogal (2013) found that applying boron up to 20 kg borax ha^{-1} resulted in a significant increase in the levels of boron, iron, manganese, copper, and zinc in plants of the mustard cultivar. Additionally, they observed an increase in the uptake of these micronutrients with boron application. Singh *et al.* (2013) found that the highest uptake of nitrogen (N),

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phosphorus (P), potassium (K), and sulfur (S) occurred with the combined application of 75% NPK fertilizers and Farm Yard Manure (FYM) treatment. However, the maximum values of available nitrogen (175 kg ha^{-1}), phosphorus (12.0 kg ha^{-1}), and potassium (155.0 kg ha^{-1}) were observed under the application of 100% NPK alone. Conversely, the maximum value of available sulfur (17.1 kg ha^{-1}) was found with the combination of 75% NPK fertilizers and 5 tons of FYM per hectare.

Saikia *et al.* (2013) conducted a field experiment on Indian mustard during the rabi season of 2009-10. Their findings indicated that applying 50% of the nitrogen (N) requirement through organic manure in combination with 50% N through chemical fertilizer resulted in a significant increase in nitrogen (N) and phosphorus (P) uptake compared to the control group. Jat *et al.* (2013) conducted a field experiment incorporating three levels of Farm Yard Manure (FYM) - control, 5 tons per hectare, and 10 tons per hectare - along with five levels of mineral nutrients. These included no mineral nutrients, 40 kg of sulfur per hectare, 40 kg of sulfur per hectare plus 25 kg of zinc sulfate per hectare, 40 kg of sulfur per hectare plus 50 kg of iron sulfate per hectare, and 40 kg of sulfur per hectare plus 25 kg of zinc sulfate per hectare plus 50 kg of iron sulfate per hectare. The results indicated that each successive level of FYM and mineral nutrients, both individually and in combination, significantly enhanced the content and uptake of nitrogen in seeds and stover of mustard compared to the control group.Singh and Singh (2014) noted that applying 5.0 tonnes per hectare of farmyard manure (FYM) along with phosphate-solubilizing microorganisms (PSM) and Azospirillum, or using only PSM, resulted in significantly higher nutrient uptake in mustard compared to solely applying 2.5 tonnes of FYM per hectare. Additionally, they observed that increasing the application of inorganic nitrogen fertilizer from 0 to 80 kg per hectare significantly enhanced the nutrient uptake of mustard. Kumar *et al.* (2014) noted that the mustard crop exhibited the highest uptake of total nitrogen, phosphorus, and potassium, amounting to 97.87 kg ha^{-1}, 21.82 kg ha^{-1}, and 152.82 kg ha^{-1}, respectively, in the treatment involving Ts {100% NPK (recommended dose of fertilizers) + 25 kg ha^{-1} of zinc (B) + 25 kg ha^{-1} of iron (B).Mallick and Raj (2015) conducted a field trial examining various levels of phosphorus (0, 30, and 60 kg P□O□/ha), sulfur (0, 20, and 40 kg S/ha), and boron (0 and 1 kg B/ha). Their findings revealed significant uptake of phosphorus and sulfur up to 60 kg P□O□/ha and 20 kg S/ha, respectively. Additionally, the application of boron led to notable enhancements in phosphorus (12.75%) and sulfur (12.78%) uptake.

EFFECT OF NUTRIENT MANAGEMENT ON QUALITY OF INDIAN MUSTARD

In a study by Ramanjaneyulu (2006) noted that the maximum oil content, oil yield, protein content, and protein yield were recorded as 39.2-39.5%%, 704.9-710.3 kg/ha, 18.1-19.3%, and 328.9-346.6 kg/ha, respectively, in plots treated with recommended dose of fertilizer (RDF). Raja *et al.* (2007), a field experiment was carried out on sandy clay loam soils on mustard crop, examining the effects of varying sulfur levels (S 0: 0 kg S/ha, S 15: 15 kg S/ha, S 30: 30 kg S/ha, S 45: 45 kg S/ha, and S 60: 60 kg S/ha). It was observed that the application of 60 kg S/ha resulted in the highest oil content and crude protein. Singh *et al.* (2010) noticed that the oil and protein content as well as oil and protein yields, showed a strong association with the highest concentrations of nitrogen, sulfur, and zinc (150:60 and 1.0 kg/ha). Sahito (2014) noted a significant rise in oil content, reaching 36.80%, in mustard crops as zinc levels were incrementally increased across six levels (0, 2, 4, 6, 8, and 10 kg Zn ha^{-1}). The increase was observed up to the 8 kg ha^{-1} level of zinc application. Similarly, Gupta *et al.* (2012) noted that the utilization of 10 tons of Farm Yard

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Manure (FYM) along with 45 kilograms of phosphorus resulted in an increase in the oil content of mustard grains across both seasons. Verma *et al.* (2012) observed that the synergistic effects of sulfur and boron were notable in enhancing protein yield, with the highest protein yield recorded in the combination of 60 kg S ha^{-1} plus 1.0 kg Fe ha^{-1} (5.43 q ha^{-1}), followed by 40 kg Sha^{-1} plus 1.0 kg Fe ha^{-1} (4.95 q ha^{-1}). Furthermore, the application of 10 kg Zn ha^{-1} significantly boosted seed yield (20.96 q ha-1), oil yield (8.03 q ha^{-1}), protein yield (4.71 q ha^{-1}) in mustard crops.

Dabi *et al.* (2015) found that under irrigated conditions, applying 100% recommended dose of nitrogen and phosphorus (90 kg N and 40 kg P□O□/ha) along with dual inoculation of Azotobacter and phosphate-solubilizing bacteria (PSB) significantly enhanced the quality and oil content of Indian mustard (cultivar 'Ashirwad').According to Ahmed *et al.* (2015), the application of potassium (K) at rates of 120 kg/ha and 90 kg/ha resulted in the highest oil content (45.1%) and protein content (27.7%), respectively.

EFFECTOF NUTRIENT MANAGEMENT ON ECONOMICS OF INDIAN MUSTARD

Kumpawat (2004) documented that during the winter season, the application of 100% recommended nitrogen-phosphorus (NP) through inorganic fertilizers yielded the highest net monetary returns (Rs 15,537/ha), benefit-cost ratio (2.07), and agronomic efficiency (16.1). Additionally, for maize and mustard crops, the treatment involving 50% and 100% recommended nitrogen and phosphorus application through fertilizers, respectively, also resulted in maximum net monetary returns, benefit-cost ratio, and agronomic efficiency equivalent to those observed in the previous case. Singh *et al.* (2005) assessed the impact of combining organic manure with chemical fertilizers on the growth of Indian mustard cv. Vardan. They found that utilizing a mixture of 75% chemical fertilizer along with farmyard manure (FYM) at a rate of 6.0 t/ha led to the highest production cost values (Rs 24,299 and Rs 24,962/ha), net returns, and benefit-cost ratio.Singh *et al.* (2010) performed a field experiment involving various nitrogen (N), sulfur (S), and zinc (Zn) application levels. They observed that the mustard crop treated with 150 kg N/ha, 30 kg S/ha, and 0.50 kg Zn EDTA/ha attained the highest net returns along with the maximum benefit-cost ratio. Similarly, Tripathi *et al.* (2011) noted that the highest net returns and benefit-cost ratio were achieved in mustard crops when fertilized with 100% recommended dose of fertilizers (120 kg N, 40 kg P□O□, and 20 kg K□O per hectare), along with 2 tons of farmyard manure (FYM), 40 kg sulfur (S), 25 kg zinc sulfate (ZnSO□), 1 kg boron per hectare, and seed treatment with Azotobacter.

Meena *et al.* (2013) observed that the application of 100% RDF (80 kg N+40 kgP205) were maximum net return (Rs. 36776) and B:C ratio (2.62) as compared to 75%RDF.Trivedi *et al.* (2013) found that the highest net monetary returns, amounting to Rs. 40,441/ha and Rs. 36,916/ha, along with benefit-cost ratios of 4.37 and 3.82, respectively, were achieved when employing two irrigation cycles and applying 125% recommended dose of fertilizers (RDF).

According to Parihar *et al.* (2014), there was a gradual rise in sulfur levels from the control group to 40 kg per hectare, resulting in the highest net returns of Rs 25913 per hectare. Subsequently, increasing the sulfur level to 60 kg per hectare led to maximized seed yield (16.09 q ha-1) and net returns (Rs 25609 per hectare), although this increase did not reach a statistically significant level.Mallick and Raj (2015) conducted a study on mustard, varying levels of phosphorus (0, 30, and 60 kg P2O5 ha^{-1}), sulfur (0, 20, and 40 kg S ha^{-1}), and boron (0 and 1 kg B ha^{-1}). They observed that the highest net returns were obtained with 60 kg P_2O_5 ha^{-1} (Rs 40852.75 per hectare) and 20 kg S ha^{-1} (Rs 38477 per hectare). Additionally, the benefit-to-cost ratio was maximized with 30 kg P_2O_5 ha^{-1} (2.87) and

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20 kg S ha^{-1} (2.48). Application of boron also significantly improved net returns (13.9%) and the benefit-to-cost ratio (7.11) compared to the control. Thaneshwar *et al.* (2017) observed that applying recommended dose of fertilizer (RDF) along with vermicompost at a rate of 5.0 tons per hectare resulted in significantly higher gross income (Rs 81575 per hectare) and net profit (Rs 35725 per hectare) compared to other treatments. The benefit-to-cost ratio was also significantly higher (1.96) with RDF application (120:60:40:30 kg/ha NPKS) compared to other treatments, except for RDF with vermicompost at 2.0 tons per hectare, which showed comparable results. The treatment with RDF alone (120:60:40:30 kg/ha NPKS) recorded the lowest gross income (Rs 69419 per hectare), while the minimum net income and benefit-to-cost ratio were observed in the treatment with RDF along with farmyard manure (FYM) at 6.0 tons per hectare.

CONCLUSION

Thereview concludes that integrating organic and inorganic nutrient management practices significantly enhances the growth, yield, and quality of mustard. Combining recommended doses of NPK fertilizers with organic amendments such as farmyard manure, vermicompost, and biofertilizers like Azotobacter and PSB leads to superior plant performance compared to the use of inorganic fertilizers alone. This integrated approach not only boosts yield attributes and oil content but also improves soil health and plant resistance to pests. Adopting such sustainable nutrient management strategies is crucial for optimizing mustard production and ensuring long-term agricultural productivity.

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