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Integrated nutrient management in rapeseed and mustard: A review

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Abstract
Integrated nutrient management is important for increasing resource efficiency and restoring and maintaining soil fertility. Overuse of chemical fertilizers has a deleterious influence on soil productivity, fertility, and other micronutrients. By changing the nutritional status in soil, integrated application of inorganic fertilizers with organic manures and bio-fertilizers greatly improves food grain yield, maintains soil fertility, and increases farmer's income. This article discuss the impact of integrated nutrition management on growth and production characteristics, nutrient content and uptake by rapeseed and mustard plants, nutrient availability in the soil, and the economics of rapeseed and mustard.

Keywords: Rapeseed and mustard, soil fertility, bio-fertilizers

Introduction
Oilseeds are India's most significant crops owing to their greater tolerance to a variety of agro-climatic conditions. India is the largest rapeseed-mustard growing country in the world, occupying the first position in area and second position in production after China. Rapeseed and mustard have a wide range of industrial applications and the oilcake from them may be used as manure (Bora *et al.*, 2021) [7]. Plant nutrients from organic and inorganic sources, as well as bio-fertilizers, are used to control the soil's long-term fertility and production while simultaneously reducing pollution (Antil and Narwal, 2007) [1]. For preserving soil fertility, health, and production, use of chemical fertilizer in combination with animal manures, compost, green manures, legumes in cropping systems, bio-fertilizers, crop residues, or recyclable garbage, and other locally accessible nutrient sources is an excellent way (Thaneshwar *et al.*, 2017) [35]. Bio-fertilizers, which are part of integrated nutrient management, are seen as cost-effective, environment friendly and renewable sources of non-bulky plant nutrients in India's sustainable agricultural system. PSB solubilizes unavailable phosphorus in soil and make it available to plants, whereas *Azotobater* is a non-symbiotic nitrogen fixing bacteria (Gudadhe *et al.*, 2005) [14].

Effect of integrated nutrient management on growth attributes
Shukla *et al.* (2002) [31] reported that total dry matter accumulation of Indian mustard (*Brassica juncea*) at harvest stage was significantly increased with the application of 100% RDF with supplementary dose of FYM @ 10 t ha^{-1}. Mishra and Giri (2004) [23] carried out a field experiment at New Delhi on mustard and reported that application of 80 kg N + 40 kg P_2O_5 ha^{-1} recorded the highest plant height and number of primary and secondary branches in mustard. Gudadhe *et al.* (2005) [14] observed that the seed inoculation with *Azotobacte*r or/and PSB along with 100% RDF significantly increased plant height, number of branches, dry matter and leaf area $plant^{-1}$ of mustard. Aswal and Yadav (2007) [2] reported that increasing levels of zinc and sulphur significantly increase the plant height and number of branches per plant in mustard. Dadheech *et al.* (2009) [9] found that application of 60 kg N + 40 kg P_2O_5 ha^{-1} significantly improved dry matter accumulation of mustard at harvest. Vivek and Singh (2009) [40] conducted a field experiment and found that application of 125% NPK increased plant height and number of branches of mustard. Tripathi *et al.* (2010) [39] conducted a field experiment at Pantnagar showed that application of recommended dose of NPK fertilizers along with FYM, S, Zn, B and seed treatment with *Azotobacter* produced significantly higher dry matter accumulation of mustard.
Tripathi *et al.* (2011) [38] reported that application of 100% RDF along with FYM, resulted in maximum plant height, dry matter accumulation and total branches in mustard. Singh *et al.*

(2014b) [32] was carried out a field experiment at Sewar, Bharatpur, Rajasthan and reported that application of FYM @ 5.0 t ha^{-1} and seed inoculation with either of the bacterial culture (*Azotobacter* and *Azospirillum*) significantly increased the number of primary and secondary branches in mustard. An experiment on integrated nutrient management in mustard was conducted by Singh *et al*. (2014a) [33] at Kanpur and the result shows that significantly highest plant height, fresh weight plant^{-1}, dry weight plant^{-1}, number of branches plant^{-1} and crop growth rate at 60 and 110 DAS of mustard was recorded with the application of 100% recommended dose of fertilizer + vermicompost @ 5.0 t ha^{-1} over 100% RDF, 100% RDF + vermicompost 2 t ha^{-1}, 100% RDF + vermicompost 3 t ha^{-1} and 100% RDF + 6 t ha^{-1}.

Mukherjee (2016) [24] reported that the highest plant height and leaf area of mustard was recorded with the application of FYM @ 30 t ha^{-1} during first year and application of FYM @ 20 t ha^{-1} in second year. The application of 100% RDF and inoculation of *Azotobacter* + *PSB* gave maximum plant height, number of primary branches and number of secondary branches in brown sarson (Brar *et al.*, 2016) [8]. Bijarnia *et al*. (2017a) [5] found that the application of 5 t FYM + 100% RDF gave highest plant height, dry matter accumulation, number of primary and secondary branches plant^{-1} and leaf chlorophyll content of mustard as compared to 5 t FYM + 50% of RDF+ Bio-fertilizer and 5 t FYM + 75% of RDF+ Bio-fertilizer. Dhruw *et al*. (2017) [10] reported that the plant height (cm), number of leaves plant^{-1} and number of branches plant^{-1} at 30, 60, 90 and 120 DAS in mustard was found maximum with the application of 120: 60: 40 kg NPK ha^{-1}. The significant effect of 75% NPK in combination with 40 kg S and 10 tonne FYM ha^{-1} on plant height, number of branches plant^{-1} and dry weight of mustard (Kumar *et al.*, 2017) [18]. Hadiyal *et al*. (2017) [15] reported significantly highest growth parameters *viz.*, number of primary and secondary branches per plant of mustard was recorded with the seed inoculation with *Azotobacter* spp. + *PSB* spp. (each @ 10 ml/kg seed). Saini *et al*. (2017) [30] conducted a field experiment and the results showed that treatment *Azotobacter* + *PSB* + 30 kg ha^{-1} N through inorganic fertilizer + 30 kg ha^{-1} N through poultry manure produced significantly higher plant height (95.53 cm) at 75 DAS, number of branch plant^{-1} (8.37) and dry weight (15.58 g) of mustard over control. The significantly better growth attributes *viz*. plant height, number of primary, secondary, tertiary and total branches per plant, fresh weight per plant and dry weight per plant of mustard was obtained with combined application of 100% RDF + vermicompost @ 5.0 t ha^{-1} over 100% RDF, 100% RDF + vermicompost @ 2.0 t ha^{-1}, 100% RDF + vermicompost @ 3.0 t ha^{-1} and 100% RDF + FYM @ 6.0 t ha^{-1} (Thaneshwar *et al.*, 2017).

According to Bisht *et al*. (2018) [6] the application of 75% RDF + 2.5 t FYM ha^{-1} was found best with respect to plant height (158.8 cm), number of primary branches per plant (5.2), number of secondary branches per plant (5.83) and dry matter accumulation (20.63 g) of mustard. Kumar *et al*. (2018b) [20] reported the plant height, branches plant^{-1}, dry matter accumulation and leaf area index of mustard was significantly increased with 50% RDF + FYM 6 t ha^{-1} + Vermicompost 2 t ha^{-1} + Bio-fertilizers than the rest of the treatments and according to Kumar *et al*. (2018a) the application of 75% RDF + *PSB* significantly increased the plant height of mustard. Murali *et al*. (2018) [25] reported that the maximum plant height (169.27 cm), number of branches (5.26) and dry weight (76.03 g) at 80 DAS of mustard was produced by application of 50% FYM + 50% vermicompost. The effect of INM on performance of mustard and results revealed that application of 75% chemical fertilizers and 25% with organic manure gave maximum plant height, number of branches, number of siliqua and weight of plant in mustard (Singh *et al.*, 2018) [34]. An experiment was conducted by Yadav *et al*. (2018) [41] at Kanpur and they reported that the highest plant height and dry weight at 90 DAS and harvest of mustard were recorded with the application of 50% RDN + 25% FYM + 25% vermicompost + *Azotobacter*.

The significant increase in plant height, branches plant^{-1} and leaf area index was observed with the application of three irrigations given at seedling, 50% flowering and pod formation stage along with 8kg Zn ha-1 as compared to control (Yadav *et al*. 2021) [42]. Diwakar *et al*. (2021) [11] reported that the highest growth attributes (at 60DAS) *viz*. plant height (83.63 and 83.70 cm), number of branches plant^{-1} (19.01 and 19.60) dry matter accumulation plant^{-1} (23.15 and 23.31) and highest growth attributes (at harvest) plant height (184.67 and 191.19 cm), number of branches plant^{-1} (23.65 and 24.53) dry matter accumulation plant^{-1} (56.72 and 57.60) with the application of 75% NPK+ N-25% (FYM) +S @40 kg + Mulching @5 t/ha^{-1} respectively, during *Rabi* session 2018-19 and 2019-20.

Effect of integrated nutrient management on yield attributes and yield

Mandal and Sinha (2004) [22] reported that the number of siliqua plant^{-1}, seeds siliqua^{-1}, 1000 seed weight and seed yield of mustard improved significantly with 100% RD of NPK along with FYM. Gudadhe *et al*. (2005) [14] observed that the seed inoculation with *Azotobacter* + PSB along with 100% RDF recorded the highest seed yield (1266 kg ha^{-1}) and straw yield (2982 kg ha^{-1}) followed by 75% RDF + *Azotobacter* + PSB, which recorded seed yield of 1227 kg ha^{-1} and stover yield of 2918 kg ha^{-1}. Premi *et al*. (2005) [28] was conducted a field experiment at Bharatpur, Rajasthan and they observed that the maximum seed yield (1625 kg ha^{-1}) was obtained by the application of 75% RDF + vermicompost @ 5 t ha^{-1}. Nagdiva *et al*. (2007) [26] observed that application of 75% RDF + *Azotobacter* + PSB along with FYM gave highest number of silique and seed yield of mustard over control. Sahoo *et al*. (2010)[29] reported that inoculation of seed with *Azotobacter* + 80 kg N ha^{-1} recorded highest seed yield of 13.17 q ha^{-1}. According to Tripathi *et al*. (2010) [39] the application of FYM 2 t ha^{-1} along with 75% RDF significantly increased mustard yield. Tripathi *et al*. (2011) [38] reported that maximum siliquae plant^{-1}, seeds siliqua^{-1}, 1000 seed weight and seed yield of mustard was produced by the application of 100% RDF along with FYM.

A field experiments was conducted at Sewar, Bharatpur, Rajasthan by Singh *et al*. (2014b) [32] and reported that application of FYM @ 5.0 t ha^{-1} and seed inoculation with either of the bacterial culture (*Azotobactor* and *Azospirillum*) significantly increased the number of pods plant^{-1}, number of seed pods^{-1}, test weight, seed and stover yield of mustard. Singh *et al*. (2014a) [33] studied that the effect of INM in mustard at Kanpur and reported that significantly maximum number of siliqua plant^{-1}, number of seeds siliqua^{-1}, seed yield, stover yield, biological yield and harvest index of mustard was recorded with the application of 100% RDF + vermicompost @ 5.0 t ha^{-1}.

According to Brar *et al.* (2016) [8] the application of 100% RDF and inoculation of *Azotobacter* + *PSB* gave maximum siliqua plant^{-1}, number of seeds siliqua^{-1} and seed yield of mustard. Kumar *et al.* (2016) [21] observed that application of 75% NPK + 5 t FYM + *PSB* + sulphur gave higher number of siliqua plant^{-1}, number of seeds siliqua^{-1} and seed yield of mustard over other treatments and control. The highest number of silique plant^{-1}, seeds siliqua^{-1} and seed yield of mustard was produced by the application of 5 t FYM + 100% RDF (Bijarnia *et al.*, 2017b) [4]. Hadiyal *et al.* (2017) [15] was reported that significantly highest number of siliqua plant^{-1}, seeds siliqua^{-1}, higher seed and stover yield of mustard was recorded with the application of FYM @ 5.0 t ha^{-1} with the seed inoculation with *Azotobacter* spp. + *PSB* spp. (each @ 10 ml/kg seed). The highest number of siliquae plant^{-1}, seed and stover yield of mustard was obtained by the application of 75% NPK in combination with 40 kg S and 10 t FYM ha^{-1} (Kumar *et al.*, 2017) [18]. According to Saini *et al.* (2017) [30], significantly highest number of siliqua plant^{-1} (235.33), number of seed siliqua^{-1} (20.40), seed yield (1500 kg ha^{-1}), stover yield (3790 kg ha^{-1}) and harvest index (28.36%) of mustard was produced with application of *Azotobacter* + *PSB* + 30 kg ha^{-1} N through inorganic fertilizer + 30 kg ha^{-1} N through poultry manure. Highest number of siliqua plant^{-1}, seeds siliqua^{-1}, test weight, seed yield, stover yield, biological yield and harvest index in mustard crop was produced with combined application of RDF + vermicompost @ 5.0 t/ha (Thaneshwar *et al.*, 2017) [35]. Bisht *et al.* (2018) [6] were revealed that significantly maximum seed weight per plant (6.03 g) and seed yield (20.09 q ha^{-1}) at harvest of mustard was recorded with the application of FYM @ 5.0 t ha^{-1}. Kumar *et al.* (2018b) [20] was conducted a field experiment and revealed that maximum siliqua length, siliqua plant^{-1}, seeds siliqua^{-1}, test weight, seed and stover yield of mustard was obtained by the application of 50% RDF + FYM 6 t ha^{-1} + Vermicompost 2 t ha^{-1} + bio-fertilizer. Kumar *et al.* (2018a) [19] was conducted a field experiment at Kanpur and reported that significant effect of 75% RDF and *PSB* was observed on number of siliqua plant^{-1}, number of seeds siliqua^{-1}, test weight, seed yield and stover yield of mustard as compared to remaining treatments. The maximum seed (2139 kg ha^{-1}) and stover (4994 kg ha^{-1}) yield was recorded under application of 75% RDF + FYM @ 5 t ha^{-1} + Zn @ 5 kg ha^{-1} + *Azotobacter*. Yadav *et al.* (2018) [41] was reported that the highest number of siliqua plant^{-1}, length of siliqua, seed yield and stover yield of mustard were recorded with the application of RDN 50% + 25% FYM + 25% vermicompost + 30 kg S + *Azotobacter*.

Diwakar *et al.* (2021) [11] conducted a field experiment during respective years 2018-19 and 2019-20 and reported that the highest seed yield and stover yield of mustard crop under the treatment 75% NPK + N-25% (FYM) + S@40 kg + Mulching @ 5 t ha^{-1}. Gora *et al.* (2022) [13] reported that the highest number of silique plant^{-1}, number of seeds siliqua^{-1}, seed yield (1.83 Mg ha^{-1}), stover yield (3.67 Mg ha^{-1}) and biological yield (5.50 Mg ha^{-1}) of mustard was significantly increase with the application of 100% RDF + Vermicompost (2 t ha^{-1}) + Azotobacter than other treatment.

Effect of integrated nutrient management on nutrient content, uptake and quality

Thanki *et al.* (2004) [36] was conducted a field experiment at Navsari and they observed that highest oil content and oil yield was recorded with combined application of 75 kg N+ 50 kg P + FYM @ 10 t ha^{-1}. Bhat *et al.* (2007) [3] observed that highest protein (23.88%) and oil content (42.90%) in mustard seed was registered with application of FYM-N (20 kg N) + 75% fertilizers N (60 kg N) + 40 kg S ha^{-1} over control.

Tiwari *et al.* (2012) [37] found that application of 100% RDF + 40 kg S ha^{-1} + 5 kg Zn ha^{-1} gave higher oil yield (831.8 kg ha^{-1}) in mustard. Kansotia *et al.* (2013) [16] conducted a field experiment and reported that application of 80 kg N + 40 kg P ha^{-1} + vermicompost up to 6 t ha^{-1} significantly increased the N and P content in seed and stover, N and P uptake in seed, stover and total plant and protein content of mustard over control and lower levels. Kansotia *et al.* (2015) [17] revealed that application of 80 kg N + 40 kg P ha^{-1} + vermicompost up to 6 t ha^{-1} significantly increased the protein content (26.0%) and oil content (39.9%) in seed of mustard.

According to Bijarnia *et al.* (2017b) [4], the application of 5 t FYM + 100% RDF gave maximum uptake of N, P and K in seed, stover and total plant of mustard. Application of 75% NPK in combination with 40 kg S and 10 t FYM ha^{-1} gave highest oil and protein content of mustard (Kumar *et al.*, 2017) [18]. Significantly highest oil content (42.03%) of mustard was produced with *Azotobacter* + *PSB* + 30 kg ha^{-1} N through inorganic fertilizer + 30 kg ha^{-1} N through poultry manure (Saini *et al.*, 2017) [30]. Kumar *et al.* (2018b) [20] was conducted a field experiment and revealed that highest nutrient uptake (N, P, K and S) by seed and stover of mustard was obtained by the application of 50% RDF + FYM 6 t ha^{-1} + Vermicompost 2 t ha^{-1} + bio-fertilizer.

Dubey *et al.* (2021) [12] conduct a experiment and reported the effect of integrated nutrient management in the mustard cultivation lead to a significantly influenced quality of mustard like oil yield, oil content, protein content and protein yield where treatment [50% RDF + FYM @ 2.5t ha^{-1} + Vermicompost @ 0.62t ha^{-1} + Bio-fertilizers @ 7.5kg ha^{-1} + $ZnSO_4$ @ 10kg ha^{-1}] shows highest return. The N, P, K content also increases with treatment T_{10} in grain as well as in straw

Effect of integrated nutrient management on economics

Singh *et al.* (2014b) [32] were carried out a field experiment at Kanpur and reported that significantly maximum gross income and net profit of mustard was recorded with the application of 100% RDF + vermicompost @ 5.0 t ha^{-1} than other treatments. Application of 80 kg N + 40 kg P ha^{-1} + vermicompost @ 5.0 t ha^{-1} gave significantly maximum net returns of mustard (Kansotia *et al.*, 2015) [17]. Bijarnia *et al.* (2017b) [4] to evaluate the effect of INM on mustard and they found that the application of 5 t FYM + 100% RDF gave maximum net returns of mustard. Hadiyal *et al.* (2017) [15] reported that significantly highest net returns and B: C ratio of mustard was recorded with the seed inoculation with *Azotobacter* spp. + *PSB* spp. (each @ 10 ml/kg seed). Kumar *et al.* (2017) [18] reported that the highest net return and B: C ratio of mustard was obtained by the application of 75% NPK in combination with 40 kg S and 10 t FYM ha^{-1}.

Saini *et al.* (2017) [30] reported that treatment with *Azotobacter* + *PSB* + 30 kg ha^{-1} N through inorganic fertilizer + 30 kg ha^{-1} N through poultry manure gave significantly highest gross return (₹ 67740 ha^{-1}), net return (₹ 33265 ha^{-1}) and benefit cost ratio (1.96) of mustard. Significantly highest gross income and net profit in mustard crop was obtained with combined application of 100% RDF + vermicompost @ 5.0 t ha^{-1} over rest of the treatments (Thaneshwar *et al.*, 2017) [35].

According to Kumar *et al.* (2018b), the gross returns and net returns of mustard was significantly increased with 50% RDF + FYM 6 t ha^{-1} + vermicompost 2 t ha^{-1} + bio-fertilizers than the rest of the treatments. Kumar *et al.* (2018a) [19] reported that significant effect on gross returns, net returns and B C ratio of mustard was noted due to application of 75% RDF and *PSB*. The application of 100% NPK + FYM @ 2.5 t/ha was recorded significantly higher net returns than other treatments and B: C ratio was increased by 115% with the application of 100% NPK + B @ 1 kg B/ha (Prasad *et al*., 2021) [27].

Conclusion

Integrated nutrient management helps to maintain productivity, profitability and quality of the rapeseed and mustard crops. Integrated nutrient management improves and sustains the productivity and fertility of soil and also protecting the environment from pollution. Hence the farmers of the rapeseed and mustard growing areas are advised to use bio-fertilizer with farmyard manure, compost, vermicompost, crop residues as well as inorganic fertilizers to achieve good quality crop with higher production and benefits.

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