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Mustard and rapeseed response to integrated nutrient management: A review

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Abstract
Integrated nutrient management plays a significant role in improving resource use efficiency, so it is important for the sustainable production of crops. The sole application of chemical fertilizers is associated with certain constraints, such as diminishing soil productivity, creating multiple nutrient deficiencies, and disorders. On the other hand, integrated application of inorganic fertilizers, organic fertilizers and biofertilizer significantly enhance food grain production, maintain soil fertility, and increase farmer's income by influencing the nutrient status in soil. This article reviews the effect of integrated nutrient management on growth and yield parameters, nutrient content and uptake by rapeseed and mustard plants, availability of nutrients in the soil, and economics of rapeseed and mustard.

Keywords: Integrated nutrient management, sustainable, growth, yield, nutrient uptake

Introduction
Rapeseed & mustard is an important oilseed crop widely grown in the majority of continents. Canada has the largest area of 8 million ha, followed by China (7 million ha) and India (6 million ha). India ranked third in rapeseed and mustard production after Canada and China. Rapeseed-Mustard accounts for one-third of total oil production in India and it ranks second after groundnut (Shekhawat *et al.* 2012) [35]. In India, rapeseed-mustard is the main oilseed crop growing in *rabi* season occupying more than 80 percent of the area under oilseeds crop. India's rapeseed-mustard seed production was 83.22 million MT in 2017-18 (Anonymous, 2017-18) [2]. Rapeseed and mustard seed is considered a rich source of oil and protein. The seeds contain oil (46-48 percent), 43.6 percent protein, and low glucosinolate content. Also, the seed residues are used as an ingredient for cattle and poultry feed in India (Mandal and Sinha, 2004 [24]; Manohar *et al.* 2009) [25]. This energy-rich crop plays an important role in human nutrition and animal feed, occupying a significant position in the diet of Indian people. Rapeseed and mustard have many industrial uses and its oilcake can also serve as manure.
Productivity is lower in India among the major rapeseed-mustard growing countries. During 2013-16, the Indian average yield was only 1161 kg/ha compared to the world average of 2144 kg/ha. The highest productivity was in the European Union (3640 kg/ha). In India, rapeseed and mustard crops are cultivated in an area of 66.52 lakh hectare with a production of 71.09 lakh tones and with average productivity of 1069 kg/ha (Anonymous, 2016) [1]. So, to go over this huge gap, integrated nutrient management is very useful in this context. Only one source of nutrients like chemical fertilizers, organic manures, and biofertilizer is unable to improve the production or maintain sustainability of production and health of the soil. Integrated nutrient management is a concept, that maintain plant nutrient supply and soil fertility in optimum amounts so that soil and crop productivity is sustained through optimization of the benefits of all the possible sources of plant nutrients in an integral manner. Through integrated nutrient management, extra mining of nutrients will have to be checked to maintain soil health. Thus, both organic and inorganic sources of plant nutrients and biofertilizer not only manage long-term fertility and productivity of the soil but also take care of environmental pollution (Antil and Narwal, 2007) [3].
Combine use of chemical and organic sources of nutrients proved superior result generally to the use of each unit separately. Sustainable oilseed production requires the efficient use of inputs by balanced fertilization, which include biofertilizer, organic manures, secondary and micronutrients, and site-specific nutrient management so that there is no wastage and harness positive interactions of nutrients and growth factors (Hegde and Sudhakara 2009) [16]. So, for attaining higher production as well as quality oilseeds the use of integration of nutrients for oilseed production is required. The oil content increased from 2 to 7% due to the use of fertilizers either singly or in combination with major, secondary, and micronutrients (Hegde and Sudhakara 2004) [15].

Effect of INM on crop growth parameters

Maximum growth parameters (plant height, branches per plant, dry matter accumulation, and leaf area index) were recorded with the application of 50% RDF + FYM @ 6 t/ha + vermicompost @ 2 t/ha + bio-fertilizer integration (Kumar *et al*. 2018, a) [21]. Combine application of RDF (120:60:40:30 NPKS kg/ha) and vermicompost @ 5.0 t/ha resulted in significantly better growth attributes of mustard (Singh *et al.* 2014) [38]. Seed inoculation with *Azotobacter chroococcum, Azospirillum brasilense, A. lipoferum,* and combination of chemical fertilizers consisting NPK in rice-rapeseed cropping system resulted in the higher crop growth rate of *Brassica napus* (Yasari *et al.* 2009) [49]. Growth attributes like plant height and branches per plant in mustard increased with every increase in levels of vermicompost (2, 4, 6 t/ha) (Parihar *et al*., 2014) [27]. Treatment having *Azotobacter* + PSB + N @ 30 kg/ha through inorganic fertilizer + N @ 30 kg/ha through poultry manure produced significantly higher plant height, number of branches/plant and dry weight of rapeseed (Saini *et al*. 2017) [33]. The application of biofertilizer results in higher leaf area index and dry matter accumulation in yellow *sarson* (Raj and Mallick, 2017) [28]. Growth attributes *viz.*, plant height, crop dry matter, primary and secondary branches per plant in taramira increased considerably with every increase in level (1, 2, and 3 t/ha) of vermicompost (Yadav *et al*. 2013) [48]. Growth characters (plant height, the number of primary branches/plant, and secondary branches/plant) of brown sarson were significantly increased with the application of biofertilizer and different fertility levels over control (Brar *et al*. 2016) [7]. Application of *Azotobacter* to rapeseed and mustard have positive effect on growth and development (Singh and Dutta 2006) [37]. Similarly, combined application of *Azotobacte*r spp. and PSB spp. increased plant growth parameters of Indian mustard as compared to control (Hadiyal *et al*. 2017) [13]. Application of 50% RDF along with FYM and seed treatment with *Azotobacter* resulted in the highest plant height and the number of branches in mustard (*B. juncea*) (Kumar *et al.* 2017) [19]. Similarly, the highest values of plant height and number of branches of mustard was obtained with a complete INM package involving 100% of recommended fertilizer, followed by treatments where the same INM package was applied with 75 and 50% of recommended fertilizer level (Pal *et al.* 2008) [26]. Plant height, total dry matter accumulation, leaf area index of mustard [*Brassica juncea* (L.) were recorded significantly higher when recommended dose of fertilizers N:P:K:S @ 120:17.6:16.6:40 kg/ha was applied along with FYM 10 t/ha, $ZnSO_4$ @ 25 kg/ha and seed treatment with *Azotobacter* (Singh and Pal 2011) [39]. Significantly higher plant height and the number of branches per plant of Indian mustard were obtained with 100% NPK in combination with FYM @10 t/ha over NPK @100% alone (Mandal and Sinha 2004) [24]. The highest number of branches per plant and total dry matter of Indian mustard were obtained when 50% or 100% of the RDF + FYM @ 10 t/ha + *Azotobacter* were applied (Shukla *et al.* 2002) [36]. Similarly in mustard, FYM @ 10 t + N @ 30 kg and P_2O_5 @ 20 kg/ha when applied, it significantly increased plant height, dry matter accumulation, and the number of primary and secondary branches as compared to the control (Jat *et al*. 2000) [17].

Effect of INM on yield attributes and yield

Combined application of RDF (120:60:40:30 NPKS kg/ha) + vermicompost @ 5.0 t/ha, significantly resulted in better yield attributes like siliqua per plant, siliqua length, the weight of siliqua per plant, number of seeds per siliqua, seed weight per plant and test weight of seed as well as grain yield (22.75 q/ha) (Singh *et al.* 2014) [38]. Maximum yield was obtained when P and S applied @ 50 kg/ha and seed inoculation with PSB biofertilizer (Solanki *et al.* 2015) [43]. Treatment containing 100% RDF of NPK + FYM @ 5 t/ha + S @ 40 kg/ha recorded significantly higher seed yield (17.96 q/ha) and oil yield (6.72 q/ha) (Singh *et al.* 2017) [42]. The grain yield of the mustard crop was significantly increased by the application of various levels of S and biofertilizer (Yadav *et al.* 2010) [47]. Combined application of RDF (120:60:40:30 kg/ha NPKS) + vermicompost @ 5.0 t/ha had significantly better yield attributes (total number of siliqua per plant, siliqua length, the weight of siliqua per plant, number of seeds per siliqua) and grain yield (22.75 q/ha) of mustard (Thaneswar *et al.*, 2017) [44].

Application of vermicompost (control, 2.5 and 5t/ha) and different nutrients (control, S @ 40 kg/ha; S @ 40 kg/ha + 9.5 kg Fe/ha; 40kg S/ha + 5kg Zn/ha and 40 kg S/ha + 9.5 kg Fe/ha + 5 kg Zn/ha) when applied to mustard along with recommended doses of NPK recorded that, with the increase in levels of vermicompost, seed and stover yield increased (Gour *et al.* 2017) [12]. Application of 75% RDF + S @ 40 kg/ha + vermicompost @ 5 t/ha+ *Azotobacter* + PSB recorded maximum number of siliquae/plant, seeds/siliqua and seed and stover yield (Chandan *et al.* 2018) [8]. The highest number of siliquae/plant, number of seeds/siliqua, seed yield, and stover yield of yellow sarson were resulted due to the application of biofertilizer (Raj and Mallick 2017) [28]. Application of biofertilizer and different fertility levels over control significantly increased the yield attributes, seed and straw yields of brown sarson (Brar *et al.* 2016) [7]. Seed inoculation with *Azotobacter* or *Azospirillum* significantly increased the number of siliquae /plant, seeds/siliqua, and yield of seed and stover yield of Indian mustard (*B. juncea*) (Singh *et al.* 2014) [38]. When N, P, K was integrated with vermicompost @ 2 t/ha + S @ 40 kg/ha + $ZnSO_4$ @ 25 kg/ha + B @ 1 kg/ha and seed inoculation with *Azotobacter* @ 10 g/kg seed, significantly higher yield and yield components were recorded (Kumar *et al.* 2016) [22].

Treatment consisting of *Azotobacter* + PSB + N @ 30 kg/ha through inorganic fertilizer + N @ 30 kg/ha through poultry manure resulted in significantly higher number of siliquae/plant, number of seeds/siliqua, test weight, seed yield, stover yield, and harvest index of rapeseed (Saini *et al.* 2017) [33]. Application of 50% RDF along with FYM and seed treatment with *Azotobacter* resulted in a higher number of siliquae/plant, seeds/siliqua, test weight, and seed yield of mustard (Kumar *et al.*, 2017) [19]. Highest seed and stover yield was recorded under treatment having 75% RDF + FYM @ 5 t/ha + Zn @ 5 kg/ha + *Azotobacter* (Sahoo *et al.* 2018) [32]. Maximum yield of the mustard crop was obtained by P and S application @ 50 kg/ha and seed inoculation with PSB biofertilizer (Solanki *et al.* 2015)[43]. Treatment having higher doses of N fertilizer (80 kg/ha) in combination with biofertilizer and FYM resulted in maximum seed yield (Singh *et al.* 2014) [38].

Balanced application of inorganic fertilizer (100% NPK) + lime + biofertilizer + FYM significantly increased the yield of the mustard crop as compared to the control plot (Saha *et al.* 2010) [31]. Application of 20 t FYM + S @ 40 kg/ha along with a recommended dose of fertilizers or 75% recommended dose of fertilizers resulted in a significant increase of 18.20% and 20.30% in mustard yield over RDF and 75% of RDF, respectively (Tripathi *et al.* 2010) [46]. Integrated use of FYM

@ 1.5 or 3 t/ha and S @ 30 kg/ha gave the highest seed yield, stover yield than that of a single application of S or FYM (Basumatary and Talukdar 2007) [5]. In yellow sarson crop, the treatment receiving 60% N fertilizer, 75% P fertilizer + 12 kg/ha biofertilizer and organic manure 5 t/ha resulted in maximum seeds per siliqua, test weight and seed yield (Dutta *et al.* 2009) [10]. The highest number of siliquae and seed yield of mustard was obtained with an INM package involving 100% of recommended fertilizer (Pal *et al.* 2008) [26]. Similarly, with the application of 50 and 100% of the recommended fertilizer rates + FYM @ 10 t/ha) + *Azotobacter* resulted in the highest number of siliquae/plant, siliqua length, 1000-seed weight, number of seeds/siliqua, seed yield/plant, and seed yield/ha of Indian mustard (Shukla *et al*. 2002) [36].

Effectof INM on quality parameters

In Indian mustard (*B. juncea* L.) combination of 100% RDF of NPK + FYM @ 5 t/ha + S @ 40 kg/ha recorded highest protein content (21.06%) (Singh *et al.* 2017) [42]. Rapeseed crop fertilized with integration of 50% RDF (30:15:15 kg/ha of NPK) + FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + neem cake @ 1.25 t/ha + poultry manure @ 1.25 t/ha, yield maximum oil and protein content in seeds (De and Sinha, 2012) [9]. The application of vermicompost increased the oil percentage, oleic, linoleic, and linolenic acids and erucic unsaturated fatty acid content decrease in rapeseed (Ghale Joughi *et al*. 2018) [11]. The oil content of the yellow sarson increased due to application of biofertilizer (Raj and Mallick 2017) [28].

Integration of chemical fertilizers, biofertilizer, and cycocel treatment enhanced the level of chlorophyll, sugar, ascorbic acid, phenol, and proline in leaves of mustard (Banerjee *et al*., 2012) [4]. Seed inoculation with a combination of *Azotobacter chroococcum, A. brasilense, A. lipoferum,* and chemical fertilizers comprised of NPK and their combination in rice-rapeseed cropping system resulted in higher seed oil content and protein content of *B. napus* (Yasari*et al.* 2009) [49]. Significantly higher oil content in rapeseed was obtained under treatment consisting of *Azotobacter* + PSB + 30 kg/ha N through inorganic fertilizer + 30 kg/ha N through poultry manure produced (Saini *et al.* 2017) [33]. Significantly higher oil content of mustard (*B. juncea* L.) was registered with 50 % RDF + FYM @ 5 t/ha + Zn @ 5 kg/ha + *Azotobacter* (Sahoo *et al*. 2018)[32]. Dual inoculation of seeds of Indian mustard with *Azotobactor* + PSB significantly increased protein content in seed over control (Rundala *et al*. 2012) [30].

Effect of INM on nutrient content and uptake

Combined application of S and Zn along with FYM and recommended doses of N, P, and K fertilizers increased N, P, K, S, and Zn uptake by rapeseed crop (Majumder *et al*,. 2017) [23]. In Indian mustard (*B. juncea*) application of vermicompost @ 6t/ha and 80 kg N/ha+40 kg P_2O_5/ha significantly increased the nutrient uptake by seed, stover, and total N and P uptake (Kansotia *et al.,* 2013) [18]. Increasing in the levels of vermicompost application increased the content and uptake of N, P, K, S, Zn, and Fe in seed and stover of mustard (Gour *et al*., 2017) [12]. Application of 75% RDF + S @ 40 kg/ha + vermicompost @ 5 t/ha+ *Azotobacter* + PSB resulted in maximum uptake of NPK by mustard crop (Chandan *et al.* 2018) [8]. The highest N, P, K uptake was in the treatment having 5.0 ton FYM + 100% RDF and 5.0 ton FYM + 75% RDF + biofertilizer (Bijarnia *et al.* 2017) [6]. Application of 75% RDF through FYM + 25% through chemical fertilizers registered significantly higher uptake of N by the seed of Indian mustard over control and 100% RDF through FYM (Rundala *et al*. 2012) [30]. Recommended fertilizers (120:40:20:40 kg N:P_2O_5:K_2O:S/ha) combined with FYM + $ZnSO_4$ + seed treatment were applied to the mustard crop, gave the highest N, P, K, S and Zn content as well as their uptake in seed and stover (Singh *et al.* 2010) [40]. N, P, S uptake in mustard were highest in plots receiving combination of 75% recommended dose of NPK (45:22.5:22.5 kg NPK/ha) + FYM @ 5 t/ha+ *Azotobacter* + PSB (Satyajeet and Nanwal 2007) [34]. When 100% recommended dose of N blended with FYM, N uptake by Indian mustard was significantly higher under that treatment (Roul *et al*. 2006) [29]. N, P, K when integrated with vermicompost @ 2 t/ha + S @ 40 kg/ha + $ZnSO_4$ @ 25 kg/ha + B @ 1 kg/ha and seed inoculation with *Azotobacter* @ 10 g/kg, significantly recorded higher nutrient uptake in Indian mustard (Kumar *et al.,* 2016) [22].

Effect of INM on soil nutrient status

Integrated application of organic, inorganic and biofertilizer not only enhances the nutrient content in seeds and stover of mustard but also enhances the nutrient content in soil after harvest of the crop. Application of elemental S and Zn-EDTA increased sulphate ion content in S-treated and DTPA extractable Zn content in Zn-treated rapeseed plots (Majumder *et al.* 2017) [23]. The soil properties after harvest of mustard improved significantly having treatment containing N-80, P-40, K-40, S-20 kg/ha and vermicompost 6 t/ha (Kumar *et al.* 2018) [21]. Application of S and biofertilizer alone or in conjunction with each other to mustard crop, showed an increase in organic carbon, available N, P, K and S in the soil samples collected after harvest of mustard crop (Yadav *et al*., 2010) [47]. The application of vermicompost @ 6 t/ha + 80 kg N/ha + 40 kg P_2O_5/ha significantly increased available N, P, K levels after harvest of mustard. Treatment having 75% RDF + 5 t/ha vermicompost recorded a significant increase in soil fertility after five years of experimentation in toria (Hazarika *et al.* 2016) [14]. The highest value of organic carbon (9.6 g/ha), available N (290 kg/ha), and available P (39.40 kg/ha) resulted due to application of 100% NPK + FYM in the mustard (Tiwari *et al.* 2002) [45].

Effect of INM on economics

Integral application of RDF (60:30:30 kg/ha of NPK) + PSB + organic mulch @ 4 t/ha had a higher gross income of ₹ 37740 /ha, the net return of ₹ 14440/ha, and B: C ratio of 1.61, respectively (Kumar *et al*. 2018) [20]. Treatment consisting of *Azotobacter* + PSB + 30 kg/ha N through inorganic fertilizer + 30 kg/ha N through poultry manure in rapeseed, recorded the highest gross return, net return, and benefit-cost ratio (Saini *et al.* 2017) [33]. Significantly higher gross income (₹ 81575) and net profit (₹ 35725) in Indian mustard was obtained by application of RDF (120:60:40:30 kg NPKS/ha) + vermicompost @ 5.0 t/ha over rest of the treatments Singh *et al.* (2014) [41]. Different levels of vermicompost (control, 2.5 and 5 t/ha) and five levels of different nutrients (control, 40 kg S/ha; 40 kg S/ha + 9.5 kg Fe/ha; 40 kg S/ha + 5 kg Zn/ha; 40 kg S/ha + 9.5 kg Fe/ha + 5 kg Zn/ha) along with recommended doses of NPK when applied to the mustard, the net return increased with the increase in levels of vermicompost (Gour *et al.* 2017) [12]. Higher net return ₹ 82037 and B: C ratio (2.97) were resulted due to combined application of *Azotobacter* spp. and PSB spp. to Indian mustard over control (Hadiyal *et al*. 2017) [13].

Conclusion

As we know that, repeated and injudicious applications of chemical fertilizers is ecologically unsound that leads to the loss of soil fertility as it disturbs microbial diversity, and as a result productivity and profitability of crops reduces. This demands, eco-friendly and economically feasible strategies that reduce the use of chemical fertilizers. So integration of inorganic fertilizer both macro and micro with organic manure and biofertilizer is the better option for balance nutrition of the rapeseed mustard crop that enriches the soil fertility status, improves growth and yield attributes of crop and also accelerates the nutrient uptake and availability in soil and ultimately the productivity and profitability and quality of food.

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