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Research Paper

Productivity, profitability and quality of Indian mustard (*Brassica juncea*) as influenced by fertilizer levels and integrated nutrient-management

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ABSTRACT

A field experiment was carried out at Chaudhary Chhotu Ram Post-Graduate College, Muzaffarnagar, Uttar Pradesh during 2009–10 and 2010–11 on sandy loam soil, to evaluate the appropriate fertilizer level of NPK in conjunction with integrated nutrient management schedule for Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]. Twelve treatment combinations consisting of 2 fertilizer levels, viz. 75% RDF and 100% recommended dose of fertilizer (RDF) (80.0 + 25.8 + 33.2 kg N + P + K/ha), and 6 INM schedules, viz. N, P, K alone and its successive combinations with vermicompost (VC), sulphur (S), zinc (Zn), boron (B) and *Azotobacter,* were studied in randomized block design (RBD) with 3 replications. Application of 100% RDF not only increased the growth and yield attributes but also increased the seed yield and nutrient uptake significantly, which resulted in higher net returns and benefit: cost ratio in comparison to 75% RDF. On an average, seed yield of Indian mustard increased to the tune of 7.4% under 100% RDF over 75% RDF. However, higher dose of inorganic fertilization had adverse effect on oil and favourable effect on glucosinolate contents and therefore, the highest values were registered under 75% RDF. Significantly higher growth, yield and yield components and nutrient uptake were recorded when N, P, K was integrated with VC 2 t/ha + sulphur 40 kg/ha +zinc sulphate 25 kg/ha + boron 1 kg/ha and seed inoculation with *Azotobacter* 10 g/kg seed, which was closely followed by the treatment N, P, K + VC + S + Zn + B. The increase in mean seed yield under the application of N, P, K + VC + S + Zn + B + *Azotobacter* was 28.14% higher over the NPK alone. Combined application of N, P, K + VC + S + Zn + B + *Azotobacter* also resulted in the maximum oil content, net returns and benefit: cost ratio, whereas the maximum glucosinolate content was observed with integrated use of N, P, K + VC + S.

***Key words* :** *Brassica juncea*, Growth, Integrated nutrient management, Nutrient uptake, Productivity, Quality

After cereals, oilseeds being the second largest agriculture commodity share 13.5 and 5% of gross cropped area and national product respectively. Amongst the oilseed crops, rapeseed–mustard group ranks next to soybean occupies 7.28 m ha area with production of 8.13 million tones and productivity of 1,117 kg/ha jointly in Uttar Pradesh and Uttrakhand. On the other hand, to bridge the gap of domestic demand and supply in edible oil, India would need 58 MT of oilseeds by 2020 in which the share of rapeseed–mustard would be 24.2 MT.

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Apart from improved crop varieties and irrigation without concomitant use of nutrients leads to nutrient mining and nutrient imbalance, resulting in present-day crisis for low soil fertility, hidden hunger and low factor productivity. Indian soils are becoming deficient in sulphur (S), zinc (Zn), boron (B) and other secondary/micro-nutrients due to intensive cultivation and use of high-analysis fertilizers. Rapeseed–mustard requires relatively large amount of macro- and micro-nutrients from the soil. None of the sources of nutrients alone can meet the total plant nutrient need of crop adequately. Restricted or no application of organic manures has further aggravated the situation. To enhance productivity of this crop, integrated use of nutrients through inorganic, organic and biofertilizer is the most efficient way to supply plant nutrients for sustained crop productivity and improvement of soil fertility. Application of vermicompost (VC) improves soil health by improving nutrient availability, soil physical properties and microbial activity. *Azotobacter chroococcum* is a non-symbiotic nitrogen-fixing agro-microbe having potential to fix considerable quantities of atmospheric nitrogen in the rhizosphere of non-legumes. Besides nitrogen fixation, *Azotobacter* synthesizes various growth hormones, anti-fungal substances and siderophores that favourably affect crop growth. Hence present investigation was planned to find out the appropriate fertilizer level and integrated nutrient management strategy for Indian mustard.

MATERIALS AND METHODS

A field experiments was conducted at Agricultural Research Farm of the Chaudhary Chhotu Ram Post-Graduate College, Muzaffarnagar, Uttar Pradesh, during winter (*rabi*) seasons of 2009–10 and 2010–11 on a fixed site. The farm is situated at 28°N and 77°E, with an elevation of 245.83 m above mean sea-level. Soil was sandy loam in texture (*Entisols*), slightly alkaline (*p*H 7.6) and medium in organic carbon (0.47%) with electrical conductivity of 0.41 dS/m. Available nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) were 152.0, 16.0, 191.0, 8.9 kg/ha, whereas the available zinc (Zn) and boron (B) were 0.34 and 0.47 ppm, respectively. The required quantity of vermicompost containing 1.86% N, 0.72% P, 0.91% K and 0.24% S, 28 ppm Zn and 3.6 ppm B was incorporated into the soil 15 days prior to sowing of crop as per treatment. The total rainfall received during the *rabi* seasons of 2009–10 and 2010–11 was 94.3 and 104.1 mm respectively.

Twelve treatments comprising 2 fertilizer levels (75 and 100% of recommended dose of fertilizer, i.e. 80.0 + 25.8 + 33.2 kg N+ P + K/ha) and 6 schedules of nutrient management, viz. N, P, K alone; N, P, K + VC; NPK + VC + S; NPK + VC + S + Zn; N, P, K + VC + S + Zn + B and N, P, K + VC + S + Zn + B + *Azotobacter* were evaluated in randomized block design with 3 replications. Mustard variety 'Kranti' was sown in rows, 30 cm apart, on 15 October 2009 and 10 October 2010 respectively. The amount of supplementary nutrients sources were VC @ 2 t/ha, sulphur @ 40 kg/ha, zinc sulphate @ 25 kg/ha, boron @ 1 kg/ha and *Azotobacter chroococcum* @ 10 g/kg seed. Urea, diammonium phosphate, muriate of potash, gypsum, zinc sulphate and borax were used to suppliment N, P, K, S, Zn and B respectively. Full dose of phosphorus, potassium, sulphur, zinc sulphate, borax and half of nitrogen (as per treatment) were applied at sowing. Remaining nitrogen was applied after first irrigation in ear-marked plots. Thinning was done 15 days after sowing to maintain plant-to-plant distance of 15 cm. All standard agronomic and required plant-protection practices were followed to harvest good crop yield. The oil content was estimated by non-destructive approach (Nuclear Magnetic Resonance method) using Newport Analyzer-4,000. Total glucosinolate content was estimated in defatted seed samples obtained after oil extraction by determining the glucose released by 'Myrosinase hydrolysis' (Wang and McGregor, 1991). Monetary returns were computed using the prices of inputs and outputs as per prevailing market rates.

RESULTS AND DISCUSSION

Growth parameters

Growth parameters of Indian mustard, viz. crop-growth rate (CGR) and leaf-area index (LAI), at successive stages differed significantly due to application of fertilizer treatments (Table 1). The maximum values for CGR and LAI were recorded with 100% recommended dose of fertilizer (RDF) against 75% RDF during both the seasons. Such improvement was owing to increased availability of nutrients leading to high accumulation of net photosynthates and better proliferation of roots with 100% RDF. The growth parameters like CGR and LAI were also affected significantly by nutrient integration during both the years. The highest CGR and LAI were observed with the application of NPK + VC + S + Zn + B + *Azotobacter,* being at par with NPK + VC + S + Zn + B. The lowest values of the above parameters were recorded under application of NPK alone. The addition of nutrient elements from inorganics, organics and biofertilizer might have resulted in better availability of nutrients for growth, which might helps in absorption and translocation of nutrients in plant that seems to have promoted CGR by way of active cell-division and elongation. Higher LAI may also be due to production of more number of leaves/plant and better leaf growth owing to favourable effect of fertilization on plant growth. Giri *et al.* (2005) were also of similar view.

Yield attributes and yield

Response of Indian mustard to fertilizer levels revealed that 100% RDF produced significantly more number of siliqua/plant and 1,000-seed weight than 75% RDF, but in case of seeds/siliquae, both the fertilizer levels could not bring statistical difference (Table 2). The per cent increase under 100% RDF was 13.69 and 15.75 in siliqua/plant and 7.87, 8.20 in 1,000-seed weight over 75% RDF during 2009–10 and 2010–11 respectively. The significant increase in yield parameters, viz. siliqua/plant and 1,000-seed weight, under 100% RDF might be possibly owing to higher availability of N, P and K in soil solution resulted in overall improvement in the yield-contributing characters which increased protoplasmic constituents and accelerated the process of cell-division, cell-elongation and expansion which in turn increased the values of yield attributes. Such positive and beneficial effects of higher levels of RDF on different yield attributes of Indian mustard crop are in accordance with those reported by Jain and Sharma (2000).

Seed yield increased significantly with application of increasing dose of inorganic fertilizers from 75% to 100% RDF. The increase in seed yield under 100% RDF over 75% RDF was 7.37%. Increase in seed yield with 100% RDF was largely a function of improved growth and the consequent increase in different yield components owing to sufficient supply of major plant nutrients under successive increase in nutrient doses. Though the higher stover yield and harvest index were also recorded with 100% RDF, the difference was non-significant over 75% RDF.

The maximum number of siliqua/plant, seeds/siliquae and 1,000-seed weight were observed under the application of NPK + VC + S + Zn + B + *Azotobacter* followed by NPK + VC + S + Zn + B (Table 2). On the other side, the above yield components were registered lowest at application of NPK alone. The highest values obtained could be attributed to better nutrient supply and synthesis of growth-promoting substances as a result of combined application of inorganic fertilizers, organic manures and biofertilizer. Rana *et al.* (2005) also reported positive effect of supplementary nutrients on yield attributes of In-

Table 1. Influence of fertilizer levels and integrated nutrient-management practices on growth parameters of Indian mustard (pooled data of 2 years)

Treatment	Crop-growth rate (g/m^2/day)		Leaf-area index		
	30–60 DAS	60–90 DAS	30 DAS	60 DAS	90 DAS
Fertilizer level					
75% RDF	1.77	3.79	0.40	1.61	1.60
100 % RDF	2.18	4.45	0.48	1.94	1.92
SEm±	0.05	0.11	0.01	0.01	0.02
CD (P=0.05)	0.14	0.31	0.03	0.03	0.06
Integrated nutrient management					
NPK alone	1.64	3.81	0.41	1.48	1.46
NPK + VC	1.85	4.07	0.42	1.65	1.64
NPK + VC + S	1.96	4.16	0.43	1.76	1.75
NPK + VC + S + Zn	2.05	4.22	0.45	1.87	1.86
NPK + VC + S + Zn + B	2.15	4.27	0.45	1.92	1.91
NPK + VC + S + Zn + B + *Azotobacter*	2.20	4.39	0.46	1.97	1.95
SEm±	0.10	0.18	0.04	0.03	0.04
CD (P=0.05)	0.28	0.51	NS	0.08	0.11

DAS, Days after sowing; RDF, Recommended dose of fertilizers; VC, Vermicompost

Table 2. Influence of fertilizers levels and integrated nutrient-management practices on yield attributes and yields of Indian mustard (pooled data of 2 years)

Treatment	Siliquae/ plant	Seeds/ siliqua	1,000-seed weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
Fertilizer level						
75% RDF	253.5	13.3	3.79	2.34	7.75	23.5
100% RDF	291.2	13.7	4.10	2.51	8.03	23.9
SEm±	4.1	0.30	0.09	0.04	0.23	0.39
CD (P=0.05)	11.5	NS	0.25	0.11	NS	NS
Integrated nutrient management						
NPK alone	201.7	11.9	3.41	2.06	7.13	23.1
NPK + VC	263.2	13.1	3.90	2.26	7.50	23.2
NPK + VC + S	278.3	13.6	4.01	2.44	7.97	23.4
NPK + VC + S + Zn	286.8	13.7	4.08	2.53	8.11	23.6
NPK + VC + S + Zn + B	298.4	14.2	4.11	2.58	8.23	23.7
NPK + VC + S + Zn + B + *Azotobacter*	305.1	14.5	4.20	2.65	8.44	24.2
SEm±	7.1	0.5	0.15	0.08	0.49	0.69
CD (P=0.05)	20.3	1.4	0.42	0.22	NS	NS

DAS, Days after sowing; RDF, Recommended dose of fertilizers; VC, Vermicompost dian mustard.

Treatment NPK + VC + S + Zn + B + *Azotobacter* gave the highest seed yield in both the years; however, it remained at par with combined application of NPK + VC + S + Zn + B, while the lowest seed yield was recorded at NPK alone. The stover yield and harvest index of Indian mustard remained non-significant among different integrated nutrient-management schedules (Table 2). The per cent increase in seed yield with NPK + VC + S + Zn + B + *Azotobacter* was to the tune of 28.42 and 27.79 over NPK alone during 2009–10 and 2010–11 respectively. The yield is directly dependent on various growth and yield parameters. Its expression was observed with integrated and enhanced supply of essential nutrients, their availability and acquisition, mobilization into plant tissues and thus improved growth and yield components and finally yields. These results confirm the findings of Singh and Sinsinwar (2006).

Nutrient uptake

The nutrients uptake was affected due to fertility levels in both the years. The uptake of N, P, K, S, Zn and B by plants increased significantly with successive increase in fertilizer level, which led to maximum uptake of these nutrients at 100% RDF (80.0 + 25.8 + 33.2 kg N + P + K/ha) that was significantly higher when compared to 75% RDF. The remarkable improvement in nutrient uptake by applying 100% RDF seems to be by the maintenance of congenial nutritional environment at the cellular level as well as in the rhizosphere, which might have led to greater availability of nutrients from the soil mass. However, nutrient uptake is the function of yield and nutrient concentration and yield is more deciding factor for higher nutrient uptake.

Nutrient uptake by crop varied significantly due to different INM treatments (Table 3). The highest nutrient uptake (N, P, K, S, Zn and B) by Indian mustard was observed with the application of NPK + VC + S + Zn + B + *Azotobacter*, which was found at par with NPK + VC + S + Zn + B. The lowest nutrient uptake was recorded under NPK alone. The maximum values of nutrient uptake obtained under the treatment could be due to consistent supply of nutrients and reduced rate of loss of releasing nutrients during the process of decomposition of organic manure (VC) and also owing to improved root growth and its functional activity which helped in greater extraction of nutrients. Further, balanced nutrition also enhanced the synergistic effect on uptake of other plant nutrients. These findings were also similar to that of Ahmad *et al.* (2007).

Quality

The effect of fertilizer levels on the oil and glucosinolate contents were very interesting wherein decrease in fertilizer level, i.e. 75% RDF could make slight increase in the oil and glucosinolate contents in both the years (Table 4). The oil content decrease with increasing levels of fertilizer from 75% to 100% RDF, could be due to increasing availability of nitrogen which increase the proportion of proteinous substance in seed and hence oil content was low and this was also suggested by Piri and Sharma (2006). The glucosinolate content is one of the important aspects related to seed quality of Indian mus-

Table 3. Influence of fertilizer levels and integrated nutrient-management treatments on nutrient uptake by Indian mustard (pooled data of 2 years)

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)		S (kg/ha)		Zn (g/ha)		B (g/ha)	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
Fertilizer level												
75% RDF	70.9	32.6	16.2	20.5	25.9	124 .1	19.0	39.3	128.2	388.6	31.3	89.9
100% RDF	83.6	37.2	18.5	23.8	29.6	140.4	21.2	44.0	155.4	449.8	41.8	114.9
SEm±	1.80	1.09	0.30	0.79	0.50	4.62	0.40	1.27	3.70	13.8	1.10	4.12
CD (P=0.05)	5.06	3.11	0.9	2.24	1.4	13.0	1.1	3.58	10.4	38.8	3.1	11.6
Integrated nutrient management												
NPK alone	58.7	24.3	13.9	17.2	19.1	105.5	15.6	33.1	107.1	322.8	27.9	78.2
NPK + VC	71.1	30.3	15.7	20.1	22.3	119.6	17.8	36.8	122.2	363.7	31.5	93.0
NPK + VC + S	78.8	34.6	17.4	22.1	27.6	132.1	20.3	42.4	137.6	413.4	35.6	100.8
NPK + VC + S + Zn	82.3	37.9	18.2	23.3	30.2	138.7	21.3	44.1	152.8	451.6	37.8	104.8
NPK + VC + S + Zn + B	85.4	40.6	19.0	24.8	32.5	147.2	22.3	46.2	161.8	481.6	42.7	116.9
NPK + VC + S + Zn + B + *Azotobacter*	86.9	41.8	19.7	25.5	33.9	150.4	23.3	47.4	169.5	482.3	44.3	120.9
SEm±	3.1	1.9	0.6	1.37	1.1	8.01	0.7	2.19	6.5	23.9	2.0	7.14
CD (P=0.05)	8.8	5.4	1.7	3.9	3.1	22.7	1.9	6.2	18.4	68.1	5.6	20.1

DAS, Days after sowing; RDF, Recommended dose of fertilizers; VC, Vermicompost

Table 4. Influence of fertilizer levels and integrated nutrient-management practices on oil and glucosinolate content and economics of Indian mustard (pooled data of 2 years)

Treatment	Oil (%)	Glucosinolate (μ mole/g seed)	Cost of cultivation (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Fertilizer level					
75% RDF	39.6	114.5	21.70	40.1	1.85
100% RDF	39.2	105.6	22.55	43.9	1.94
SEm±	1.08	0.98		0.61	0.01
CD (P=0.05)	NS	2.80		1.76	0.03
Integrated nutrient management					
NPK alone	35.6	113.1	20.36	35.2	1.73
NPK + VC	36.0	105.2	21.56	38.6	1.78
NPK + VC + S	40.8	120.2	22.26	42.3	1.90
NPK + VC + S + Zn	41.1	113.6	22.66	43.8	1.94
NPK + VC + S + Zn + B	41.3	105.5	22.96	45.3	1.98
NPK + VC + S + Zn + B + *Azotobacter*	41.5	102.7	22.99	46.8	2.04
SEm±	1.86	1.29		0.89	0.03
CD (P=0.05)	5.2	3.63		2.34	0.08

DAS, Days after sowing; RDF, Recommended dose of fertilizers; VC, Vermicompost

tard. Glucosinolate content in seed decreased with increasing levels of fertilizer from 75% to 100% RDF (Table 4). This may be owing to dilution effect as higher fertility enhanced the growth and dry-matter production. Integrated application of NPK coupled with VC, sulphur, zinc, boron and seed inoculation resulted in the highest oil content; however, reverse trend of oil content in seed was registered at application of NPK alone during the experimentation (Table 4). The oil content increased from 35.6% under NPK alone to 41.5% under the application of NPK + VC + S + Zn + B + *Azotobacter.* Such a large variation in oil content on addition of sulphur was also reported by Singh *et al.* (2013). The increase in oil content under NPK +VC + S + Zn + B + *Azotobacter* treatment might be attributed to increased availability of S and Zn that involved in an increased conversion of primary fatty acids metabolites to the end products of fatty acids, as reported by Tripathi *et al.* (2010). Further, sole use of higher levels of chemical fertilization improved N availability that helped more production and made potential deficiency of carbohydrates vis-a vis 'Acetyl co-enzyme A', precursor of fatty acids, resulting into low oil content. The glucosinolate content in seed decreased with successive increase in various nutrient integration packages. The maximum glucosinolate content was observed with combined application of NPK + VC + S. It was mainly owing to the role of sulphur in increasing the content of S-containing amino acids which are precursors for the biosynthesis of glucosinolates. Tripathi *et al.* (2010) had also similar opinion. The lowest glucosinolate was recorded in NPK + VC + S + Zn + B + *Azotobacter,* followed by NPK + VC + S + Zn + B. This may be due to the fact that addition of zinc, boron and seed inoculated with *Azotobacter* reduced the glucosinolate content on account of simple dilution effect resulting from increased dry-matter production and diversion of more N and S for protein synthesis. Yang *et al.* (1993) also reported decrease in glucosinolate content with boron application.

Economics

The maximum net return and benefit: cost ratio were obtained from 100% RDF, while the lowest values from 75% RDF (Table 4). This was mainly owing to slight increase in the cost of cultivation and higher productivity under 100% RDF. Among the various INM treatments, the minimum cost of cultivation was recorded under the application of NPK alone, whereas it was the maximum when it combined with all the supplementary nutrients. The highest net return and benefit: cost ratio were noted under NPK integrated with all the supplementary ingredients, viz. VC, sulphur, zinc, boron and seed treatment with *Azotobacter,* during both the years, which might be owing to production of higher seed yield.

It was concluded that nutrition of Indian mustard with NPK combined with 2 tonnes VC/ha, 40 kg S/ha, 25 kg zinc sulphate/ha, 1 kg boron/ha and seed inoculation with *Azotobacter chroococcam* is a viable option for enhancing growth, yield, seed quality and net returns on *Entisols* under irrigated conditions of western Uttar Pradesh.

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