



Yield performance and quality in Indian mustard (*Brassica juncea*) as affected by integrated nutrient management

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ABSTRACT

A field experiment was conducted during *rabi* 2005-06 and 2006-07 at Pantnagar to study the effect of integrated nutrient management (INM) on Indian mustard (*Brassica juncea*). Twelve treatments consisting of recommended dose of fertilizers (RDF) i.e. 120-17.6-16.7 kg N-P-K/ha and 75% RDF either alone or with addition of farmyard manure (FYM), sulphur (S), zinc (Zn), boron (B) and *Azotobacter* were tested in RBD with 3 replications. Application of 2 t FYM + 40 kg S along with RDF or 75% RDF resulted in significant increase in mustard yield i.e. 18.2 and 20.3% over RDF (1.69 t/ha) and 75% RDF (1.57 t/ha) alone. However, net returns indicated that INM treatment i.e. RDF + FYM + S + Zn + B + *Azotobacter* with mean returns of Rs. 19,505 is promising to rest of the treatments. The addition of zinc, boron and seed treatment with *Azotobacter* reduced the glucosinolate content at both RDF and 75% RDF.

Key words: *Brassica juncea*, Economics, Growth, Nutrient uptake, Oils

Identification of the critical inputs to enhance the mustard production is need of hour. Apart from improved varieties and irrigation, balanced fertilization was critical for realizing higher yield. 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. Nutrient indexing work on soils and crops done at the Pantnagar revealed negative balance of sulphur, zinc and boron in *tarai* region (Srivastava *et al.*, 2006). The rapeseed-mustard (*Brassica juncea* L.) requires relatively large amount of these nutrients for realization of yield potential but inadequate supply often leads to low productivity. Under such situation, organic manures can be exploited to boost the production and also to improve fertilizer use efficiency. However, the use of total organic or inorganic nutrient sources has some limitations. Judicious combination of FYM, biofertilizers and chemical fertilizers facilitate profitable and sustainable production (Singh and Sinsinwar, 2006). Farmyard manure (FYM) improves soil quality apart from supplying all essential nutrients. The biofertilizer inoculation by way of nitrogen-fixation, production of growth hormones, antifun-

gal substances and siderophores favorably effect crop growth. Therefore, an attempt was made to assess the response of Indian mustard to integrated nutrient management.

MATERIALS AND METHODS

The experiment was carried out at the Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during *rabi* 2005-06 and 2006-07. The soil was loam having 7.5 pH, 0.90% organic carbon, 230-19-302 kg/ha available N-P-K and 11-0.47-0.62 ppm of sulphur - zinc - boron. The treatments consisted of recommended dose of fertilizer (RDF) i.e. 120-17.6-16.7 kg N-P-K/ha and 75% RDF alone and in their combination with farmyard manure (2 tonne/ha) applied in furrows, sulphur (40 kg/ha), zinc sulphate (25 kg/ha), boron (1 kg/ha) and seed treatment with *Azotobacter* (10 g/kg seed). The fertilizer nutrients were supplied through urea, diammonium phosphate, muriate of potash, gypsum, zinc sulphate and borax. The 12 treatments were replicated thrice in randomized block design. Mustard 'Kranti' was sown in rows 30 cm apart on 14 and 10 October, 2005 and 2006, respectively. Thinning was done 10 days after sowing to maintain plant to plant distance of 15 cm. The required amount of FYM containing 0.32% N, 0.20% P, 0.40% K, and 0.15% S, 0.73 ppm Zn and 2.1 ppm B as per the treatment was incorporated

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into the soil 15 days before sowing of crop. Full dose of phosphorus, potassium, sulphur, zinc sulphate, boron and half of nitrogen (as per treatment) were applied at sowing. Remaining half of nitrogen was applied after first irrigation. The crop was harvested in February during both the crop seasons. Total rainfall in 2005-06 was scarce (9.2 mm) whereas in 2006-07 it was high (61.0 mm) and well distributed. The processed plant samples were analyzed to determine nitrogen, phosphorus, potassium, sulphur, zinc and boron content in plant. However, boron free glassware was used for boron determination. The oil content was estimated by non-destructive approach (Nuclear Magnetic Resonance method) using Newport Analyser-4000. The total glucosinolate content in the seed was estimated by using Sodium Tetrachloro Palladate [Na (pdCl₄)] method using ELISA Reader (Micro Scan MS 5605A, Electronic Corporation of India Ltd.). The total glucosinolate content was expressed in m moles/g defatted seed meal.

RESULTS AND DISCUSSION

Growth

The application of recommended dose of NPK fertilizer (RDF) along with FYM, S, Zn, B and seed treatment with *Azotobacter*, being at par with 75% RDF + above nutrients produced significantly higher dry matter accumulation (DMA), crop growth rate (CGR) and leaf area index (LAI). Crop receiving 75% recommended dose of fertilizer exhibited lower values of CGR and LAI when compared with recommended dose of fertilizer, though the differences were not significant than other nutrient management prac-

tices (Table 1). Adequate supply of readily available N and other nutrients produced taller plants. Taller plants produced more dry matter because of more opportunity to production and accumulation of photosynthates. These results are in accordance with the findings of Mandal and Sinha (2002) and Shukla *et al.* (2002). Higher LAI may be due to more number of leaves/plant and better leaf growth owing to favorable effect of fertilization on plant growth which resulted in better CGR. These results corroborate with the findings of Giri *et al.* (2005).

Yield components and yield

The yield components, *viz.*, siliquae/plant, seeds/siliqua and test weight were significantly influenced by INM treatments (Table 2). Mustard crop fertilized with RDF/75% RDF along with Zn + FYM + 40 kg S + 25 kg ZnSO₄ + 1 kg B + seed treatment with *Azotobacter* produced significantly more number of siliqua/plant, seeds/siliqua and test weight than RDF or 75% RDF alone respectively during both the years of study. The lowest values of above parameters were recorded under 75% RDF alone treatment. The more number of branches under above treatment may be correlated with the more plant height and dry matter accumulation as a result of better nutrient supply to the crop resulting in profused branching. Profused branching provided area to develop more number of siliquae in the same treatment. Increase in seeds/siliqua and 1,000-seed weight could be ascribed to better growth and more photosynthate accumulation as a result of adequate nutrients availability to the crop.

The crop fertilized with 75% RDF produced lowest seed and biological yield, though it was at par with that of

Table 1. Growth parameters of Indian mustard as affected by integrated nutrient management

Treatment	CGR (g/day x 10 ⁻¹)				LAI					
	2005-06		2006-07		2005-06			2006-07		
	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T ₁ , RDF	4.47	2.37	4.97	2.63	0.52	2.99	1.21	0.65	3.14	2.48
T ₂ , T ₁ + FYM (2 t/ha)	4.70	2.47	5.37	2.80	0.58	3.24	1.43	0.71	3.40	2.68
T ₃ , T ₂ + Sulphur (40 kg/ha)	5.33	2.80	5.93	2.97	0.67	3.57	1.75	0.77	3.70	2.85
T ₄ , T ₃ + Zinc sulphate (25 kg/ha)	5.77	2.83	6.20	3.30	0.69	3.79	1.93	0.82	3.99	3.07
T ₅ , T ₄ + Boron (1 kg/ha)	5.93	3.03	6.43	3.53	0.75	4.00	2.03	0.86	4.17	3.15
T ₆ , T ₅ + <i>Azotobacter</i>	6.27	3.23	6.83	3.60	0.85	4.21	2.25	0.93	4.39	3.29
T ₇ , 75% RDF	4.03	2.30	4.57	2.60	0.46	2.68	1.13	0.59	2.85	2.18
T ₈ , T ₇ + FYM (2 t/ha)	4.50	2.47	5.03	2.93	0.52	2.98	1.32	0.66	3.13	2.35
T ₉ , T ₈ + Sulphur (40 kg/ha)	4.83	2.83	5.46	3.20	0.58	3.21	1.55	0.71	3.39	2.55
T ₁₀ , T ₉ + Zinc sulphate (25 kg/ha)	5.10	3.23	5.70	3.50	0.63	3.44	1.68	0.76	3.58	2.66
T ₁₁ , T ₁₀ + Boron (1 kg/ha)	5.40	3.20	5.90	3.53	0.67	3.62	1.77	0.79	3.79	2.74
T ₁₂ , T ₁₁ + <i>Azotobacter</i>	5.63	3.23	6.20	3.70	0.75	3.81	1.92	0.82	3.96	2.90
SEm±	0.31	0.41	0.37	0.52	0.06	0.22	0.14	0.06	0.25	0.21
CD (P=0.05)	0.91	NS	1.10	NS	0.17	0.66	0.41	0.19	0.74	0.63

DAS, Days after sowing; RDF, Recommended dose of fertilizers (120-17.6-16.7 kg N-P-K/ha)

Table 2. Effect of integrated nutrient management on yield components, seed and biological yield (t/ha) of Indian mustard

Treatment	Siliquae/plant		Seeds/silique		Test weight (g)		Seed yield		Biological yield	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
T ₁ , RDF	195.8	206.9	11.2	12.0	3.31	3.64	1.33	1.53	6.26	6.98
T ₂ , T ₁ + FYM (2 t/ha)	217.8	226.2	11.7	12.6	3.44	3.75	1.44	1.66	6.77	7.45
T ₃ , T ₂ + Sulphur (40 kg/ha)	245.1	255.3	12.4	13.1	3.57	3.87	1.56	1.82	7.27	8.13
T ₄ , T ₃ + Zinc sulphate (25 kg/ha)	257.2	265.1	12.8	13.6	3.60	3.95	1.60	1.87	7.36	8.29
T ₅ , T ₄ + Boron (1 kg/ha)	266.5	272.6	13.2	14.1	3.73	4.04	1.64	1.91	7.40	8.36
T ₆ , T ₅ + <i>Azotobacter</i>	274.6	284.7	13.7	14.5	3.89	4.11	1.67	1.95	7.44	8.43
T ₇ , 75 % RDF	171.4	183.4	10.8	11.6	3.21	3.54	1.21	1.40	5.91	6.68
T ₈ , T ₇ + FYM (2 t/ha)	191.4	205.5	11.3	12.0	3.31	3.63	1.31	1.52	6.41	7.21
T ₉ , T ₈ + Sulphur (40 kg/ha)	221.6	233.7	12.0	12.7	3.46	3.73	1.45	1.69	6.78	7.87
T ₁₀ , T ₉ + Zinc sulphate (25 kg/ha)	233.3	245.8	12.4	13.3	3.54	3.81	1.49	1.75	6.92	7.99
T ₁₁ , T ₁₀ + Boron (1 kg/ha)	244.2	255.1	12.7	13.7	3.64	3.88	1.53	1.78	7.09	8.04
T ₁₂ , T ₁₁ + <i>Azotobacter</i>	251.8	263.1	13.2	13.9	3.75	3.96	1.57	1.82	7.19	8.16
SEm±	7.1	9.7	0.3	0.3	0.08	0.07	0.08	0.10	0.31	0.38
CD (P=0.05)	24.5	31.7	0.8	0.9	0.24	0.18	0.23	0.29	0.90	1.02

DAS, Days after sowing

RDF during both the seasons (Table 2). Integrating FYM with RDF or 75% RDF failed to improve seed and biological yield to the level of statistical significance. However, addition of FYM and sulphur with RDF significantly improved seed and biological yield over both RDF and 75% RDF alone. Further, addition of zinc sulphate, boron and seed treatment with *Azotobacter* improved seed and biological yield under both set of treatments. The highest seed and biological yield was attained under RDF coupled with FYM, sulphur, zinc, boron and *Azotobacter*. As yield is the resultant outcome of the effect of various growth and yield parameters, its expression was observed with their integrated influence. With the increment in supply of essential nutrients to Indian mustard, their availability, acquisition, mobilization and influx into the plant tissues increased and thus improved growth attributes and yield components and finally the yield. These results are in agreement with the findings of Singh and Sinsinwar (2006).

Nutrient uptake

Nutrient uptake by crop varied significantly due to different fertility levels (Table 3). The highest nutrient uptake (N, P, K, S, Zn, and B) by mustard was noted with the application of RDF along with FYM, sulphur, zinc, boron and *Azotobacter* during both the years that could be ascribed to all nutrients availability to crop that has increased biomass production and thus uptake. Similar results were reported by Mandal and Sinha (2002). Integration FYM and S with RDF and 75% RDF resulted in significantly higher nutrient uptake than that of RDF and 75% of RDF alone. The lowest nutrient uptake was noted with 75% RDF during both the crop seasons.

Quality

Crop fertilized with RDF and 75% RDF along with sulphur recorded significantly higher oil content than that of RDF and 75% RDF during both the years. Lowest oil content was noted in RDF alone during both the crop seasons (Table 4). The low oil content under RDF alone was due to more availability of N which increased the proportion of proteinous substance in the seed. Under high N supply, a large proportion of photosynthates may have diverted to protein formation leaving a potential deficiency of carbohydrates to be degraded to 'acetyl co-enzyme A' for the synthesis of fatty acids. These results are in close conformity with the findings of Shukla *et al.* (2002). The increase in the oil content with sulphur fertilization over RDF may be attributed to its role in oil synthesis. Integrated application of FYM and sulphur with RDF and 75% RDF resulted in significantly higher oil yield than that of RDF and 75% RDF alone. However, the lowest oil yield was recorded with 75% RDF alone during both the crop seasons.

The glucosinolate content in seed decreased with increase in RDF from 75 to 100%. This may be due to simple dilution effect resulting from the increased dry matter production. The maximum glucosinolate content was noted under 75% RDF with FYM and sulphur. This may be due to the role of sulphur in increasing the content of S containing amino acids which are precursors for the biosynthesis of glucosinolates. Krishna *et al.* (2005) also noted increase in glucosinolate content with increasing S application. The addition of zinc, boron and seed treatment with *Azotobacter* reduced the glucosinolate content owing to simple dilution effect resulting from increased dry mat-

Table 3. Effect of integrated nutrient management on nutrient uptake of Indian mustard

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)		S (kg/ha)		Zn (g/ha)		B (g/ha)	
	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
T ₁ ¹ , RDF	22.1	25.7	92.3	107.0	34.9	39.4	311.2	368.7	81.2	99.2	104.2	98.4
T ₁ ² , T ₁ + FYM (2 tonne/ha)	25.0	28.7	103.1	118.0	38.6	43.2	344.9	407.4	90.2	108.1	107.3	100.9
T ₁ ³ , T ₂ + Sulphur (40 kg/ha)	28.2	33.0	114.5	133.6	44.2	50.0	392.4	455.3	101.0	122.9	117.2	107.4
T ₁ ⁴ , T ₃ +Zinc sulphate (25 kg/ha)	30.4	35.5	119.0	138.8	45.9	52.3	426.3	499.7	103.2	126.1	110.1	99.5
T ₁ ⁵ , T ₄ + Boron (1 kg/ha)	31.9	37.1	120.9	140.4	47.2	53.6	450.3	520.5	117.7	136.7	105.0	95.2
T ₁ ⁶ , T ₅ + Azotobacter	33.2	38.8	124.3	145.3	49.2	56.6	458.5	539.0	120.1	139.9	97.5	94.1
T ₁ ⁷ , 75 % RDF	19.2	23.2	81.8	97.4	30.9	35.7	258.5	311.0	62.9	85.3	114.1	106.1
T ₁ ⁸ , T ₇ + FYM @ 2 tonne/ha	21.5	25.8	92.2	107.5	34.3	39.4	289.5	353.3	70.4	94.4	116.3	109.3
T ₁ ⁹ , T ₈ + Sulphur (40 kg/ha)	23.9	29.9	101.5	122.6	38.9	45.6	323.2	391.8	78.4	107.7	128.2	111.2
T ₁ ¹⁰ , T ₉ + Zinc sulphate (25 kg/ha)	25.7	31.3	104.9	127.7	40.6	47.3	358.5	425.4	80.4	110.5	116.4	107.4
T ₁ ¹¹ , T ₁₀ + Boron (1 kg/ha)	27.8	32.8	109.1	128.7	42.5	48.8	380.1	442.0	98.5	120.2	106.3	102.3
T ₁ ¹² , T ₁₁ + Azotobacter	29.5	34.8	113.4	133.0	44.2	51.0	397.7	468.4	102.3	123.6	103.2	101.0
SE _{im} ±	1.8	1.9	6.5	7.7	2.6	2.7	23.3	26.7	5.8	7.2	3.1	2.9
CD (P=0.05)	5.2	5.7	19.3	22.7	7.6	7.7	68.4	78.3	16.9	21.0	9.2	8.5

Table 4. Effect of integrated nutrient management on oil quality and economics (x 10³Rs/ha) of Indian mustard

Treatment	Oil content (%)		Oil yield(kg/ha)		Gluco-sinolate (mmole/g seed)		Mean cost of cultivation		Net return		Net benefit: cost ratio	
	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
T ₁ ¹ , RDF	38.36	38.66	510.2	591.3	104.2	98.4	9.29	13.31	16.95	1.43	1.83	
T ₁ ² , T ₁ + FYM (2 tonne/ha)	38.65	38.95	555.3	645.9	107.3	100.9	10.29	14.14	18.17	1.37	1.77	
T ₁ ³ , T ₂ + Sulphur (40 kg/ha)	39.05	39.34	610.3	717.2	117.2	107.4	10.84	15.73	20.44	1.45	1.89	
T ₁ ⁴ , T ₃ +Zinc sulphate (25 kg/ha)	39.27	39.60	630.4	743.2	110.1	99.5	11.16	16.11	20.98	1.44	1.88	
T ₁ ⁵ , T ₄ + Boron (1 kg/ha)	39.50	39.80	647.6	758.3	105.0	95.2	11.38	16.48	21.29	1.45	1.87	
T ₁ ⁶ , T ₅ + Azotobacter	39.81	40.09	664.5	781.8	97.5	94.1	11.39	16.98	22.03	1.49	1.93	
T ₁ ⁷ , 75 % RDF	38.99	39.30	471.1	549.0	114.1	106.1	8.77	11.76	15.20	1.34	1.73	
T ₁ ⁸ , T ₇ + FYM @ 2 tonne/ha	39.25	39.59	514.8	602.5	116.3	109.3	9.77	12.52	16.31	1.28	1.67	
T ₁ ⁹ , T ₈ + Sulphur (40 kg/ha)	39.67	40.00	573.5	676.8	128.2	111.2	10.33	14.26	18.71	1.38	1.81	
T ₁ ¹⁰ , T ₉ + Zinc sulphate (25 kg/ha)	39.86	40.26	593.7	704.4	116.4	107.4	10.64	14.71	19.41	1.38	1.82	
T ₁ ¹¹ , T ₁₀ + Boron (1 kg/ha)	40.17	40.49	616.0	720.6	106.3	102.3	10.87	15.19	19.66	1.40	1.81	
T ₁ ¹² , T ₁₁ + Azotobacter	40.48	40.78	634.0	743.4	103.2	101.0	10.88	15.73	20.39	1.45	1.87	
SE _{im} ±	0.22	0.23	30.9	39.2	3.1	2.9						
CD (P=0.05)	0.66	0.67	90.6	114.8	9.2	8.5						

Price of seed (Rs/tonne): 17,000 (2005-06) and 17,150 (2006-07)

ter 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 cost of cultivation was lowest for inorganic fertilizer level of 75% RDF alone whereas, it was highest when RDF was combined with all the supplementary nutrients. Highest net return and benefit : cost ratios was noted under RDF coupled with all the supplementary ingredients viz., FYM, sulphur, zinc, boron and seed treatment with *Azotobacter* during both the seasons owing to higher seed yield and despite of its highest cost of cultivation (Table 4). The lowest net return was noted in 75% RDF alone whereas, B:C ratio was lowest in 75 % RDF + FYM.

From the two year investigation it is concluded that integrated nutrition of mustard with recommended dose of N-P-K fertilizers (120-17.6-16.7) along with 40 kg S, 25 kg ZnSO₄, 1 kg B and 2 t FYM is promising for productivity and profitability.

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